UnboundID® Data Store Administration Guide

Version 5.2.0.1

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Preface

This guide presents the procedures and reference material necessary to install, administer and troubleshoot the UnboundID Data Store in multi-client, high-load production environments.

Purpose of This Guide

The purpose of this guide is to provide procedures and concepts that can be used to manage the UnboundID® Data Store in a multi-client environment. It also provides information to monitor and set up the necessary logs needed to troubleshoot the server's performance.

The Data Store is part of the UnboundID Platform. The UnboundID Platform is the consumer-grade identity access and management platform—built specifically to handle the massive scale and real-time demands of hundreds of millions of customers. It delivers a consistent, seamless, personalized brand experience that makes each customer feel valued.

The UnboundID Platform provides a unified view of customer data across all applications, channels, partners, and lines of business. The result is:

- Increased customer trust and confidence through greater transparency and customer control of personal data.
- A consistent, personalized customer experience that promotes better conversion, up-selling, and cross-selling.

Audience

The guide is intended for administrators responsible for installing, maintaining, and monitoring servers in large-scale, high load production environments. It is assumed that the reader has the following background knowledge:

- UnboundID Platforms and LDAPv3 concepts
- System administration principles and practices
- Understanding of Java VM optimization and garbage collection processes
- Application performance monitoring tools

Related Documentation

The following list shows the full documentation set that may help you manage your deployment:

- *UnboundID® Data Store Administration Guide*
- *UnboundID® Data Store Reference Guide (HTML)*
- *UnboundID® Proxy Server Administration Guide*
- *UnboundID® Proxy Server Reference Guide (HTML)*

- *UnboundID® Data Sync Server Administration Guide*
- *UnboundID® Data Sync Server Reference Guide (HTML)*
- *UnboundID® Metrics Engine Administration Guide*
- *UnboundID® Data Broker Administration Guide*
- *UnboundID Security Guide*
- *UnboundID® LDAP SDK*
- *UnboundID® Server SDK*

Document Conventions

The following table shows the document convention used in this guide.

Convention	**Usage**
`Monospace`	Commands, filenames, directories, and file paths
`Monospace Bold`	User interface elements, menu items and buttons
Italic	Identifies file names, doc titles, terms, variable names, and emphasized text

Chapter 1 Overview of the Server

The UnboundID® Data Store is a high performance, extensible directory and UnboundID Platform, written completely in Java™. The Data Store centralizes consumer and user identity management information, subscriber data management, application configurations, and user credentials into a network, enterprise, or virtualized database environment. It provides seamless data management over a distributed system based on a standardized solution that meets the constant performance demands for today's markets. The Data Store simplifies administration, reduces costs, and secures information in systems that scale for very large numbers of users.

This chapter provides an overview of the Data Store's features and components.

Topics:

Server Features

The UnboundID Data Store is a powerful, 100% Java, production-proven UnboundID Platform solution for mission-critical and large-scale applications. The Data Store provides an extensive feature-rich set of tools that can meet the production needs of your system.

- **Full LDAP Version 3 Implementation**. The Data Store fully supports the Lightweight Directory Access Protocol version 3 (LDAP v3), which supports the Request For Comments (RFCs) specified in the protocol. The Data Store provides a feature-rich solution that supports the core LDAPv3 protocol in addition to server-specific controls and extended operations.
- **High Availability**. The Data Store supports N-way multi-master replication that eliminates single points of failure and ensures high availability for a networked topology. The Data Store allows data to be stored across multiple machines and disk partitions for fast replication. The Data Store also supports replication in entry-balancing proxy server deployments.
- **Administration Tools**. The Data Store provides a full set of command-line tools, a Web-based administration management console, and a graphical user interface (GUI) Java-based setup tool to configure, monitor, and manage any part of the server. The Data Store has a task-based subsystem that provides automated scheduling of basic functions, such as backups, restores, imports, exports, restarts, and shutdowns. The set of utilities also includes a troubleshooting support tool that aggregates system metrics into a zip file, which administrators can send to your authorized support provider for analysis.
- **Security Mechanisms**. The Data Store provides extensive security mechanisms to protect data and prevent unauthorized access. Access control list (ACL) instructions are available down to the attribute value level and can be stored within each entry. The Data Store allows connections over Secure Sockets Layer (SSL) through an encrypted communication tunnel. Clients can also use the StartTLS extended operation over standard, non-encrypted ports. Other security features include a privilege subsystem for fine-grained granting of rights, a password policy subsystem that allows configurable password validators and storage schemes, and SASL authentication mechanisms to secure data integrity, such as PLAIN, ANONYMOUS, EXTERNAL, CRAM-MD5, Digest-MD5, and GSSAPI. The Data Store also supports various providers and mappers for certificate-based authentication in addition to the ability to encrypt specific entries or sensitive attributes.
- **Monitoring and Notifications**. The Data Store supports monitoring entries using the Metrics Engine, JConsole, Simple Network Management Protocol (SNMP), or using the Management Console. Administrators can track the response times for LDAP operations using a monitoring histogram as well as record performance statistics down to sub-second granularity. The Data Store also supports configurable notifications, auditing, and logging subsystems with filtered logging capabilities.
- **Powerful LDAP SDK**. The Data Store is based on a feature-rich LDAP SDK for Java, designed by UnboundID. The UnboundID® LDAP SDK is a Java API standard that overcomes the many limitations of the Java Naming and Directory Interface (JNDI) model. For example, JNDI does not address the use of LDAP controls and extended operations. The LDAP SDK for Java provides support for controls and extended operations to leverage the Data Store's extensible architecture for their applications.

  The Standard LDAP SDK for Java is available for free to public users and can be downloaded from the UnboundID web site. The Commercial version of the LDAP SDK for

Java is part of the Data Store distribution. For more information on the LDAP SDK for Java, to go http://www.unboundid.com/products/ldapsdk.

- **SCIM Extension**. The Data Store provides a System for Cross-domain Identity Management (SCIM) servlet extension to facilitate moving users to, from, and between cloud-based Software-as-a-Service (SaaS) applications in a secure and fast manner.
- **Server SDK**. UnboundID also provides the Server SDK, which is a library of Java packages, classes, and build tools to help in-house or third-party developers create client extensions for the UnboundID® Data Store, UnboundID® Proxy Server, and UnboundID® Data Sync Server. The servers were designed with a highly extensible and scalable architecture with multiple plug-in points for your customization needs. The Server SDK provides APIs to alter the behavior of each server's components without affecting its code base.
- **Multi-Platform Support**. The UnboundID Data Store is a pure Java application and is certified VMWare Ready™. It is intended to run within the Java Virtual Machine on any Java Standard Edition (SE) or Enterprise Edition (EE) certified platform. For the list of supported platforms and Java versions, access your Customer Support Center portal or contact your authorized support provider.

  Any known OS or JDK-related issues will be documented in the release notes distributed with the product. Direct any questions or requests for additional platform certifications to your authorized support provider.

Administration Framework

The Data Store provides an administration and configuration framework capable of managing stand-alone servers, server groups, and highly-available deployments that include multiple redundant server instances. Administrators can configure changes locally or remotely on a single server or on all servers in a server group. Each server configuration is stored as a flat file (LDIF) that can be accessed under the `cn=config` branch of the Directory Information Tree (DIT). Administrators can tune the configuration and perform maintenance functions over LDAP using a suite of command-line tools, a GUI-based Java console (for installs, uninstalls, and server status), or a web management console (for configuration and monitoring). The Data Store also provides plug-ins to extend the functionality of its components.

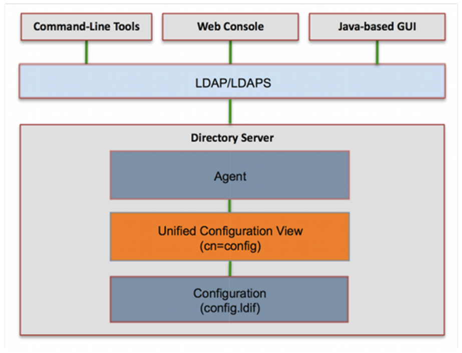


Figure 1: Data Store Configuration Network

Server Tools Location

UnboundID distributes the Data Store, Management Console, and LDAP SDK for Java in zip format. After unzipping the file, you can access the `setup` utility in the server root directory, located at `UnboundID-DS`. The Data Store stores a full set of command-line tools for maintaining your system in the `UnboundID-DS/bin` directory for UNIX® or Linux® machines and the `UnboundID-DS\bat` directory for Microsoft® Windows® machines.

Prior to installing the data store, read Chapter 2 *Preparing Your Environment*, which presents important information on setting up your machines. Chapter 3 *Installing the Data Store* presents procedures to install a server instance using the `setup` utility. This utility can be run in one of the three available installation modes: interactive command-line, non-interactive command-line, and GUI mode. Chapter 4 *Configuring the Data Store* provides procedures to modify the configuration of a server instance or a group of servers using the command-line tools and the web management console.

Chapter 2 Preparing Your Environment

The UnboundID Data Store offers a highly portable and scalable architecture that runs on multiple platforms and operating systems. The Data Store is specifically optimized for those operating systems used in environments that process a very large number of entries.

This chapter presents some procedures to set up your server machines for optimal processing efficiency.

Topics:

Before You Begin

The Data Store requires certain software packages for the proper operation of the server. For optimized performance, the UnboundID Data Store requires Java for 64-bit architectures. To view the minimum required Java version, access your Customer Support Center portal or contact your authorized support provider for the latest software versions supported.

It is also highly recommended that a Network Time Protocol (NTP) system be in place so that multi-server environments are synchronized and timestamps are accurate.

Installing Java

For optimized performance, the UnboundID Data Store requires Java for 64-bit architectures. You can view the minimum required Java version on your Customer Support Center portal or contact your authorized support provider for the latest software versions supported.

Even if your system already has Java installed, you may want to create a separate Java installation for use by the UnboundID Data Store to ensure that updates to the system-wide Java installation do not inadvertently impact the Data Store. This setup requires that the JDK, rather than the JRE, for the 64-bit version, be downloaded.

To Install Java (Oracle/Sun)

1. Open a browser and navigate to the Oracle download site.
2. Download the latest version Java JDK. Click the JDK Download button corresponding to the latest Java update.
3. On the Java JDK page, click the Accept Licence Agreement button, then download the version based on your operating system.

To Install Java (IBM)

1. Open a browser and navigate to the IBM download site.
2. Select the Java version for your operating system.

Preparing the Operating System (Solaris)

The UnboundID Data Store has been extensively tested on multiple operating systems. We have found that serveral operating system optimizations lead to improved performance. These optimizations include using the ZFS filesystem on Solaris systems, restricting ZFS memory consumption, limiting transaction group writes, using compression and disabling access time updates.

Using ZFS

UnboundID strongly recommends the use of ZFS™ as the underlying filesystem on Solaris 10 and OpenSolaris systems. ZFS is a 128-bit filesystem that can store billions of times more data than traditional 64-bit systems. Based on a storage pool model, ZFS aggregates devices (mirrors, RAID-Z with single or double parity, concatenated or striped storage) into a virtual data source from which filesystems can be constructed. ZFS provides excellent performance, end-to-end data integrity, simple administration management, and unmatched scalability. It also provides many useful features, such as automatic checksum, dynamic striping, variable block sizes, compression, and unlimited constant-time snapshots. ZFS is part of the Solaris 10 and OpenSolaris operating systems.

All of the Data Store's components should be located on a single storage pool (zpool), rather than having separate pools configured for different server components (for example, one pool for the database and a second for log files). Single zpool configurations are the simplest and easiest to manage. From there, you can create multiple filesystems inside the pool and optionally reserve space for one or more of the filesystems.

ZFS's copy-on-write transactional model does not require isolating I/O-intensive components. Therefore, all available disks should be placed in the same zpool, so that as many underlying spindles as possible can be used to provide the configuration with the greatest number of I/O operations per second.

To Restrict ZFS Memory Consumption

Despite its excellent performance, ZFS does not release memory fast enough for some LDAP operations that might need it. This delay could cause some processes to fail to start while attempting to allocate a large amount of memory for a JVM heap.

To curb memory allocation problems, make sure that the system is configured to limit the amount of memory for caching (for example, up to two gigabytes). The Data Store relies on database caching rather than filesystem caching for its performance. Thus, the underlying system should be configured, so that the memory used by ZFS will not interfere with the memory used by the Data Store. In most environments, we recommend that systems be configured to allow ZFS to use no more than 2 GB of memory for caching.

1. Open the `/etc/system` file.

2. ZFS caches data from all active storage pools in the ARC cache. We can limit its memory consumption by setting the maximum size of the ARC caches using the `zfs_arc_max` property. For example, add the following line to the end of the `/etc/system` file.

   ```
   set zfs:zfs_arc_max= 0x80000000
   ```

   This property sets the maximum size of the ARC cache to 2 GB (0x80000000 or 2147483648 bytes) for ZFS. Note that your system may require a different value.

3. If your system processes large write operations, see the section on Limiting ZFS Transaction Group Writes. Otherwise, reboot the machine for the change to take effect. Also note that this operation requires Solaris 10 update 4 (08/07) and Nevada (build 51) release or later.

To Limit ZFS Transaction Group Writes

UnboundID has found that the Data Store can exhibit uneven throughput performance during continuous write loads for Oracle Berkeley DB Java Edition backends on ZFS systems. We have found that the ZFS Write Throttle feature stalls write operations when transaction groups are flushed to disk. During these periods, operation throughput can drop significantly with these large I/O bursts.

To smooth out write throughput and improve latency, we recommend setting the `zfs_write_limit_override` property in the `etc/system` file to the size of the available disk cache on the system.

1. Open the `/etc/system` file.
2. Add the following line to the end of the file. Set the value to the size of your onboard cache. For example, for a system that has a 32MB cache per disk, set the following parameter:

   ```
   set zfs:zfs_write_limit_override=0x2000000
   ```

3. For the change to take effect, reboot the machine. Also note that this operation requires Solaris 10 update 4 (08/08) or later.

ZFS Access to Underlying Disks

Storage requirements vary depending on whether ZFS has access to the underlying disks. If possible, ZFS should be given direct access to the underlying disks that will be used to back the storage. Direct access to the underlying disks makes it possible to configure the system with the greatest degree of reliability and flexibility.

To configure the system, ZFS should be given direct access to the underlying disks that will be used to back the storage. In this configuration, the zpool used for the Data Store should have a RAID 1+0 configuration (a stripe across one or more 2-disk mirrors). Although this setup reduces the amount of available space when compared with other configurations, like RAID-Z (ZFS data-parity scheme with full dynamic stripe width) or RAID-Z2 (ZFS dual parity RAID-Z), RAID 1+0 provides dramatically better performance and reliability.

If ZFS cannot get direct access to the underlying disks (for example, the system only has access to a logical unit number, LUN, on a storage area network, SAN), then the provided storage should already include some level of redundancy. Again, the RAID 1+0 configuration is recommended over other schemes like, RAID 5 or RAID 6. If the storage includes redundancy, then the zpool should be created with only that LUN and should not add any additional redundancy. In such a configuration, ZFS is not able to take advantage of its advanced self-healing capabilities when it detects any corruption at the filesystem level. However, ZFS check-summing can still detect those types of problems.

Configuring ZFS Compression

The ZFS filesystem should have compression enabled to improve performance as it reduces the amount of data that needs to be written or read from the underlying disks. In most cases, the reduced costs of the disk I/O outweighs the CPU cost of compressing and decompressing the data.

The following procedure assumes that the ZFS filesystem is named ds. The changes take effect immediately with no need to reboot or perform any other action.

Caution:

Knowing the actual size of files is useful when you need to back up files to a non-ZFS filesystem or estimate the amount of memory dedicated to caching. On traditional UNIX filesystems, the `du` command reports the sum of all the specified file sizes. However, on ZFS, `du` reports the amount of disk space consumed, which might not equal the sum of the file sizes if features like compression or multiple copies are enabled. Administrators should be aware of this difference when determining the database size using `du`.

Instead of using `du`, UnboundID Data Store provides a utility, `bin/sum-file-sizes`, that determines the size (in bytes, kilobytes, megabytes, or gigabytes) of the sum of a set of files even if ZFS compression or multiple copies are enabled.

To Configure ZFS Compression

- Turn on ZFS compression by running the `zfs` command.

```
# zfs set compression=on ds
```

To Disable the Access Time Update for Reads

You must have ZFS installed and configured on your system. Assume that the ZFS filesystem is named `ds`.

You should disable the access time update (*atime*) tracking, so that the kernel will not update the access time of a file every time it is requested. ZFS stores the filesystem attributes within the filesystem itself, so that you can access the attributes.

1. Disable the access time update for read operations.

```
# zfs set atime=off ds
```

2. To view all filesystem attributes, use the following command:

```
# zfs get all ds
```

Preparing the Operating System (Linux)

The UnboundID Data Store has been extensively tested on multiple operating systems. We have found that several operating system optimizations lead to improved performance. These optimizations include increasing the file descriptor limit on Linux systems, setting filesystem flushes, editing OS-level environment variables, downloading some useful monitoring tools for Redhat Linux systems, and configuring for Huge Page support.

Configuring the File Descriptor Limits

The UnboundID Data Store allows for an unlimited number of connections by default, but is restricted by the file descriptor limit on the operating system. If needed, increase the file descriptor limit on the operating system.

If the operating system relies on `systemd`, refer to the Linux operating system documentation for instructions on setting the file descriptor limit.

To Set the File Descriptor Limit (Linux)

The Data Store allows for an unlimited number of connections by default but is restricted by the file descriptor limit on the operating system. Many Linux distributions have a default file descriptor limit of 1024 per process, which may be too low for the server if it needs to handle a large number of concurrent connections.

Once the operating system limit is set, the number of file descriptors that the server will use can be configured by either using a `NUM_FILE_DESCRIPTORS` environment variable, or by creating a `config/num-file-descriptors` file with a single line such as, `NUM_FILE_DESCRIPTORS=12345`. If these are not set, the default of 65535 is used. This is strictly optional if wanting to ensure that the server shuts down safely prior to reaching the file descriptor limit.

1. Display the current hard limit of your system. The hard limit is the maximum server limit that can be set without tuning the kernel parameters in the `proc` filesystem.

```
ulimit -aH
```

2. Edit the `/etc/sysctl.conf` file. If there is a line that sets the value of the `fs.file-max` property, make sure its value is set to at least 65535. If there is no line that sets a value for this property, add the following to the end of the file:

```
fs.file-max = 65535
```

3. Edit the `/etc/security/limits.conf` file. If the file has lines that sets the soft and hard limits for the number of file descriptors, make sure the values are set to 65535. If the lines are not present, add the following lines to the end of the file (before “#End of file”). Also note that you should insert a tab, rather than spaces, between the columns.

```
* soft nofile 65535
* hard nofile 65535
```

4. Reboot your system, and then use the `ulimit` command to verify that the file descriptor limit is set to 65535.

   ```
   # ulimit -n
   ```

File System Tuning

Newer ext4 systems use delayed allocation to improve performance. This delays block allocation until it writes data to disk. Delayed allocation improves performance and reduces fragmentation by using the actual file size to improve block allocation. This feature may cause a risk of data loss in cases where a system loses power before all of the data has been written to disk. This may occur if a program is replacing the contents of a file without forcing a write to the disk with `fsync`. Make sure the default `auto_da_alloc` option is enabled on ext4 filesystems.

Administrators can tune ext3 and ext4 filesystems by setting the filesystem flushes and noatime to improve server performance. The following changes can be made in the `/etc/fstab` file.

To Set the Filesystem Flushes

With the out-of-the-box settings on Linux systems running the ext3 filesystem, the data is only flushed to disk every five seconds. If the Data Store is running on a Linux system using the `ext3` filesystem, consider editing the mount options for that filesystem to include the following:

```
commit=1
```

This variable changes the flush frequency from five seconds to one second.

You should also set the flush frequency to the `/etc/fstab` file. Doing the change via the mount command alone will not survive across reboots.

To Set noatime on ext3 and ext 4 Systems

If you are using an `ext3` or `ext4` filesystem, it is recommended that you set `noatime`, which turns off any *atime* updates during read accesses to improve performance. You should also set the flush frequency to the `/etc/fstab` file. Doing the change via the mount command alone will not survive across reboots.

- Run the following command on an ext3 system.

  ```
  # mount -t ext3 -o noatime /dev/fs1
  ```

- Run the following command on an ext34 system.

  ```
  # mount -t ext4 -o noatime /dev/fs1
  ```

Setting the Maximum User Processes

On some Linux distributions (Redhat Enterprise Linux Server/CentOS 6.0 or later), the default maximum number of user processes is set to 1024, which is considerably lower than the same parameter on older distributions (e.g., RHEL/CentOS 5.x). The default value of 1024 leads to some JVM memory errors when running multiple servers on a machine due to each Linux thread being counted as a user process. (Note that this is not an issue on Solaris and AIX platforms as individual threads are not counted as user processes.)

At startup, the Data Store and its tools automatically attempt to raise the maximum user processes limit to 16,383 if the value reported by `ulimit` is less than that. If, for any reason, the server is unable to automatically set the maximum processes limit to 16,383, an error message will be displayed. It is recommended that the limit be set explicitly in `/etc/security/limit.conf`. For example:

```
* soft nproc 65535
* hard nproc 65535
```

The (*) can be replaced with the name of the user under which the software will run. These settings can also be manually configured by setting the `NUM_USER_PROCESSES` environment variable to 16383 or by setting the same variable in a file named `config/num-user-processes`.

About Editing OS-Level Environment Variables

Certain environment variables can impact the Data Store in unexpected ways. This is particularly true for environment variables that are used by the underlying operating system to control how it uses non-default libraries.

For this reason, the Data Store explicitly overrides the values of key environment variables like *PATH*, *LD_LIBRARY_PATH*, and *LD_PRELOAD* to ensure that something set in the environments that are used to start the server does not inadvertently impact its behavior.

If there is a legitimate need to edit any of these environment variables, the values of those variables should be set by manually editing the `set_environment_vars` function of the `lib/_script-util.sh` script. You will need to stop (bin/stop-ds) and re-start (bin/start-ds) the server for the change to take effect.

Install sysstat and pstack (Red Hat)

For Red Hat® Linux systems, you should install a couple of packages, `sysstat` and `pstack`, that are disabled by default, but are useful for troubleshooting purposes in the event that a problem occurs. The troubleshooting tool `collect-support-data` uses the `iostat`, `mpstat`, and `pstack` utilities to collect monitoring, performance statistics, and stack trace information on the server's processes. For Red Hat systems, make sure that these packages are installed, for example:

```
$ sudo yum install sysstat gdb dstat -y
```

Install dstat (SUSE Linux)

The `dstat` utility is used by the `collect-support-data` tool and can be obtained from the OpenSuSE project website. The following example shows how to install the `dstat` utility on SuSE Enterprise Linux 11 SP2:

1. Login as Root.
2. Add the appropriate repository using the `zypper` tool.

3. Install the `dstat` utility.

```
$ zypper install dstat
```

To Disable Filesystem Swapping

For all deployments, we recommend disabling disk swapping on the filesystem to protect the Data Store JVM process from an overly aggressive filesystem cache.

- Run the following command:

```
% sysctl -w vm.swappiness=0
```

Omit vm.overcommit_memory

Administrators should be aware that an improperly configured value for the `vm.overcommit_memory` property in the `/etc/sysctl.conf` file can cause the `setup` or `start-ds` tool to fail.

For Linux systems, the `vm.overcommit_memory` property sets the kernel policy for memory allocations. The default value of 0 indicates that the kernel determines the amount of free memory to grant a `malloc` call from an application. If the property is set to a value other than zero, it could lead the operating system to grab too much memory, depriving memory for the `setup` or `start-ds` tool.

We recommend omitting the property in the `/etc/sysctl.conf` file to ensure that enough memory is available for these tools.

Managing System Entropy

Entropy is used to calculate random data that is used by the system in cryptographic operations. Some environments with low entropy may have intermittent performance issues with SSL-based communication. This is more typical on virtual machines, but can occur in physical instances as well. Monitor the `kernel.random.entropy_avail` in `sysctl` value for best results.

If necessary, update `$JAVA_HOME/jre/lib/security/java.security` to use `file:/dev/./urandom` for the `securerandom.source` property.

Running as a Non-Root User

The Metrics Engine installer cannot be run as the root user, and generally the Metrics Engine (and PostgreSQL) should not be run as root. The drawback to not running as root is the inability to use network port numbers below 1024. Some operating system provide workarounds for this limitation, but the best practice is to install and run the Metrics Engine as a user, other than root, and select port numbers greater than 1024.

On systems running Solaris 10 and OpenSolaris, you can use the User and Process Rights Management subsystem with the Role-Based Access Control (RBAC) mechanisms to grant users or roles only the privileges necessary to accomplish a specific task. Using RBAC avoids the assignment of full super-user (root) privileges to the user. For example, you can grant the `net_privaddr` privilege to a non-root user, or role, that gives him or her the ability to listen on privileged ports (for example, on ports 1024 or below). Similarly, granting the `sys_resource` privilege allows a user to bypass restrictions on resource limits, such as the number of file descriptors a process might use.

The Solaris User and Process Rights Management system can also be used to remove capabilities from users. For example, removing the `proc_info` privilege from a user prevents the user from seeing processes owned by other users. Removing the `file_link_any` privilege can prevent users from creating hard links to files owned by other users. Hard links are not needed by the Data Store and can represent a security risk under certain conditions. The following table summarizes the Solaris privileges that you may want to assign to non-root users.

Privilege	Description
net_privaddr	Provides the ability to listen on privileged network ports.
sys_resource	Provides the ability to bypass restrictions on resource limits (including the number of available file descriptors).
proc_info	Provides the ability for users to see processes owned by other users on the system. This privilege is available to all users by default, but it can pose a security risk in some cases. UnboundID recommends that it be removed from the role used by the Data Store.
file_link_any	Provides the ability to create hard links to files owned by other users on the system. This privilege is available to all users by default, but it can pose a security risk in some cases. UnboundID recommends that it be removed from the role used by the Data Store.

Running as a Non-Root User (Linux)

Linux systems do not provide a direct analog to the Solaris User and Process Rights Management subsystems. As a result, there is no easy way to allow a non-root user to listen on a privileged port.

To run as a non-root user but still allow connections on a privileged port, two options are available:

- **Use a Load-Balancer or Proxy Server**. In many environments, the server can be run on a non-privileged port but can be hidden by a hardware load-balancer or LDAP proxy server.
- **Use `netfilter`**. The `netfilter` mechanism, exposed through the `iptables` command, can be used to automatically redirect any requests from a privileged port to the unprivileged port on which the server is listening.

Creating a Solaris Role

To give multiple administrators access to the Data Store, UnboundID Data Store recommends that a Solaris role be created to run the server and that all necessary administrators be added to that role. The Solaris role provides an audit trail that can be used to identify which administrator performed a given action, while still allowing administrators to run the server, to view and edit files used by the server, and to execute commands as that same user. As with normal user accounts, roles can be assigned privileges. The role used for the Data Store should include the `net_privaddr` and `sys_resource` privileges and should exclude the `proc_info` and `file_link_any` privileges for improved security (that is, to eliminate the need for root access).

To Create a Solaris Role for Multiple Administrators

To give multiple administrators access to the Data Store, UnboundID Data Store recommends that a Solaris role be created to run the server and that all necessary administrators be added to that role. The Solaris role provides an audit trail that can be used to identify which administrator performed a given action, while still allowing administrators to run the server, to view and edit files used by the server, and to execute commands as that same user. As with normal user accounts, roles can be assigned privileges. The role used for the Data Store should include the `net_privaddr` and `sys_resource` privileges and should exclude the `proc_info` and `file_link_any` privileges for improved security (that is, to eliminate the need for root access).

1. Create a Solaris role. Assume the role is named `ds` with all of the appropriate privileges needed to run the Data Store. Make sure to enter the whole command on a single line.

   ```
   # roleadd -d /export/home/ds -m -s /usr/bin/bash \
     -K defaultpriv=basic,net_privaddr,sys_resource,-prov_info,-file_link_any ds
   ```

2. Assign a password.

   ```
   # passwd ds
   ```

3. For each administrator who is allowed to manage the Data Store, assign the role with the `usermod` command. For example, to give someone with a user name of “john” the ability to assume the `ds` role, issue the following command:

   ```
   # usermod -R ds john
   ```

   If a user is already a member of one or more roles, then the entire list of existing roles, separated by commas, must also be provided or the user will be removed from those roles. For example, if the root account is also a role and the user “john” is also a member of that role, then the command would be:

   ```
   # usermod -R root,ds john
   ```

4. Log in using a normal user account and then use the `bin/su` command to assume the role created for the Data Store. You cannot log directly into a system as a role. Only users that have been explicitly assigned to a role will be allowed to assume it.

Chapter 3 Installing the Server

After you have prepared your hardware and software system based on the instructions in Chapter 2, you can begin the setup process using of the UnboundID Data Store's easy-to-use installation modes.

This chapter presents the various installation options and procedures available to the administrator.

Topics:

Getting the Installation Packages

To begin the installation process, obtain the latest ZIP release bundle from UnboundID and unpack it in a folder of your choice. The release bundle contains the Data Store code, tools, and package documentation.

To Unpack the Build Distribution

1. Download the latest zip distribution of the Data Store software.
2. Unzip the compressed zip archive file in a directory of your choice.

   ```
   $ unzip UnboundID-DS-<version>.zip
   ```

   You can now set up the Data Store.

About the RPM Package

UnboundID supports the UnboundID Data Store release bundle in an RPM Package Manager (RPM) package for customers who require it. By default, the RPM unpacks the code at /opt/unboundid/ds, after which you can run the `setup` command to install the server at that location.

If the RPM install fails for any reason, you can perform an RPM erase if the RPM database entry was created and manually remove the target RPM install directory (e.g., “/opt/unboundid/ds” by default). You can install the package again once the system is ready.

To Install the RPM Package

1. Download the latest RPM distribution of the Data Store software.
2. Unpack the build using the `rpm` command with the `--install` option. By default, the build is unpacked to `/opt/unboundid/ds`. If you want to place the build at another location, use the `--prefix` option and specify the file path of your choice.

   ```
   $ rpm --install unboundid-ds-<version>.rpm
   ```

3. From /opt/unboundid/ds/UnboundID-DS, run the `setup` command to install the server on the machine.

About the Layout of the Data Store Folders

Once you have unzipped the Data Store distribution file, you will see the following folders and command-line utilities, shown in the table below.

Table 1: Layout of the Data Store Folders

Directories/Files/Tools	Description
License.txt	Licensing agreement for the Data Store.
README	README file that describes the steps to set up and start the Data Store.
bak	Stores the physical backup files used with the `backup` command-line tool.
bat	Stores Windows-based command-line tools for the Data Store.
bin	Stores UNIX/Linux-based command-line tools for the Data Store.
classes	Stores any external classes for server extensions.
collector	Used by the server to make monitored statistics available to the Metrics Engine.
config	Stores the configuration files for the backends (admin, config) as well as the directories for messages, schema, tools, and updates.
db	Stores the Oracle Berkeley Java Edition database files for the Data Store.
docs	Provides the release notes, Configuration Reference file and a basic Getting Started Guide (HTML).
import-tmp	Stores temporary imported items.
ldif	Stores any LDIF files that you may have created or imported.
legal-notices	Stores any legal notices for dependent software used with the Data Store.
lib	Stores any scripts, jar, and library files needed for the server and its extensions.
locks	Stores any lock files in the backends.
logs	Stores log files for the Data Store.
metrics	Stores the metrics that can be gathered for this server and surfaced in the Metrics Engine.
resource	Stores the MIB files for SNMP and can include ldif files, make-ldif templates, schema files, dsconfig batch files, and other items for configuring or managing the server.
revert-update	The `revert-update` tool for UNIX/Linux systems.
revert-update.bat	The `revert-update` tool for Windows systems.
setup	The `setup` tool for UNIX/Linux systems.
setup.bat	The `setup` tool for Windows systems.
scim-data-tmp	Used to create temporary files containing SCIM request data.
uninstall	The `uninstall` tool for UNIX/Linux systems.
uninstall.bat	The `uninstall` tool for Windows systems.
update	The `update` tool for UNIX/Linux systems.
update.bat	The `update` tool for Windows systems.
Velocity	Stores any customized Velocity templates and other artifacts (CSS, Javascript, images), or Velocity applications hosted by the server.

About the Server Installation Modes

One of the strengths of the UnboundID Data Store is the ease with which you can install a server instance using the `setup` tool. The `setup` tool allows you to quickly install and configure a stand-alone Data Store instance.

To install a server instance, run the `setup` tool in one of the following modes: graphical user interface (GUI) mode, interactive command-line, or non-interactive command-line mode.

- **Graphical User Interface (GUI) Mode**. Used primarily for evaluation purposes. GUI mode launches a Java-based graphical `setup` tool that enables you to install the Data Store, load it with data, and get it running quickly on desktop systems. If a graphical environment is not available, then `setup` will fall back to the interactive command-line mode.
- **Interactive Command-Line Mode**. Interactive command-line mode prompts for information during the installation process. To run the installation in this mode, use the `setup --cli` command.
- **Non-Interactive Command-Line Mode**. Non-interactive command-line mode is designed for setup scripts to automate installations or for command-line usage. To run the installation in this mode, `setup` must be run with the `--no-prompt` option as well as the other arguments required to define the appropriate initial configuration.

All installation and configuration steps should be performed while logged on to the system as the user or role under which the Data Store will run.

Setting Up the Server for Evaluation Purposes

To quickly evaluate the UnboundID Data Store, use the Graphical User Interface (GUI) installation mode to set up a server instance. GUI mode provides an easy-to-use Java-based graphical installer that allows fast deployment of your UnboundID Data Store instance. If your system does not support a graphical environment, the installation falls back to interactive command-line mode. If you want to set up a multi-master replication topology using the GUI installer, skip to the next section “Setting Up a Replication Topology for Evaluation Purposes” and follow its instructions.

To Install the Server Using the GUI

To view the minimum required Java version, access your Customer Support Center portal or contact your authorized support provider for the latest software versions supported. Your server environment also must be able to support a Java-based graphical application.

The Data Store provides a Java-based graphical installer that allows fast deployment of a stand-alone server instance. The installer should be used to set up a server for evaluation purposes only.

1. After you have unpacked the software, go to the server root directory.

   ```
   $ cd UnboundID-DS
   ```

2. Install the Data Store by launching `setup` with the appropriate `JAVA_HOME` directory. By default, the utility launches the graphical tool if your system supports a graphical environment.

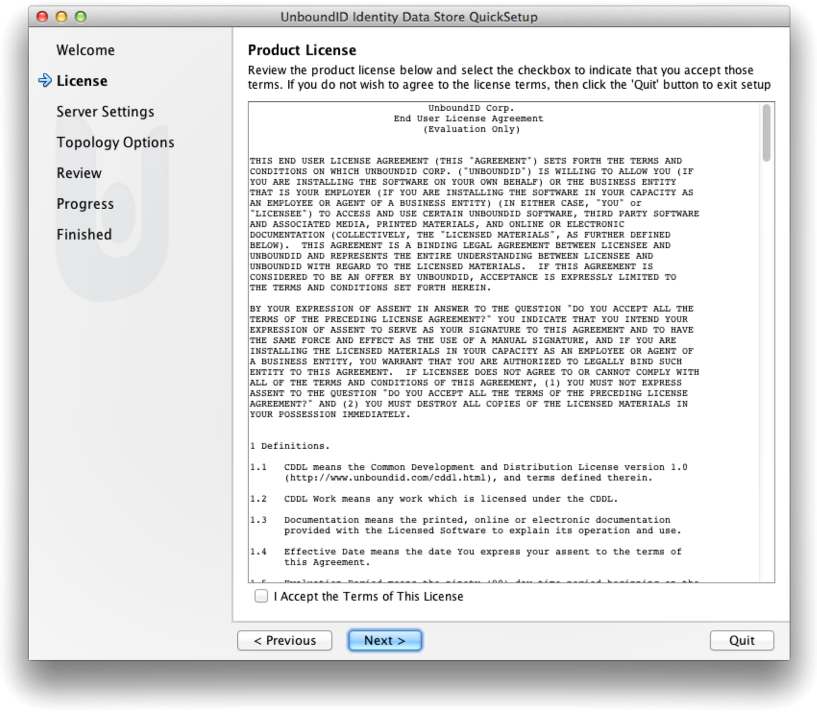
   ```
   $ ./setup
   ```

If you have a separate Java installation, you can specify the `JAVA_HOME` directory.

```
$ env JAVA_HOME=/ds/java ./setup
```

3. On the UnboundID Data Store Quicksetup dialog, click **Next**.

4. Read the licensing and terms of agreement. If you agree to its terms, select **I accept the Terms of This License**, and then click **Next**.



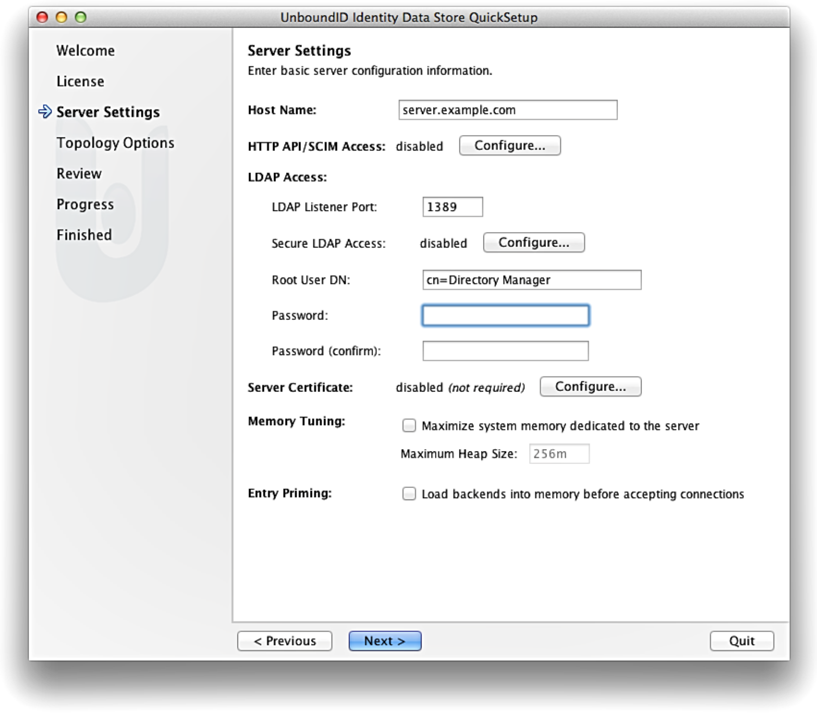
Product License

Review the product license below and select the checkbox to indicate that you accept those terms. If you do not wish to agree to the license terms, then click the 'Quit' button to exit setup

```
                              UnboundID Corp.
                         End User License Agreement
                             (Evaluation Only)


THIS END USER LICENSE AGREEMENT (THIS "AGREEMENT") SETS FORTH THE TERMS AND
CONDITIONS ON WHICH UNBOUNDID CORP. ("UNBOUNDID") IS WILLING TO ALLOW YOU (IF
YOU ARE INSTALLING THE SOFTWARE ON YOUR OWN BEHALF) OR THE BUSINESS ENTITY
THAT IS YOUR EMPLOYER (IF YOU ARE INSTALLING THE SOFTWARE IN YOUR CAPACITY AS
AN EMPLOYEE OR AGENT OF A BUSINESS ENTITY) (IN EITHER CASE, "YOU" or
"LICENSEE") TO ACCESS AND USE CERTAIN UNBOUNDID SOFTWARE, THIRD PARTY SOFTWARE
AND ASSOCIATED MEDIA, PRINTED MATERIALS, AND ONLINE OR ELECTRONIC
DOCUMENTATION (COLLECTIVELY, THE "LICENSED MATERIALS", AS FURTHER DEFINED
BELOW).  THIS AGREEMENT IS A BINDING LEGAL AGREEMENT BETWEEN LICENSEE AND
UNBOUNDID AND REPRESENTS THE ENTIRE UNDERSTANDING BETWEEN LICENSEE AND
UNBOUNDID WITH REGARD TO THE LICENSED MATERIALS.  IF THIS AGREEMENT IS
CONSIDERED TO BE AN OFFER BY UNBOUNDID, ACCEPTANCE IS EXPRESSLY LIMITED TO
THE TERMS AND CONDITIONS SET FORTH HEREIN.

BY YOUR EXPRESSION OF ASSENT IN ANSWER TO THE QUESTION "DO YOU ACCEPT ALL THE
TERMS OF THE PRECEDING LICENSE AGREEMENT?" YOU INDICATE THAT YOU INTEND YOUR
EXPRESSION OF ASSENT TO SERVE AS YOUR SIGNATURE TO THIS AGREEMENT AND TO HAVE
THE SAME FORCE AND EFFECT AS THE USE OF A MANUAL SIGNATURE, AND IF YOU ARE
INSTALLING THE LICENSED MATERIALS IN YOUR CAPACITY AS AN EMPLOYEE OR AGENT OF
A BUSINESS ENTITY, YOU WARRANT THAT YOU ARE AUTHORIZED TO LEGALLY BIND SUCH
ENTITY TO THIS AGREEMENT.  IF LICENSEE DOES NOT AGREE TO OR CANNOT COMPLY WITH
ALL OF THE TERMS AND CONDITIONS OF THIS AGREEMENT, (1) YOU MUST NOT EXPRESS
ASSENT TO THE QUESTION "DO YOU ACCEPT ALL THE TERMS OF THE PRECEDING LICENSE
AGREEMENT?" AND (2) YOU MUST DESTROY ALL COPIES OF THE LICENSED MATERIALS IN
YOUR POSSESSION IMMEDIATELY.


1 Definitions.

1.1   CDDL means the Common Development and Distribution License version 1.0
      (http://www.unboundid.com/cddl.html), and terms defined therein.

1.2   CDDL Work means any work which is licensed under the CDDL.

1.3   Documentation means the printed, online or electronic documentation
      provided with the Licensed Software to explain its operation and use.

1.4   Effective Date means the date You express your assent to the terms of
      this Agreement.
```

☐ I Accept the Terms of This License

5. On the **Server Settings** dialog, enter the server information described below.

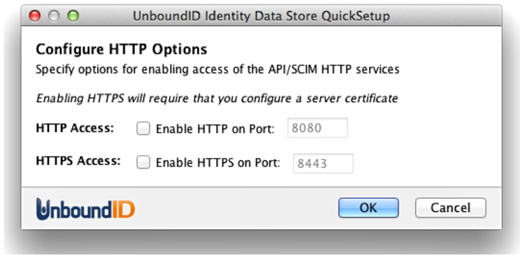


Server Settings
Enter basic server configuration information.

Host Name: server.example.com
HTTP API/SCIM Access: disabled
LDAP Access:
LDAP Listener Port: 1389
Secure LDAP Access: disabled
Root User DN: cn=Directory Manager
Password:
Password (confirm):
Server Certificate: disabled *(not required)*
Memory Tuning: ☐ Maximize system memory dedicated to the server
Maximum Heap Size: 256m
Entry Priming: ☐ Load backends into memory before accepting connections

Host Name	Data StoreHost name or IP address. The default is localhost.
HTTP API/SCIM Access	Click Configure to set up HTTP/S access for SCIM Servlet Extension or other applications.
LDAP Listener Port	LDAP port for the Data Store. If you run the `setup` tool as the root user (or as a user or role with the `net_privaddr` privilege), the default port is 389. If you run the `setup` tool as a non-root user, the default port is 1389.
Secure LDAP Access	Click Configure to set up SSL or StartTLS communication to the server.
Root User DN	Default, cn=Directory Manager
Password	Root user bind DN password
Password Confirm	Confirm the password.
Server Certificate	Click Configure to set up your server certificate.
Memory Tuning	Maximize the memory for JVM optimization. This option should only be selected if the server is the primary application, and no other process consumes a significant amount of memory. You can specify the maximum heap size by entering the value with “m” for megabytes (for example, 256m) or “g” for gigabytes (for example, 1g). For more information on the memory tuning feature, see *JVM Properties for Both Server and Command-Line Tools*.
Entry Priming	Set the prime method property to `preload`, which loads the contents of the database from disk into cache memory at startup before accepting connections. Enabling priming ensures that the server provides optimum performance as soon as startup has completed. Note that entry priming can greatly increase the startup time of the server. Select this option if you have strict throughput or response time performance requirements, or if you plan to have other replicas in a topology that can accept traffic while this is starting. Setting the prime method to `preload` also allows the server to determine a recommended value for the `CMSInitiatingOccupancyFraction` when a Java garbage collection pause occurs. For more information, see *JVM Garbage Collection Using CMS*.

6. On the **Configure HTTP Options** dialog, fill in the required information described below, and click **OK** to continue. Enabling HTTPS Access requires that you configure a server certificate, presented later in this procedure.


UnboundID Identity Data Store QuickSetup

Configure HTTP Options

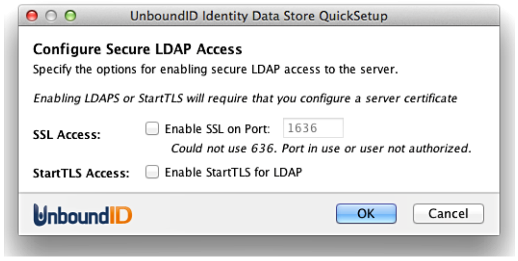
Specify options for enabling access of the API/SCIM HTTP services

Enabling HTTPS will require that you configure a server certificate

HTTP Access: ☐ Enable HTTP on Port: 8080

HTTPS Access: ☐ Enable HTTPS on Port: 8443

7. On the **Configure Secure Access** dialog, click and fill in the required information described below, and click **OK** to continue. Enabling SSL or StartTLS require that you configure a server certificate, presented later in this procedure.


UnboundID Identity Data Store QuickSetup

Configure Secure LDAP Access

Specify the options for enabling secure LDAP access to the server.

Enabling LDAPS or StartTLS will require that you configure a server certificate

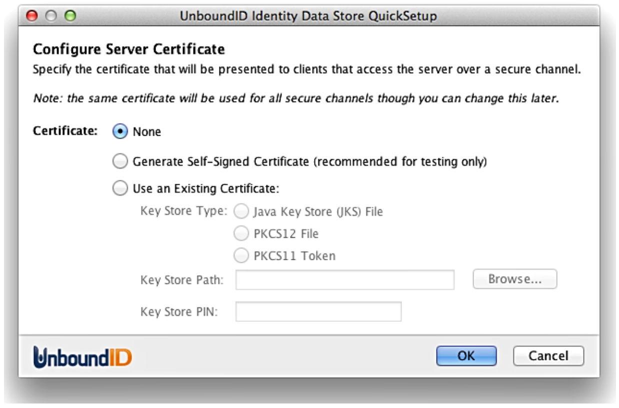
SSL Access: ☐ Enable SSL on Port: 1636

Could not use 636. Port in use or user not authorized.

StartTLS Access: ☐ Enable StartTLS for LDAP

SSL Access	Enable SSL on the specified port. If you run the `setup` tool as a root user or sufficiently privileged user, the default secure port is 636. If you run the `setup` tool as a non-root user, the default secure port is 1636.
StartTLS Access	Enable StartTLS for LDAP. StartTLS allows clients to promote a non-secure LDAP connection on the standard LDAP port to a secure connection.

8. On the **Configure Server Certificate** dialog, click the type of server certificate for your server: self-signed certificate (recommended for testing purposes only) or use an existing certificate. If you are using an existing certificate, enter the keystore type, keystore path, and keystore PIN.


UnboundID Identity Data Store QuickSetup

Configure Server Certificate

Specify the certificate that will be presented to clients that access the server over a secure channel.

Note: the same certificate will be used for all secure channels though you can change this later.

Certificate: [✓ None]

Generate Self-Signed Certificate (recommended for testing only)

Use an Existing Certificate:

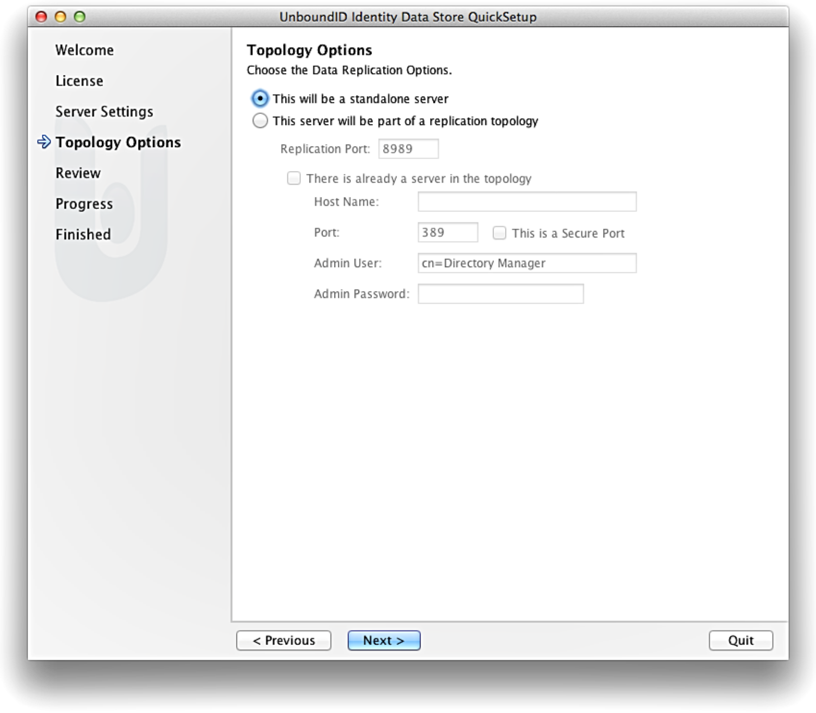
Key Store Type: Java Key Store (JKS) File / PKCS12 File / PKCS11 Token

Key Store Path:

Key Store PIN:

9. On the **Topology Options** dialog, select whether the Data Store is a standalone server or part of a replication topology, and then click **Next**.

For instructions on setting up replication using the GUI installer, see *To Set Up a Replication Topology for Evaluation Purposes*.



Topology Options
Choose the Data Replication Options.

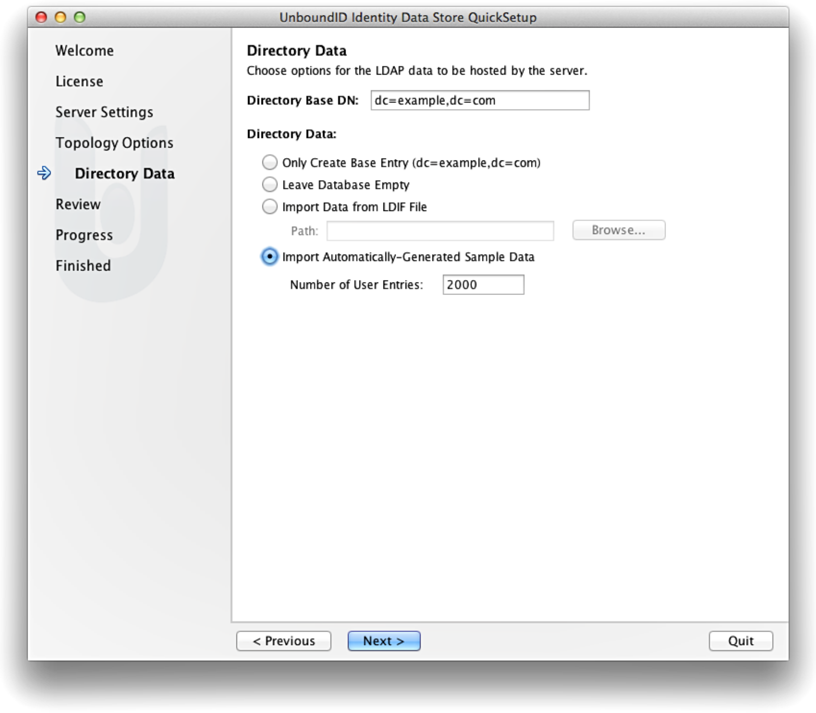
(●) This will be a standalone server
( ) This server will be part of a replication topology

Replication Port: 8989

[ ] There is already a server in the topology

Host Name:
Port: 389 [ ] This is a Secure Port
Admin User: cn=Directory Manager
Admin Password:

10. On the **Directory Data** dialog, specify how to load data into your server, and then click **Next**.



UnboundID Identity Data Store QuickSetup

Directory Data

Choose options for the LDAP data to be hosted by the server.

Directory Base DN: dc=example,dc=com

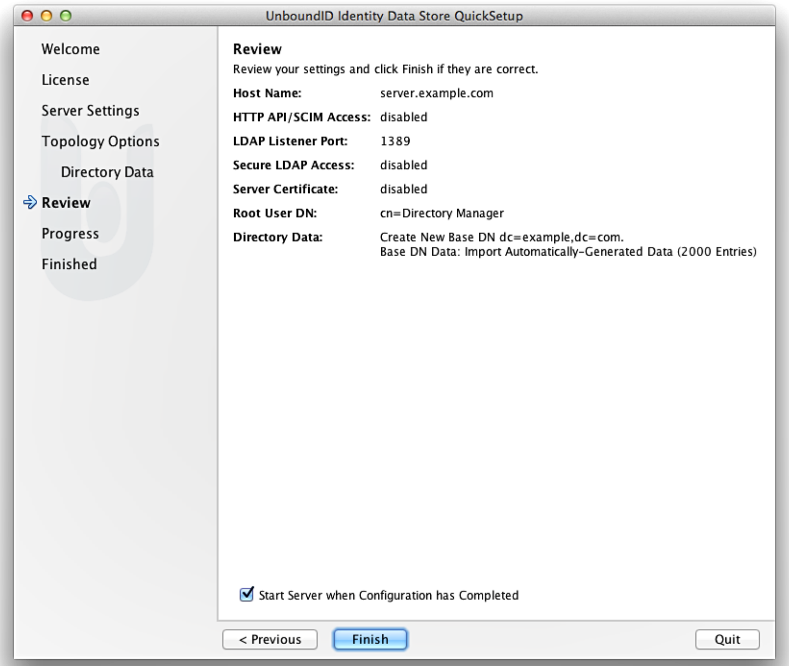
Directory Data:

( ) Only Create Base Entry (dc=example,dc=com)
( ) Leave Database Empty
( ) Import Data from LDIF File
Path:
(●) Import Automatically-Generated Sample Data
Number of User Entries: 2000

Directory Base DN	Base DN for your directory.
Directory Data	**Only Create Base Entry**. Create a base entry but no children entries below the base DN. By default, the server uses `dc=example,dc=com`. You can enter a base DN for your company.
	Leave Database Empty. Create a stand-alone Data Store that contains no data. For more information on populating the database, see *Initializing Data onto the Server*.
	Import Data from LDIF File. Populate the server with existing LDIF data. Type the path to the LDIF file or click **Browse** to select the path.

	Import Automatically-Generated Sample Data. Populate the Data Store with sample data for testing purposes, and type the number of sample user entries. The default number of entries is 2000. This option is convenient if you are quickly installing and evaluating the Data Store. The Data Store generates sequential user entries for quick searches over specified DN ranges and loads the searchable entries that are sequentially ordered:
	`uid=user.0,ou=People,dc=example,dc=com`
	`uid=user.1,ou=People,dc=example,dc=com`
	`uid=user.n,ou=People,dc=example,dc=com`
	where n is the number of entries specified during setup. Also, note that the maximum number of sample entries allowed for the GUI installer is 1 million entries but if your heap size is too small (e.g., 256MB), the installation may hang. For example, for 1 million entries, you can successfully run the server with a heap size of 1 GB although the system will not be optimally primed.

11. On the **Review** dialog, review your configuration. Select **Start Server when Configuration has Completed** to automatically start the server after it has been configured. Click **Finish** to complete the installation.



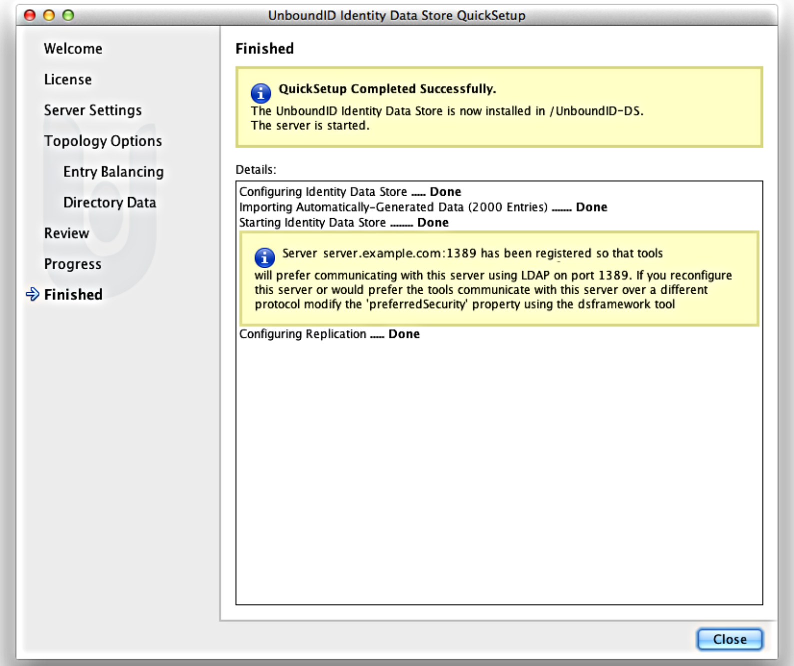
Review

Review your settings and click Finish if they are correct.

Host Name:	server.example.com
HTTP API/SCIM Access:	disabled
LDAP Listener Port:	1389
Secure LDAP Access:	disabled
Server Certificate:	disabled
Root User DN:	cn=Directory Manager
Directory Data:	Create New Base DN dc=example,dc=com. Base DN Data: Import Automatically-Generated Data (2000 Entries)

☑ Start Server when Configuration has Completed

12. On the **Finished** dialog, click **Close** to finish.



Finished

QuickSetup Completed Successfully.

The UnboundID Identity Data Store is now installed in /UnboundID-DS.
The server is started.

Details:

```
Configuring Identity Data Store ..... Done
Importing Automatically-Generated Data (2000 Entries) ...... Done
Starting Identity Data Store ....... Done
```

Server server.example.com:1389 has been registered so that tools will prefer communicating with this server using LDAP on port 1389. If you reconfigure this server or would prefer the tools communicate with this server over a different protocol modify the 'preferredSecurity' property using the dsframework tool

```
Configuring Replication ..... Done
```

13. Read the section *Where to Go From Here*.

You have successfully installed a stand-alone Data Store instance.

To Set Up a Replication Topology for Evaluation Purposes

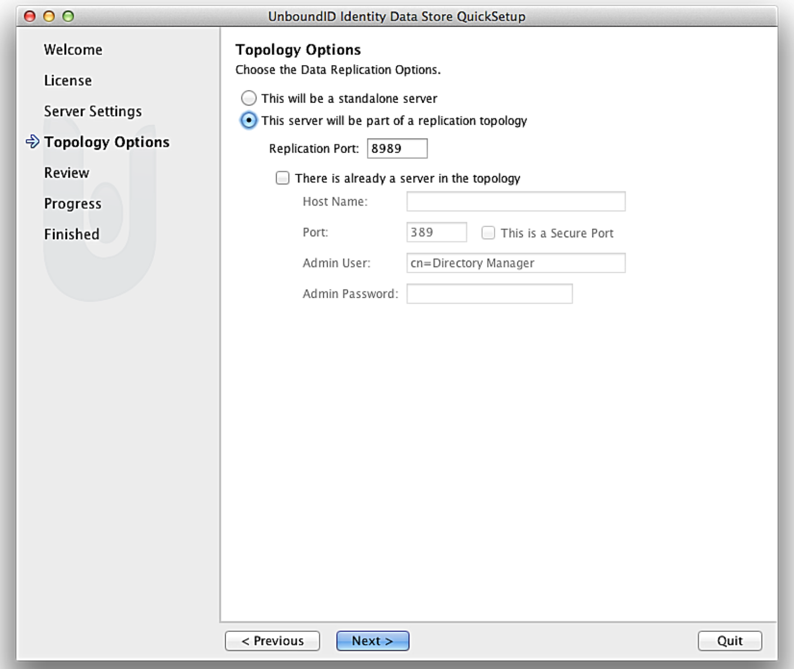
To view the minimum required Java version, access your Customer Support Center portal or contact your authorized support provider for the latest software versions supported. Your server environment also must be able to support a Java-based graphical application.

The Data Store's GUI `setup` tool allows you to quickly install a multi-master replication topology on desktop systems that support a graphical environment. The following procedure shows how to configure two multi-master replication servers using the GUI `setup` tool for evaluation purposes. Production deployments require more fine-grained setup procedures that must be run from the command line or from scripts. For production deployments, follow the instructions in *Setting Up the Data Store in Non-Interactive Mode*.

1. For the first Data Store instance, repeat steps 1-8 in *To Install the Server Using the GUI*.

2. On the **Topology Options** dialog, click **This server will be part of a replication topology**, and then click **Next** to continue.

   Use the default replication port 8989 for this first replica.



Topology Options
Choose the Data Replication Options.

( ) This will be a standalone server
(●) This server will be part of a replication topology

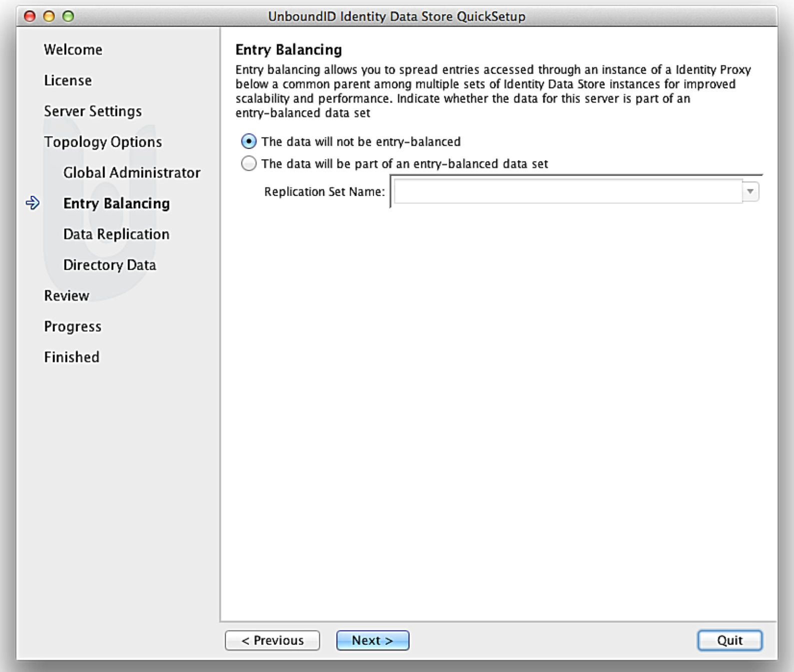
Replication Port: 8989

[ ] There is already a server in the topology

Host Name:
Port: 389 [ ] This is a Secure Port
Admin User: cn=Directory Manager
Admin Password:

3. Next, if you plan to use this Data Store in an entry-balancing deployment with the Proxy Server, then you must specify the name of the replication set that will be replicated to other replicas. Entry-balancing allows you to spread entries among multiple sets of Data Store

instances, which can be accessed through a proxy server instance below a common parent DN. On the **Entry Balancing** dialog, click if the data will be part of any entry-balancing dataset, and then select or enter a name for the replication set. For more information on entry-balancing deployments, see the *UnboundID Proxy Server Administration Guide*.



Entry Balancing

Entry balancing allows you to spread entries accessed through an instance of a Identity Proxy below a common parent among multiple sets of Identity Data Store instances for improved scalability and performance. Indicate whether the data for this server is part of an entry-balanced data set

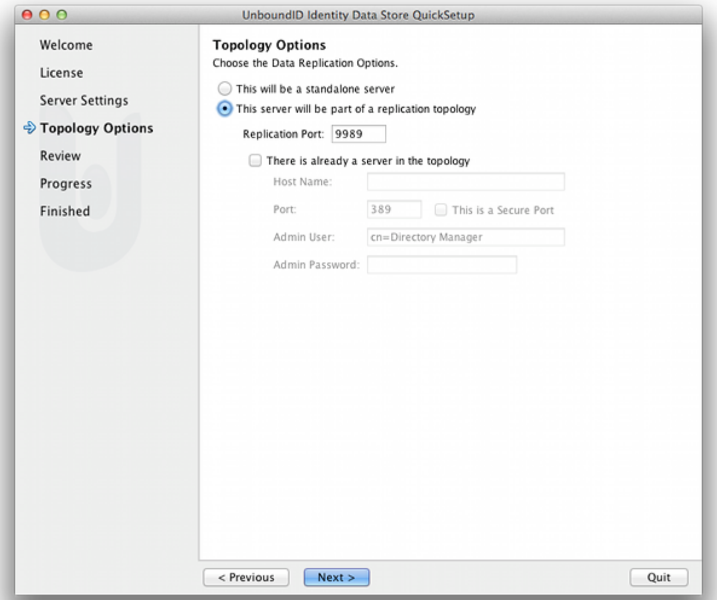
[✓ The data will not be entry-balanced]
The data will be part of an entry-balanced data set

Replication Set Name:

4. Complete the installation. On the **Directory Data** dialog, generate and import 2000 sample entries. Then, on the **Review** dialog, click **Finish**. Check that the **Start Server when Configuration has Completed** option has been selected to automatically start the server after it has been configured. This first server must be online to set up the other servers for replication.

5. To install the second server, repeat steps 1-5 in *To Install the Server Using the GUI*.

6. On the **Topology Options** dialog for the second server, type the Replication Port number, host name, LDAP listener port, bind DN (or Admin user ID), and bind password (or Admin user password) for the first replica, server1.example.com. Then click **Next**.



Topology Options
Choose the Data Replication Options.

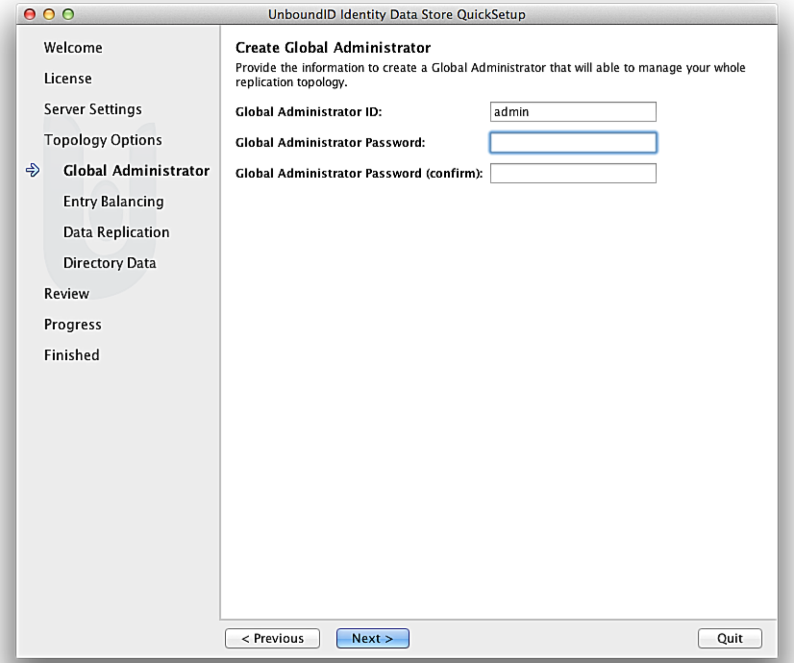
( ) This will be a standalone server
(•) This server will be part of a replication topology

Replication Port: 9989

[ ] There is already a server in the topology

Host Name:
Port: 389 [ ] This is a Secure Port
Admin User: cn=Directory Manager
Admin Password:

7. On the **Global Administrator** dialog, type a global administrator ID or accept the default, and then type the password. The Global Administrator ID manages replication server groups.

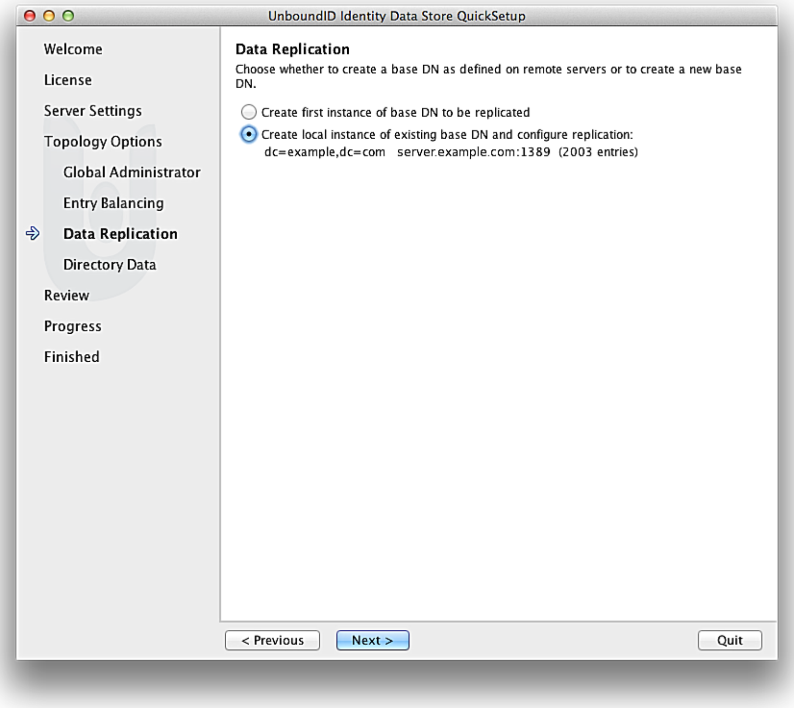


Create Global Administrator
Provide the information to create a Global Administrator that will able to manage your whole replication topology.

Global Administrator ID: admin
Global Administrator Password:
Global Administrator Password (confirm):

8. On the **Entry Balancing** dialog, click if the data will be part of an entry-balancing dataset, and then select or enter a name for the replication set.

9. On the **Data Replication** dialog, click the base DN that was configured on the first server.

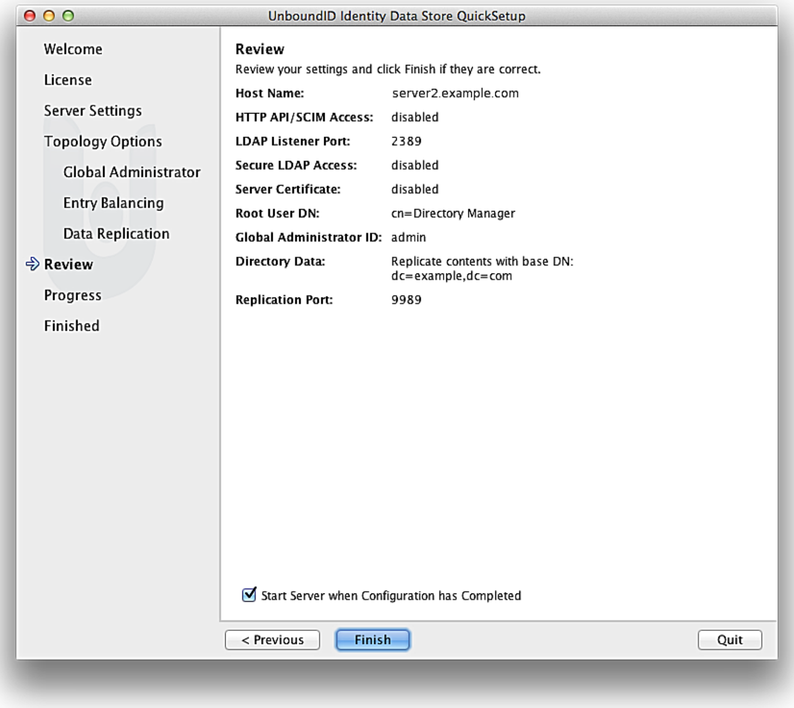


Data Replication

Choose whether to create a base DN as defined on remote servers or to create a new base DN.

( ) Create first instance of base DN to be replicated
(●) Create local instance of existing base DN and configure replication:
dc=example,dc=com server.example.com:1389 (2003 entries)

10. Review the installation on the second server, and then click **Finish**.



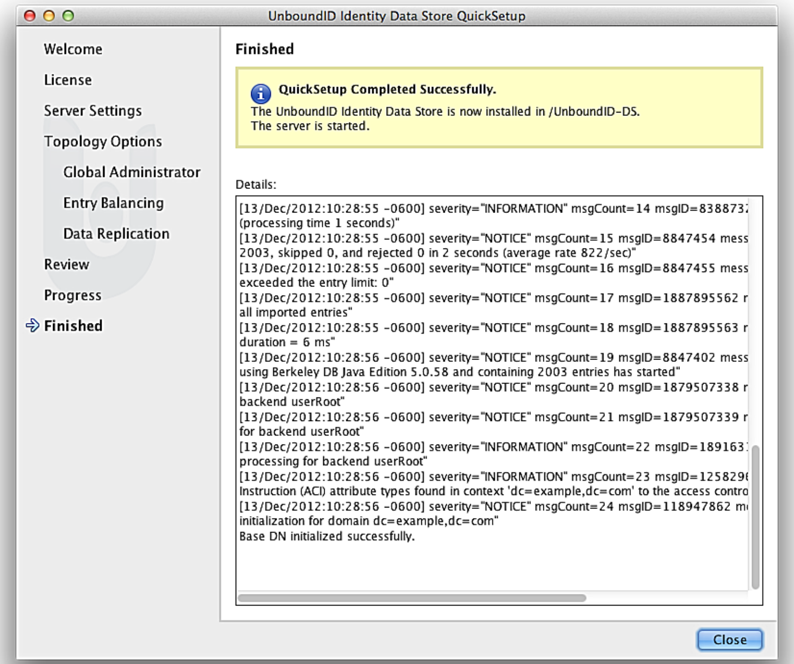
Review

Review your settings and click Finish if they are correct.

Host Name:	server2.example.com
HTTP API/SCIM Access:	disabled
LDAP Listener Port:	2389
Secure LDAP Access:	disabled
Server Certificate:	disabled
Root User DN:	cn=Directory Manager
Global Administrator ID:	admin
Directory Data:	Replicate contents with base DN: dc=example,dc=com
Replication Port:	9989

☑ Start Server when Configuration has Completed

11. Click **Close** to finish.



Finished

QuickSetup Completed Successfully.
The UnboundID Identity Data Store is now installed in /UnboundID-DS.
The server is started.

Details:

```
[13/Dec/2012:10:28:55 -0600] severity="INFORMATION" msgCount=14 msgID=838873
(processing time 1 seconds)"
[13/Dec/2012:10:28:55 -0600] severity="NOTICE" msgCount=15 msgID=8847454 mess
2003, skipped 0, and rejected 0 in 2 seconds (average rate 822/sec)"
[13/Dec/2012:10:28:55 -0600] severity="NOTICE" msgCount=16 msgID=8847455 mess
exceeded the entry limit: 0"
[13/Dec/2012:10:28:55 -0600] severity="NOTICE" msgCount=17 msgID=1887895562 r
all imported entries"
[13/Dec/2012:10:28:55 -0600] severity="NOTICE" msgCount=18 msgID=1887895563 r
duration = 6 ms"
[13/Dec/2012:10:28:56 -0600] severity="NOTICE" msgCount=19 msgID=8847402 mess
using Berkeley DB Java Edition 5.0.58 and containing 2003 entries has started"
[13/Dec/2012:10:28:56 -0600] severity="NOTICE" msgCount=20 msgID=1879507338 r
backend userRoot"
[13/Dec/2012:10:28:56 -0600] severity="NOTICE" msgCount=21 msgID=1879507339 r
for backend userRoot"
[13/Dec/2012:10:28:56 -0600] severity="INFORMATION" msgCount=22 msgID=189163
processing for backend userRoot"
[13/Dec/2012:10:28:56 -0600] severity="INFORMATION" msgCount=23 msgID=125829
Instruction (ACI) attribute types found in context 'dc=example,dc=com' to the access contro
[13/Dec/2012:10:28:56 -0600] severity="NOTICE" msgCount=24 msgID=118947862 m
initialization for domain dc=example,dc=com"
Base DN initialized successfully.
```

You have successfully configured a multi-master replication topology with two Data Stores. You can get a status of your replication topology by running the `dsreplication status` command-line tool. For information on the status option, see Command Line Interface.

Before You Begin

After you have unzipped the Data Store ZIP file, you may want to carry out the following functions depending on your deployment requirements:

- **Custom Schema Elements**. If your deployment uses custom schema elements in a custom schema file (for example, `98-schema.ldif`), you may do one of the following:
  - Copy your custom schema file to the `config/schema` directory before running setup.
  - Copy your custom schema file to the `config/schema` directory after setup and re-start the server. If replication is enabled, the restart will result in the schema replicating to other servers in the replication topology.
  - Use the **Schema Editor** after setup. If replication is enabled, schema definitions added through the **Schema Editor** will replicate to all servers in the replication topology without the need for a server restart.
- **Certificates**. If you are setting up a new machine instance, copy your keystore and truststore files to the `<server-root>/config` directory prior to running setup. The keystore and

truststore passwords can be placed, in clear text, in corresponding `keystore.pin` and `truststore.pin` files in `<server-root>/config`.

- **Locations**. Location names are used to define a grouping of UnboundID Server products based on physical proximity. For example, a location is most often associated with a single datacenter location. During the installation, assign a location to each server for optimal inter-server behavior. The location assigned to a server within Global Configuration can be referenced by components within the server as well as processes external to the server to satisfy "local" versus "remote" decisions used in replication, load balancing, and failover.
- **Validate ACIs**. Many directory servers allow for less restrictive application of its access control instructions (ACIs), so that they accept invalid ACIs. For example, if a Sun/Oracle server encounters an access control rule that it cannot parse, then it will simply ignore it without any warning, and the server may not offer the intended access protection. Rather than unexpectedly exposing sensitive data, the UnboundID Data Store rejects any ACIs that it cannot interpret, which ensures data access is properly limited as intended, but it can cause problems when migrating data with existing access control rules to an UnboundID Data Store. If you are migrating from a Sun/Oracle deployment to an UnboundID Data Store, the UnboundID Data Store provides a `validate-acis` tool in the `bin` directory (UNIX or Linux systems) or `bat` directory (Windows systems) that identifies any ACI syntax problems before migrating data. For more information, see *Validating ACIs Before Migrating Data*.

Important:

Each Server Deployment Requires an Execution of Setup - Duplicating a Server-root is not Supported. The installation of the server does not write or require any data outside of the server-root directory. After executing `setup`, copying the server-root to another location or system, in order to *duplicate* the installation, is not a supported method of deployment. The server-root can be moved to another host or disk location if a host or file system change is needed.

Setting Up the Data Store in Interactive Mode

The `setup` tool also provides an interactive text-based command-line interface to set up a Data Store instance.

To Install the Data Store in Interactive Mode

1. Unzip the distribution ZIP file, review *Before You Begin*, and then go to the server root directory if you are not already there. Use the `setup` utility with the `--cli` option to install the server in interactive mode.

```
$ ./setup --cli
```

If your *JAVA_HOME* environment variable is set to an older version of Java, you must explicitly specify the path to the Java JDK installation during the setup process. You can either set the *JAVA_HOME* environment variable with the Java JDK path or execute the `setup` command in a modified Java environment using the `env` command.

```
$ env JAVA_HOME=/ds/java ./setup --cli
```

2. Read the UnboundID End-User License Agreement. If you agree to its terms, type `yes` to continue.

3. Next, enter the root user DN, or press **Enter** to accept the default (cn=Directory Manager), and then type the root user password.

4. Type the LDAP listener port number for your server, or accept the default 1389.

   If you are logged in as a root user, you will see port 389.

5. The next two options ask if you want to use SSL or StartTLS. Type `yes` to enable one or both. Enabling SSL sets up a separate connection handler (i.e., LDAPS Connection Handler) to allow SSL over its client connections. Enabling StartTLS sets up the LDAP Connection Handler to allow StartTLS over its client connections. If you do not need a secure connection, accept the default (`no`) to use a standard LDAP connection.

6. If you typed `yes` for SSL or StartTLS, select the certificate options.

   - If you want to generate a self-signed certificate for testing purposes only.
   - If you have an existing certificate using a Java Keystore, enter the keystore path and keystore PIN.
   - If you have an existing certificate using use a PKCS#12 keystore, enter the keystore path and the keystore PIN.
   - If you use the PKCS#11 token, enter only the keystore PIN.

7. Next, type `yes` if you would like the Data Store to listen for client connections on specific host names or IP addresses, and then enter the specific host name or IP address. You can enter as many host names or IP addresses as you would like. If you prefer the default (the server listens on all network interfacess), then press **Enter** to accept the default (`no`).

8. Type the base DN for the data, or accept the default base DN of `dc=example,dc=com`.

9. On the **Options for populating the database** menu, enter the option to generate and import sample data. Type the desired number of entries, or press Enter to accept the default number (2000). This option is used for quick evaluation of the Data Store.

   See *Initializing Data onto the Server* if you want to use other options to initialize the server.

10. Next, type `yes` if you would like to tune the amount of memory that will be consumed by the Data Store and its tools.

    This option should only be selected if the Data Store is the primary application on that machine, and that no other processes consume a significant amount of memory.

    - If you selected optimized memory tuning, enter the maximum amount of memory (heap) to be allocated to the Data Store. Use “m” for megabytes (for example, 256m) or “g” for gigabytes (for example, 16g). The displayed value will be based on the available resources on your system.

- Otherwise, accept the default allocated memory as determined for your system.

11. Next, type `yes` if you want to prime or preload the database cache at startup prior to accepting client connections.

Note that priming the cache can increase the startup time for the Data Store but provides optimum performance once starup has completed. This option is best used if you have strict throughput or response time performance requirements, or if you plan to have other replicas in a replication topology that can accept traffic while this Data Store instance is starting. Priming the cache also helps determine the recommended JVM option, `CMSInitiatingOccupancyFraction`, when a Java garbage collection pause occurs. See *JVM Garbage Collection Using CMS*.

12. Next, type (`yes`), or press **Enter** to accept the default (yes) to start the Data Store after the configuration has completed. If you plan to configure additional settings or import data, you can type `no` to keep the server in shutdown mode.

13. On the **Setup Summary** page, confirm the configuration. Press Enter to accept the default (set up with the parameters given), enter the option to repeat the installation process, or enter the option to cancel the setup completely.

Installing the Data Store in Non-Interactive Mode

You can run the `setup` command in non-interactive mode to automate the installation process using a script or to run the command directly from the command line. Non-interactive mode is useful when setting up production or QA servers with specific configuration requirements.

The non-interactive command-line mode requires that all mandatory options be present for each command call. If there are missing or incorrect arguments, the `setup` tool fails and aborts the process. You must also use a `--no-prompt` option to suppress interactive output, except for errors, when running in non-interactive mode. Additionally, you must also use the `--acceptLicense` option and specify the port using the `--ldapPort` or `--ldapsPort` option. If neither option is specified, an error message is displayed. To view the license, run `bin/review-license` command.

To automatically tune the JVM to use maximum memory, use the `--aggressiveJVMTuning` and `--maxHeapSize` {memory} options. To preload the database at startup, use the `--primeDB` option.

To configure a deployment using a truststore, see *Installing the Data Store in Non-Interactive Mode with a Truststore*.

To see a description of the available command-line options for the `setup` tool, use `setup --help`.

To Install the Data Store in Non-Interactive Mode

The following procedure shows how to install a Data Store in a production or QA environment with no security enabled.

- Unzip the distribution ZIP file, review “Before You Begin”, and then use `setup` with the `--cli` and `--no-prompt` options for non-interactive mode from the `<server-root>` directory. The following command uses the default root user DN (cn=Directory Manager) with the specified `--rootUserPassword` option. You must include the `--acceptLicense` option or the setup will generate an error message.

```
$ ./setup --cli --no-prompt --rootUserPassword "password" \
  --baseDN "dc=example,dc=com" --acceptLicense --ldapPort 389
```

To Install the Data Store in Non-Interactive Mode with a Truststore

You can set up the Data Store using an existing truststore for secure communication. This section assumes that you have an existing keystore and truststore with trusted certificates.

- Unzip the distribution ZIP file, review *Before You Begin*, and then, from the server root directory, use `setup` with the `--cli` and `--no-prompt` options for non-interactive mode. The following example enables security using both SSL and StartTLS. It also specifies a JKS keystore and truststore that define the server certificate and trusted CA. The `userRoot` database contents will remain empty and the base DN entry will not be created.

```
$ ./setup --cli --no-prompt --rootUserPassword "password" \
  --baseDN "dc=example,dc=com" --ldapPort 389 --enableStartTLS \
  --ldapsPort 636 --useJavaKeystore config/keystore.jks \
  --keyStorePasswordFile config/keystore.pin \
  --certNickName server-cert --useJavaTrustStore config/truststore.jks \
  --acceptLicense
```

  The password to the private key with the keystore is expected to be the same as the password to the keystore. If this is not the case, the private key password can be defined with the Management Console or the `dsconfig` tool by editing the Trust Manager Provider standard configuration object.

Installing a Lightweight Server

Users who want to demo or test a lightweight version of the Data Store on a memory-restricted machine can do so by removing all unused or unneeded configuration objects. All configuration entries, whether enabled or not, take up some amount of memory to hold the definition and listeners that will be notified of changes to those objects.

The configuration framework will not allow you to remove objects that are referenced, and in some cases if you have one configuration object referencing another but really do not need it, then you will first need to remove the reference to it. If you try to remove a configuration object that is referenced, both `dsconfig` and the web console should prevent you from removing it and will tell you what still references it.

Depending on your test configuration, some example configuration changes that can be made are as follows:

- **Reduce the number of worker threads**. Each thread has a stack associated with it, and that consumes memory. If you're running a bare-bones server, then you probably do not have enough load to require a lot of worker threads.

```
$ bin/dsconfig set-work-queue-prop \
  --set num-worker-threads:8 \
  --set num-administrative-session-worker-threads:4 \
  --set max-work-queue-capacity:100
```

- **Reduce the percentage of JVM memory used for the JE database cache**. When you have a memory-constrained environment, you want to ensure that as much of the memory that is there is available for use during processing and not tied up caching database contents.

```
$ bin/dsconfig set-backend-prop --backend-name userRoot --set db-cache-percent:5
```

- **Disable the Dictionary Password Validator**. The Dictionary Password Validator takes a lot of memory to hold its dictionary. Disabling it will free up some memory. You can delete the other password validators if not needed, such as Attribute Value, Character Set, Length-based, Repeated Characters, Similarity-based, or Unique Characters Password Validator.

```
$ bin/dsconfig delete-password-validator --validator-name Dictionary
```

- **Remove non-essential schema files**. Although not recommended for production deployments, some candidates that you can remove are the following: `03-rfc2713.ldif`, `03-rfc2714.ldif`, `03-rfc2739.ldif`, `03-rfc2926.ldif`, `03-rfc2985.ldif`, `03-rfc3712.ldif`, `03-uddiv3.ldif`.

There are other items that can be removed, depending on your desired configuration. Contact your authorized support provider for assistance.

Running the Status Tool

The Data Store provides a `status` tool that outputs the current state of the server as well as other information, such as server version, JE Environment statistics, Operation Processing Times, Work Queue, and Administrative Alerts. The `status` tool is located in the `bin` directory (UNIX, Linux) or the `bat` directory (Windows).

To Run the Status Tool

- Run the `status` command on the command line. The following command displays the current Data Store status and limits the number of viewable alerts in the last 48 hours. It provides the current state of each connection handler, data sources, JE environment statistics, processing times by operation type and current state of the work queue.

```
$ bin/status --bindDN “uid=admin,dc=example,dc=com” --bindPassword secret

          --- Server Status ---
Server Run Status:    Started 28/Mar/2012:10:47:17.000 -0500
Operational Status:   Available
Open Connections:     13
Max Connections:      13
Total Connections:    50

          --- Server Details ---
Host Name:            server1.example.com
Administrative Users: cn=Directory Manager
Installation Path:    UnboundID-DS
Server Version:       UnboundID Data Store 5.2.0.1
Java Version:         jdk-7u9

          --- Connection Handlers ---
```

```
Address:Port : Protocol : State
-------------:----------:---------
0.0.0.0:1389 : LDAP     : Enabled
0.0.0.0:1689 : JMX      : Disabled
0.0.0.0:636  : LDAPS    : Disabled

           --- Data Sources ---
Base DN:             dc=example,dc=com
Backend ID:          userRoot
Entries:             2003
Replication:         Enable
Replication Backlog: 0
Age of Oldest Backlog Change: not available

           --- JE Environment ---
ID                 : Cache Full :  Cache   : On-Disk : Alert
-------------------:------------:----------:---------:------
replicationChanges : 6 %     : 328.8 kb : 30.4 kb : None
userRoot        : 9 %        : 6.2mb    : 146.6mb : None

           --- Operation Processing Time ---
Op Type   : Total Ops : Avg Resp Time (ms)
----------:-----------:------------------
Add       : 0         : 0.0
Bind      : 0         : 0.0
Compare   : 0         : 0.0
Delete    : 0         : 0.0
Modify    : 2788567   : 0.921
Modify    : 0         : 0
DN        : 2267266   : 0.242
Search    : 5055833   : 0.616
All

            --- Work Queue ---
           : Recent : Average : Maximum
-----------:--------:---------:--------
Queue Size : 4   : 0    : 10
% Busy  : 26  : 5    : 100

            --- Administrative Alerts ---
Severity : Time                       : Message
---------:----------------------------:---------------------------------------------
Info     : 28/Mar/2012 10:47:17 -0500 : The Directory Server has started successfully
Info     : 28/Mar/2012 10:47:14 -0500 : The Directory Server is starting
Info     : 28/Mar/2012 10:44:22 -0500 : The Directory Server has started successfully
Info     : 28/Mar/2012 10:44:18 -0500 : The Directory Server is starting

Shown are alerts of type [Info,Warning,Error,Fatal] from the past 48 hours Use the
--maxAlerts and/or --severity options to filter this list
```

Note: By default, the `status` command displays the alerts generated in the last 48 hours. You can limit the number of alerts by using the `--maxAlerts` option.

Where To Go From Here

After you have set up your Data Store instance, you can configure any specific server settings, import your user database, or run initial performance tests to optimize your server’s throughput.

- **Apply Server Configurations**. Apply your server configuration changes individually or using a `dsconfig` batch file. The batch file defines the Data Store configuration tool, `dsconfig`, commands necessary to configure your server instance. For more information on using batch files, see *Using dsconfig in Batch Mode*.

If you are migrating from a Sun Java System 5.x, 6.x, 7.x directory server, you can use the `bin/migrate-sun-ds-config` command to migrate your configuration settings to this newly installed server instance.

- **Import Data**. Import your user data using the `import-ldif` tool. The import serves as an initial test of the schema settings.

```
$ bin/import-ldif --backendID userRoot --ldifFile ../user-data.ldif
```

- **Run Performance Tests**. The Data Store provides two tools for functional performance testing using in-house LDAP clients that accesses the server directly: `searchrate` (tests search performance) and `modrate` (tests modification performance):

```
$ bin/searchrate --baseDN "dc=example,dc=com" --scope sub \
  --filter "(uid=user.[0-1999])" --attribute givenName --attribute sn \
  --attribute mail --numThreads 10

$ bin/modrate --entryDN "uid=user.[0-1999],ou=People,dc=example,dc=com" \
  --attribute description --valueLength 12 --numThreads 10
```

Working with Multiple Backends

You can create multiple local database backends, each containing one or more different base DNs. There should be at most one replicating domain on each local database backend. The replication domain should not span multiple local database backends. The typical entry-balancing configuration involves two local database backends: one backend to serve the global domain data that resides above the entry-balancing point and a backend that is defined with the entry-balancing point as the base DN, such as `ou=people,dc=example,dc=com`.

With multiple local database backends configured, the data existing with each backend can be managed independently. In addition, separate index settings are applied to each local database backend.

When creating multiple databse backends, consider the following:

- No two backends may have the same base DN.
- If any base DN for a given backend is subordinate to a base DN on another backend, then all base DNs on that backend must be subordinate to the base DN of the other backend.
- The total of all db-cache-percent values should be no more than 65-70% in most cases and should never be configured to exceed 100%.

Importing Data

After installation, the database, such as userRoot, will need to have data imported. For a server to be added to a replicating set, the database will be imported as part of the `dsreplication initialize` operation, which is performed after `dsreplication enable`. A server that will not be added to a replicating set, or the first server of a future replicating set, should have data imported with the `bin/import-ldif` tool. See Chapter 8, Importing and Exporting Data, for more infomation about the `bin/import-ldif` tool.

Generating Sample Data

The UnboundID Data Store provides LDIF templates that can be used to generate sample entries to initialize your server. You can generate the sample data with the `make-ldif` utility together with template files that come bundled with the ZIP build, or you can use templates files that you create yourself. The templates create sequential entries that are convenient for testing the UnboundID Data Store with a range of dataset sizes. The Data Store templates are located in the `config/MakeLDIF`.

To randomize the data, the `make-ldif` command has a `--randomSeed` option that can be used to seed the random number generator. If this option is used with the same seed value, the template will always generate exactly the same LDIF file.

The sample data templates generate a dataset with basic access control privileges that grants anonymous read access to anyone, grants users the ability to modify their own accounts, and grants the Admin account full privileges. The templates also include the uid=admin and ou=People entries necessary for a complete dataset. You can bypass the `make-ldif` command entirely and use the `--templateFile` option with the `import-ldif` tool.

- Use the `make-ldif` command to generate sample data. The command generates 10,000 sample entries and writes them to an output file, `data.ldif`. The random seed generator is set to 0.

  ```
  $ bin/make-ldif --templateFile config/MakeLDIF/example-10k.template \
    --ldifFile /path/to/data.ldif --randomSeed 0
  ```

To Import Data on the Data Store Using Offline Import

1. Create an LDIF file that contains entries, or locate an existing file.

   The import-ldif tool requires an LDIF file, which conforms to standard LDIF syntax without change records. This means the changeType attribute is not allowed in the input LDIF. For information on adding entries to the Data Store, see Managing Entries.

2. Stop the Data Store.

3. Use the offline `import-ldif` to import data from an LDIF file to the Data Store. For assistance with the list of options, run `import-ldif --help`.

   In the following example, the data is imported from the `data.ldif` file to the `userRoot` backend. If any entry is rejected due to a schema violation, then the entry and the reason for the rejection is written to the `rejects.ldif` file. Skipped entries, written to `skipped.ldif`, occur if an entry cannot be placed under a branch node in the DIT or if exclusion filtering is used (`--excludeBranch`, `--excludeAttribute`, or `--excludeFilter`). The `--overwrite` option instructs `import-ldif` to overwrite existing skipped and rejected files. The `--overwriteExistingEntries` option indicates that any existing data in the backend should be overwritten. Finally, the `--stripTrailingSpaces` option strips trailing spaces on attributes that would otherwise result in a LDIF parsing error.

   ```
   $ bin/import-ldif --backendID userRoot --ldifFile /path/to/data.ldif --rejectFile
   ```

```
    rejects.ldif --skipFile skipped.ldif --overwrite --overwriteExistingEntries --
stripTrailingSpaces
```

4. Re-start the Data Store.

Running the Server

To start the Data Store, run the bin/start-ds command on UNIX or Linux systems (an analogous command is in the `bat` folder on Microsoft Windows systems). The bin/start-ds command starts the Data Store as a background process when no options are specified. To run the Data Store as a foreground process, use the bin/start-ds command with the `--nodetach` option.

To Start the Data Store

Use bin/start-ds to start the server.

```
$ bin/start-ds
```

To Run the Server as a Foreground Process

1. Enter bin/start-ds with the `--nodetach` option to launch the Data Store as a foreground process.

```
$ bin/start-ds --nodetach
```

2. You can stop the Data Store by pressing `CNTRL+C` in the terminal window where the server is running or by running the bin/stop-ds command from another window.

To Start the Server at Boot Time

By default, the UnboundID Data Store does not start automatically when the system is booted. Instead, you must manually start it with the bin/start-ds command. To configure the Data Store to start automatically when the system boots, use the `create-rc-script` utility to create a run control (RC) script, or create the script manually.

1. Create the startup script.

```
$ bin/create-rc-script --outputFile UnboundID-DS.sh --userName ds
```

2. As a root user, move the generated UnboundID-DS.sh script into the `/etc/init.d` directory and create symlinks to it from the `/etc/rc3.d` directory (staring with an “S” to ensure that the server is started) and `/etc/rc0.d` directory (starting with a “K” to ensure that the server is stopped).

```
# mv UnboundID-DS.sh /etc/init.d/
# ln -s /etc/init.d/UnboundID-DS.sh/etc/rc3.d/S50-boot-ds.sh
# ln -s /etc/init.d/UnboundID-DS.sh /etc/rc0.d/K50-boot-ds.sh
```

Some Linux implementations may not like the “-” in the scripts. If your scripts do not work, try renaming the scripts without the dashes. You can also try symlinking the S50* file into the `/etc/rc3.d` or the `/etc/rc0.d` directory or both, based on whatever runlevel the server enters when it starts. Some Linux systems do not even use `init.d-style` startup scripts, so depending on whatever flavor of Linux you are using you might have to put the script somewhere else or use some other mechanism for having it launched at startup.

3. Log out as root, and re-assume the ds role if you are on a Solaris system.

Stopping the Data Store

The Data Store provides a simple shutdown script, bin/stop-ds, to stop the server. You can run it manually from the command line or within a script.

If the Data Store has been configured to use a large amount of memory, then it can take several seconds for the operating system to fully release the memory and make it available again. If you try to start the server too quickly after shutting it down, then the server can fail because the system does not yet have enough free memory. On UNIX systems, run the `vmstat` command and watch the values in the "free" column increase until all memory held by the Data Store is released back to the system.

You can also set a configuration option that specifies the maximum shutdown time a process may take.

To Stop the Server

- Use the bin/stop-ds tool to shut down the server.

```
$ bin/stop-ds
```

To Schedule a Server Shutdown

- Use the `bin/stop-ds` tool with the `--stopTime YYYYMMDDhhmmss` option to schedule a server shutdown.

  The Data Store schedules the shutdown and sends a notification to the `server.out` log file. The following example sets up a shutdown task that is scheduled to be processed on June 6, 2012 at 8:45 A.M. CDT. The server uses the UTC time format if the provided timestamp includes a trailing “Z”, for example, 20120606134500Z. The command also uses the `--stopReason` option that writes the reason for the shut down to the logs.

```
$ bin/stop-ds --stopTime 20120606134500Z --port 1389 \
  --bindDN "uid=admin,dc=example,dc=com" --bindPassword secret \
  --stopReason "Scheduled offline maintenance"
```

To Restart the Server

Re-start the Data Store using the bin/stop-ds command with the `--restart` or `-R` option. Running the command is equivalent to shutting down the server, exiting the JVM session, and then starting up again.

- Go to the server root directory, and run the bin/stop-ds command with the `-R` or `--restart` options.

  ```
  $ bin/stop-ds --restart
  ```

Uninstalling the Server

The Data Store provides an `uninstall` command-line utility for quick and easy removal of the code base.

To uninstall a server instance, run the `uninstall` tool in one of the following modes: graphical user interface (GUI) mode, interactive command-line, or non-interactive command-line mode.

- **Graphical User Interface (GUI) Mode**. Used primarily for evaluation purposes. GUI mode launches a Java-based graphical `setup` tool that enables you to uninstall the Data Store. If a graphical environment is not available, then `uninstall` will fall back to the interactive command-line mode.
- **Interactive Command-Line Mode**. Interactive command-line mode is a text-based interface that prompts the user for input. You can start the command using the `bin/uninstall` command with the `--cli` option. The utility prompts you for input if more data is required.
- **Non-Interactive Command-Line Mode**. Non-interactive mode suppresses progress information from being written to standard output during processing, except for fatal errors. This mode is convenient for scripting and is invoked using the `bin/uninstall` command with the `--no-prompt` option.

Note: For stand-alone installations with a single Data Store instance, you can also manually remove the Data Store by stopping the server and recursively deleting the directory and subdirectories. For example:

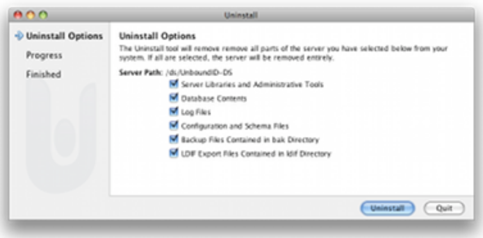
```
$ rm -rf /ds/UnboundID-DS
```

To Uninstall the Server Using in GUI Mode

1. From the UnboundID Data Store server root directory, run the following command:

   ```
   $ ./uninstall
   ```

2. Select the directories that you want to remove, and then click `Uninstall`.



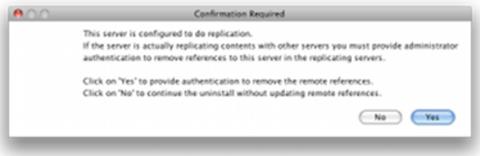
Uninstall Options

The Uninstall tool will remove remove all parts of the server you have selected below from your system. If all are selected, the server will be removed entirely.

Server Path: /ds/UnboundID-DS

- ✓ Server Libraries and Administrative Tools
- ✓ Database Contents
- ✓ Log Files
- ✓ Configuration and Schema Files
- ✓ Backup Files Contained in bak Directory
- ✓ LDIF Export Files Contained in ldif Directory

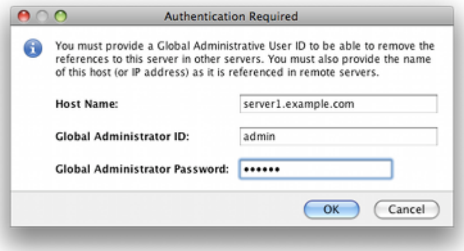
3. If the server is part of a replication topology, click **Yes** to disable replication. If the server is not part of a replication topology, continue to step 5.



This server is configured to do replication.
If the server is actually replicating contents with other servers you must provide administrator authentication to remove references to this server in the replicating servers.

Click on 'Yes' to provide authentication to remove the remote references.
Click on 'No' to continue the uninstall without updating remote references.

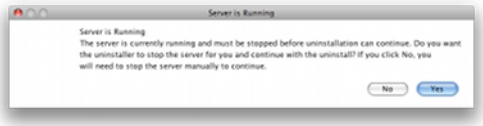
4. Type the Global Administrator password and click **OK**. The Global Administrator is responsible for managing replication server groups. For more information, see *Configuring a Global Administrator*.



You must provide a Global Administrative User ID to be able to remove the references to this server in other servers. You must also provide the name of this host (or IP address) as it is referenced in remote servers.

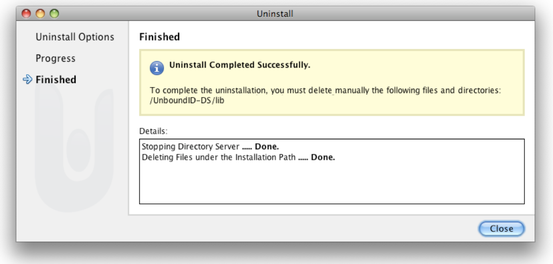
Host Name:	server1.example.com
Global Administrator ID:	admin
Global Administrator Password:	••••••

5. If the server is running, click **Yes** to stop the server.



Server is Running
The server is currently running and must be stopped before uninstallation can continue. Do you want the uninstaller to stop the server for you and continue with the uninstall? If you click No, you will need to stop the server manually to continue.

6. Click **Close** to exit the process. Manually remove any remaining files or directories if necessary.



Finished

Uninstall Completed Successfully.

To complete the uninstallation, you must delete manually the following files and directories:
/UnboundID-DS/lib

Details:

```
Stopping Directory Server ..... Done.
Deleting Files under the Installation Path ..... Done.
```

To Uninstall the Server in Interactive Mode

Interactive mode uses a text-based, command-line interface to help you remove your instance. If `uninstall` cannot remove all of the Data Store files, the `uninstall` tool generates a message with a list of the files and directories that must be manually deleted. The `uninstall` command must be run as either the root user or the same user (or role) that installed the Data Store.

1. From the server root directory, run the `uninstall` command.

```
$ ./uninstall --cli
```

2. Select the components to be removed. If you want to remove all components, press **Enter** to accept the default (remove all). Enter the option to specify the specific components that you want to remove.

```
Do you want to remove all components or select the components to remove?

1) Remove all components
2) Select the components to be removed

q) quit
Enter choice [1]:
```

3. For each type of server component, press **Enter** to remove them or type `no` to keep it.

```
Remove Server Libraries and Administrative Tools? (yes / no) [yes]:
Remove Database Contents? (yes / no) [yes]:
Remove Log Files? (yes / no) [yes]:
Remove Configuration and Schema Files? (yes / no) [yes]:
Remove Backup Files Contained in bak Directory? (yes / no) [yes]:
Remove LDIF Export Files Contained in ldif Directory? (yes / no) [yes]:
```

4. If the Data Store is part of a replication topology, type `yes` to provide your authentication credentials (Global Administrator ID and password). If you are uninstalling a stand-alone server, continue to step 7.

5. Type the Global Administrator ID and password to remove the references to this server in other replicated servers. Then, type or verify the host name or IP address for the server that you are uninstalling.

6. Next, select how you want to trust the server certificate if you have set up SSL or StartTLS. For this example, press **Enter** to accept the default.

```
How do you want to trust the server certificate for the Data Store
on server.example.com:389?
```

```
1) Automatically trust
2) Use a trust store
3) Manually validate

Enter choice [3]:
```

7. If your Data Store is running, the server is shutdown before continuing the uninstall process. The uninstall processes the removal requests and completes. View the logs for any remaining files. Manually remove any remaining files or directories, if listed.

To Uninstall the Server in Non-Interactive Mode

The `uninstall` utility provides a non-interactive method to enter the command with the `--no-prompt` option. Another useful argument is the `--forceOnError` option that continues the uninstall process when an error is encountered. If an option is incorrectly entered or if a required option is omitted and the `--forceOnError` option is not used, the command will fail and abort.

1. From the server root directory, run `uninstall` tool with the `--remove-all` option to remove all of the Data Store's libraries. The `--quiet` option suppresses output information and is optional. The following command assumes that the Data Store is stand-alone and not part of a replication topology.

```
$ ./uninstall --cli --remove-all --no-prompt --quiet --forceOnError
```

2. If any files or directories remain, manually remove them.

To Uninstall Selected Components in Non-Interactive Mode

From the server root directory, run `uninstall` with the `--backup-files` option to remove the Data Store's backup files. Use the `--help` or `-H` option to view the other options available to remove specific components.

```
$ ./uninstall --cli --backup-files --no-prompt --quiet --forceOnError
```

To Uninstall the RPM Build Package

1. From the server root directory, remove the RPM package use the `--erase` option with the <rpm-id>. The <rpm-id> is unboundid-ds and removes the files at /opt/unboundid/ds/UnboundID-DS.

```
$ rpm --erase unboundid-ds
```

2. The `rpm` command specifies if any files or directories require manual deletion. Manually remove any remaining directories or files using `rm -rf <directory>`.

Installing the Management Console

The UnboundID Data Store provides a graphical web application tool, the UnboundID Management Console. The Management Console provides configuration and schema management functionality in addition to monitoring and server information. Like the `dsconfig` configuration tool, all changes made using the Management Console are recorded in `logs/config-audit.log`. In addition, anytime a configuration is made to the system, the configuration backend is automatically updated and saved as gzip-compressed files. You can access the changes in the `config/archived-configs` folder.

The Management Console is a web application that must be deployed in a servlet container that supports the servlet API 2.5 or later. An installation using Apache Tomcat is described below for illustration purposes only.

Note: The Management Console supports JBoss 7.1.1 or later. Refer to the JBoss Compatibility section in the `WEB-INF/web.xml` file for specific configuration steps.

To Install the Management Console Out of the Box

1. Download and install the servlet container. For example, download `apache-tomcat-<version>.zip` from the Apache website, and then unzip this file in a location of your choice.

2. Set the appropriate Apache Tomcat environment variables. The `setclasspath.sh` and `catalina.sh` files are in the tomcat `bin` directory.

```
$ echo "BASEDIR=/path/to/tomcat" >> setclasspath.sh
$ echo "CATALINA_HOME=/path/to/tomcat" >> catalina.sh
```

3. Download the Management Console ZIP file, `UnboundID-DS-web-console-5.2.0.1.zip` and unzip the file on your local host. You should see the following files:

```
3RD-PARTY-LICENSE.TXT
LICENSE.TXT
README
dsconsole.war
```

4. Create a `dsconsole` directory in `apache-tomcat-<version>/webapps/dsconsole`. Then, copy the dsconsole.war file to `apache-tomcat-<version>/webapps/dsconsole`. If the servlet is running and auto-deploy is enabled, copy the .war file to the `/webapps` directory and it will install in the directory.

```
$ mkdir apache-tomcat-<version>/webapps/dsconsole
$ cp dsconsole.war apache-tomcat-<version>/webapps/dsconsole
```

5. Go to the `apache-tomcat-<version>/webapps/dsconsole` directory to extract the contents of the console. The jar command is included with the JDK.

```
$ cd apache-tomcat-<version>/webapps/dsconsole
$ jar xvf dsconsole.war
```

6. Optional. Edit the `WEB-INF/web.xml` file to point to the correct Data Store instance. Change the host and port to match your server. The parameters in the `web.xml` file appear between <!-- and --> as comments. Uncomment the parameters you need to use. For example, you can specify the server or servers that the console uses to authenticate using the following parameters:

```
<context-param>
   <param-name>ldap-servers</param-name>
   <param-value>localhost:389</param-value>
</context-param>
```

Note: If the `ldap-servers` parameter is left as-is (i.e., undefined by default), the web console displays a form field for the user to enter the server host and port.

7. Optional. With the default configuration, Tomcat will time out sessions after 30 minutes of inactivity, forcing the user to log back in again. This can be changed on a servlet container wide basis by editing `apache-tomcat-<version>/conf/web.xml`, and updating the value of this configuration parameter:

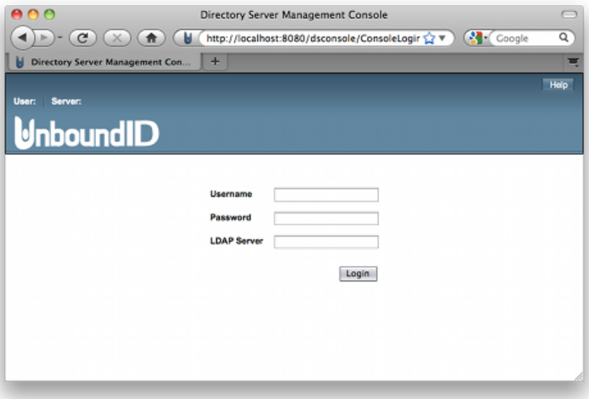
```
<session-config>
     <session-timeout>120</session-timeout>
</session-config>
```

   The session expires after the specified number of minutes. Changing the value to 120, for example, will extend the expiration to two hours. Changes to this setting might not take effect until the servlet container is restarted, so consider changing the value before starting the server for the first time.

8. Start the Data Store if it is not already running, and then start the Management Console using the `apache-tomcat-<version>/bin/startup.sh` script. Use `shutdown.sh` to stop the servlet container. (On Microsoft Windows, use `startup.bat` and `shutdown.bat`.) Note that the *JAVA_HOME* environment variable must be set to specify the location of the Java installation to run the server.

```
$ env JAVA_HOME=/ds/java bin/startup.sh
Using CATALINA_BASE:    /apache-tomcat-<version>
Using CATALINA_HOME:    /apache-tomcat-<version>
Using CATALINA_TMPDIR:  /apache-tomcat-<version>/temp
Using JRE_HOME:         /ds/java
```

9. Open a browser to `http://hostname:8080/dsconsole`. By default, Tomcat listens on port 8080 for HTTP requests.


Directory Server Management Console
http://localhost:8080/dsconsole/ConsoleLogin
Help
User: Server:
UnboundID
Username
Password
LDAP Server
Login

Note: If you re-start the Data Store, you must also log out of the current Management Console session and then log back in to start a new console session.

Logging into the Management Console

To log into the console, you can either use a DN (for example, cn=Directory Manager) or provide the name of an administrator, which is stored under cn=admin data. The `dsframework` command can be used to create a global administrator, for example:

```
$ dsframework create-admin-user \
  --hostname server1.example.com \
  --port 1389 --bindDN "cn=Directory Manager" \
  --bindPassword secret \
  --userID someAdmin --set password:secret
```

To Log into the Management Console

1. Go to the server root directory.

```
$ cd UnboundID-DS
```

2. Start the Data Store.

```
$ bin/start-ds
```

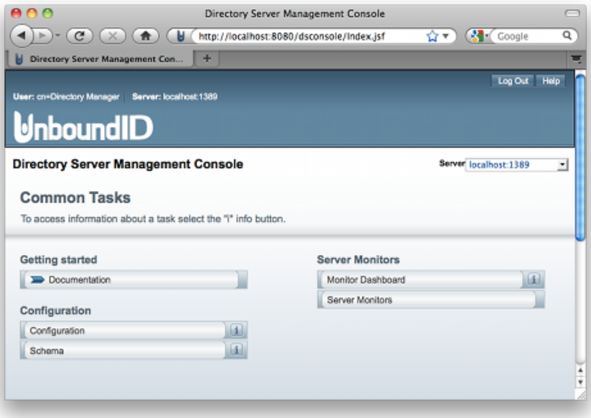
3. Start the Apache Tomcat application server.

```
$ /apache-tomcat-<version>/bin/startup.sh
```

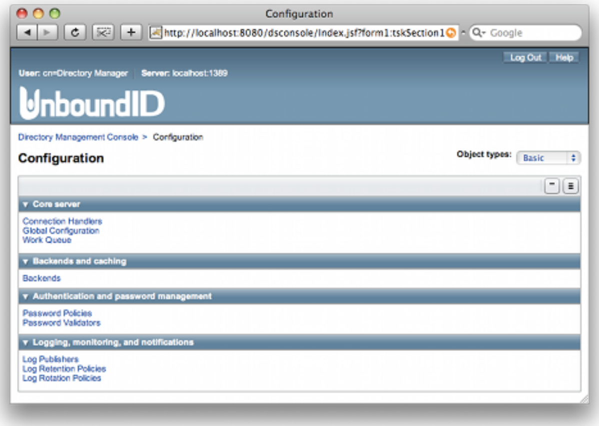
4. Open a browser to http://hostname:8080/dsconsole/.

5. Type the root user DN (or any authorized administrator user name) and password, and then click **Login**.

6. On the Management Console, click **Configuration**.


Directory Server Management Console
http://localhost:8080/dsconsole/index.jsf
Log Out
Help
User: cn=Directory Manager
Server: localhost:1389
UnboundID
Directory Server Management Console
Server localhost:1389
Common Tasks
To access information about a task select the "i" info button.
Getting started
Documentation
Configuration
Configuration
Schema
Server Monitors
Monitor Dashboard
Server Monitors

7. View the Configuration menu. By default, the console displays the Basic object type properties. You can change the complexity level of the object types using the **Object Types** drop-down list.



Fine-Tuning the Management Console

The Management Console uses a `web.xml` descriptor file for its configuration and deployment settings. Instead of specifying the host name and port on the Login page, you can configure one or more primary servers in the `web.xml` file as well as configure security and truststore settings for your Data Store console. If you specify any servers using the `web.xml` file, the Login page will no longer display the LDAP Server field. It will automatically attempt to connect to the primary server(s) specified in the `web.xml` file in the order in which they are specified until one of the servers can authenticate the username and password. The console also uses this server to "discover" other servers in the topology, making them available for monitoring and management in the console.

To Configure One or More Primary Servers for the Console

1. Open the `dsconsole/WEB-INF/web.xml` file in a text editor to specify the server(s) that the console uses to authenticate. First, remove the comment tags (<!-- and -->) in the `ldap-servers` section.

2. Next, specify the servers as `host:port` (e.g., server1.example.com:389) or using the LDAPS protocol to specify security information (e.g., ldaps://server1.example.com:389). If you specify more than one server, you must separate them using a space. For example, if you have two servers: one using standard LDAP communication, the other using SSL, you would see the following:

```
<context-param>
     <param-name>ldap-servers</param-name>
     <param-value>localhost:389 ldaps://svr1.example.com:389</param-value>
</context-param>
```

3. Save the file.

To Configure SSL for the Primary Console Server

You can configure the console so that it will communicate with all of its primary servers over SSL or StartTLS. See the previous section on how to specify one or more primary servers.

1. Open the `dsconsole/WEB-INF/web.xml` file in a text editor to specify the type of communication to authenticate. First, remove the comment tags (<!-- and -->) in the security section.

2. Specify `none`, `ssl`, or `starttls` for the type of security that you are using to communicate with the Data Store.

```
<context-param>
     <param-name>security</param-name>
     <param-value>ssl</param-value>
</context-param>
```

3. Save the file.

To Configure a Generic Error Page

The console can be configured so that it displays a generic error page that does not contain sensitive LDAP or server information. If configured, server logs will still contain detailed error information.

1. Open the `dsconsole/WEB-INF/web.xml` file in a text editor to specify.

2. To display a generic error page in the Management Console, change the value of the following configuration parameter to `false`:

```
<context-param>
  <param-name>detailedErrorMessages</param-name>
  <param-value>false</param-value>
</context-param>
```

3. Save the file.

To Configure a Truststore for the Console

For SSL and StartTLS communication, you can specify your truststore and its password (or password file) in the `web.xml` file. If no truststore is specified, all server certificates will be blindly trusted.

1. Open the `dsconsole/WEB-INF/web.xml` file in a text editor to specify the truststore. First, remove the comment tags (<!-- and -->) in the truststore section.

2. Specify the path to your truststore.

```
<context-param>
     <param-name>trustStore</param-name>
     <param-value>/path/to/truststore</param-value>
</context-param>
```

3. Next, specify the password or the path to the password pin file.

```
<context-param>
     <param-name>trustStorePassword</param-name>
     <param-value>password</param-value>
</context-param>

<context-param>
     <param-name>trustStorePasswordFile</param-name>
     <param-value>/path/to/truststore/pin/file</param-value>
</context-param>
```

4. Save the file.

Upgrading the Management Console

You can easily upgrade the Management Console by first moving the `web.xml` file to another location, unpacking the latest Management Console distribution, and then replacing the newly deployed `web.xml` file with the previous build.

To Upgrade the Management Console

1. Shut down the console and servlet container.

2. In the current deployment of the Management Console, move the `webapps/dsconsole/WEB-INF/web.xml` file to another location.

3. Download and deploy the latest version for the Management Console. Follow steps 2–5 outlined in the section "To Install the Console Out of the Box".

4. Assuming you had not renamed the `.war` file when you originally deployed the Management Console, run a diff between the previous and newer version of the web.xml file to determine any changes that should be applied to the new web.xml file. Make those changes to the new file, and then replace the newly deployed Management Console's `web.xml` to `webapps/dsconsole/WEB-INF/web.xml`.

5. Start the servlet container.

Uninstalling the Management Console

You can easily remove the existing Management Console by removing the `webapps/dsconsole` directory when no longer needed on your system.

To Uninstall the Management Console

1. Close the Management Console, and shut down the servlet container. (On Microsoft Windows, use `shutdown.bat`).

   ```
   $ apache-tomcat-<version>/bin/shutdown.sh
   ```

2. Remove the `webapps/dsconsole` directory.

   ```
   $ rm -rf webapps/dsconsole
   ```

3. Restart the servlet container instance if necessary. Alternatively, if no other applications are installed in the servlet instance, then the entire servlet installation can be removed by deleting the servlet container directory.

Chapter 4 Upgrading the Server

UnboundID issues software release builds periodically with new features, enhancements, and fixes for improved server performance. Administrators can use the Data Store's update utility to upgrade the current server code version.

This chapter presents some update scenarios and their implications that you should consider when upgrading your server code.

Topics:

Upgrade Overview and Considerations

The upgrade process involves downloading and unzipping a new version of the Data Store ZIP file on the server to be updated, and running the `update` utility with the `--update` option value from the new root server pointing to the installation to be upgraded.

Consider the following when upgrading replicating servers:

- Upgrade affects only the server being upgraded. The process does not alter the configuration of other servers.
- The `update` tool will verify that the version of Java that is installed meets the new server requirements. To simplify the process, install the version of Java that is supported by the new server before running the tool.
- To be safe, backup the user data (userRoot) before an upgrade. Restoring from a backup could be necessary if all other servers in the replication topology have been upgraded and a database or encoding change in the new server version prevents the database from being used with the older server version. The `update` and `revert-update` utilities will issue a warning when this is the case.
- Temporarily raise the replication purge delay for all servers in the topology to cover the expected downtime for maintenance. This will result in a temporary increase in disk usage for the replicationChanges database stored in `<server-root>/changelogDb`.
- Replication does not need to be disabled on a server before an upgrade.
- Make sure upgraded servers are working as expected before upgrading the last server in the topology
- Enable new features after all replicating servers are upgraded.

To Upgrade the Data Store

Perform an upgrade with the following steps.

1. Download and unzip the new version of the Data Store in a location outside the existing server's installation. For these steps, assume the existing server installation is in `/prod/UnboundID-DS` and the new server version is unzipped into `/home/stage/UnboundID-DS`.
2. Run the `update` tool provided with the new server package to update the existing Data Store. The update tool may prompt for confirmation on server configuration changes if it detects customization.

```
$ /home/staging/UnboundID-DS/update --serverRoot /prod/UnboundID-DS
```

To Upgrade the RPM Package

If the Linux RPM package was used to install the Data Store, the following should be performed to upgrade the server.

- Assume that the new RPM package, unboundid-ds-<new-version>.rpm, is placed in the server root directory. From the server root directory, run the `rpm` command with the `--upgrade` option.

  ```
  $ rpm --upgrade unboundid-ds-<new-version>.rpm
  ```

  The RPM package does not support a revert option once the build is upgraded.

  The upgrade history is written to /opt/unboundid/ds/UnboundID-DS/history/<timestamp>/update.log.

Reverting an Update

An installation can be reverted (one level back) using the `revert-update` tool. The `revert-update` tool will place the server's binaries and configuration back to its prior state. If multiple updates have been performed, the tool can be run multiple times to revert to each prior update sequentially, but only one level at a time.

1. Stop the server and run the `revert-update` command:

```
$ bin/stop-ds
$ ./revert-update
```

2. Before starting the server, make sure there were no warnings, such as:

Warning: Additional steps must be taken once this revert has completed. The current server uses an on disk database format that is not compatible with the server version being reverted to. After performing the revert, compatible databases must be put in place before restarting the server. Different steps must be taken to restore the Local DB Backend, Replication Changelog, and LDAP Changelog databases.

This type of message indicates that the userRoot, replicationChange and changelog (if enabled) databases need to be restored before starting the server. These databases can be backed up from another server of the same version in the replication topology and restored on the newly reverted server. For example, from another server in the topology, perform the following:

```
$ bin/backup --backendID userRoot --backupDirectory /backups/userRoot
$ bin/backup --backendID replicationChanges --backupDirectory /backups/
replicationChanges
$ bin/backup --backendID changelog --backupDirectory /backups/changelog
```

Transfer the backups to the reverted server and restore each database with the following commands:

```
$ bin/restore --backupDirectory /transfered/userRoot
$ bin/restore --backupDirectory /transfered/changelog
$ bin/restore --backupDirectory /transfered/replicationChanges
```

3. After all databases have been restored, start the server with the following command:

```
$ bin/start-ds
```

Configure SCIM After Upgrade

Modifications in SCIM PATCH are mapped directly to LDAP modifications to use the matching rules configured in the Data Store, when matching deleted values. Since the SCIM PATCH is now applied by the Data Store, the Permissive Modify Request Control (1.2.840.113556.1.4.1413) is now required by the SCIM component. This ensures that adding an existing value or deleting a non-existent value in the PATCH request will not generate an error. This affects upgrades from server versions prior to 5.0.0.

To continue using the SCIM component after an upgrade, access controls and configuration must be updated to allow access to the Permissive Modify Request Control. Run the `dsconfig` commands to update these components:

```
$ dsconfig set-access-control-handler-prop \
  --remove 'global-aci:(targetcontrol="1.3.6.1.1.13.2 || 1.2.840.113556.1.4.473 ||
 1.2.840.113556.1.4.319 || 2.16.840.1.113730.3.4.9 || 1.3.6.1.1.12")(version 3.0;acl
 "Authenticated access to controls used by the SCIM servlet extension"; allow (all)
 userdn="ldap:///all";)'
```

```
$ dsconfig set-access-control-handler-prop \
  --add 'global-aci:(targetcontrol="1.3.6.1.1.13.2 || 1.2.840.113556.1.4.473
 || 1.2.840.113556.1.4.319 || 2.16.840.1.113730.3.4.9 || 1.3.6.1.1.12 ||
 1.2.840.113556.1.4.1413")(version 3.0;acl "Authenticated access to controls used by the
 SCIM servlet extension"; allow (all) userdn="ldap:///all";)'
```

Chapter 5 Tuning the Server

The UnboundID Data Store's installation process automatically determines the optimal Java Virtual Machine (JVM) settings based on calculations of the machine running setup. While the majority of the default configuration and JVM settings are suitable for most deployments, it is not uncommon in high performance environments to make slight adjustments to the Data Store's JVM settings as well as performance and resource-related configuration changes with the `dsconfig` tool.

This chapter provides guidance for tuning the Data Store and its tools for both optimum performance with regard to throughput and disk space usage. This chapter presents the following topics:

Topics:

About Minimizing Disk Access

Most critical to data store performance is minimizing disk access. Defining a JVM heap size that can contain the entire contents of the database cache in memory is essential to minimizing read operations from disk and achieving optimal performance. It is also important to understand that the database on-disk is comprised of transaction log files, which are only appended to. After an initial database import, the size on-disk will grow by a factor of at least 25% as inactive records accumulate within the transaction logs. Therefore, during normal operation, the on-disk size of the database transaction logs do not represent the memory needed to cache the database.

Another consideration is to minimize the size of the database based on the known characteristics of your data. Minimizing the size of the database not only reduces hard disk requirements but also reduces the memory requirements for the database cache. The Data Store has the capability to automatically compact common parent DNs, which is an example of optimizing the database size based on known characteristics of the data.

Another consideration is to consider the write load on your server and its affect on the database. While write operations will always require an associated write to disk, an environment that sustains a high load of write operations may consider tuning the background database cleaner to minimize the size of the database on disk.

Memory Allocation and Database Cache

The Data Store's optimal performance is dependent on the proper allocation of memory to the JVM heap, the number of processor cores in the system, and the correct combination of JVM options for optimized garbage collection. The `setup` tool for the Data Store automatically assigns the JVM options and determines the memory allocation based on the total amount of memory on the system. However, in most production deployments, additional tuning may be required to meet the performance objectives for your system.

Most often, data store performance tuning can be accomplished by adjusting a few settings. Tuning these settings, which include both JVM and configuration options, require an understanding of the JVM heap structure as well as the expected database usage. This section describes the basic components of the Data Store footprint and logic behind the automated tuning of the `setup` tool.

Data Store Process Memory

The Data Store is comprised mostly of a JVM heap and a marginal amount of memory allocated by the JVM’s execution of native code. While we frequently refer to the JVM Heap as the maximum memory consumed by the Data Store, the actual process size will be slightly larger than the `Xmx` value due to accumulation of small chunks of native code that Java requires for things, such as SSL sockets.

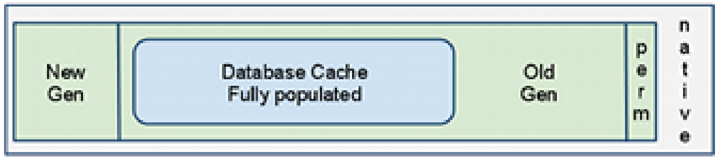


Figure 2: JDK Heap Structure

Within the JVM Heap, the principal memory components are the New, Old and Permanent Generations. Each area serves a specific purpose. Old Generation is responsible for longer-lived objects. It is in the Old Generation that the database cache will eventually need to reside with room enough to allow the expected object churn. The Old Generation size is computed from the leftover heap after defining the New and Permanent Generation sizes; therefore, it is not explicitly stated in the JVM options. A typical set of Generation definitions for the JVM is as follows:

```
-Xmx16g -Xms16g -XX:MaxNewSize=2g -XX-NewSize=2g -XX:PermSize=64M
```

The `-Xms` value instructs the JVM to allocate an initial heap of 16G while the `-Xmx` represents the maximum the JVM is allowed to allocate. We recommend setting these values identically to prevent the JVM from spending time re-sizing the heap between the initial and maximum values.

The `NewSize` value instructs the JVM to set the default size of the New Generation to 2G while the `MaxNewSize` represents the maximum size of the New Generation. Again, we recommend setting these values identically. Note also that the definitions of `MaxNewSize` and `NewSize` are not required; the JVM will define a small New Generation in the event the parameters are not provided.

The `PermSize` value instructs the JVM to allocate an additional heap of 64M in addition to the JVM heap specified by `-Xmx`. Permanent Generation never undergoes garbage collection and stores class or method objects.

Note: For `MaxNewSize` and `PermSize`, no matter how large the heap (specified by the `-Xmx`/`Xms` values), the `MaxNewSize`/`NewSize` should be defined at or below 2 GB. Likewise, the `PermSize` is less dependent on database size and should not need to be raised above 64M.

Performance testing of the Data Store has shown that the New and Permanent Generation areas should be defined within a relatively tight threshold with the `setup` tool, doing the best job at predicting the needed New and Permanent sizes. Considering the New and Permanent Generations as fixed points helps simplify the tuning process of Old Generation with just the modification of `-Xmx`/`Xms`.

A Method for Determining Heap and Database Cache Size

The most straightforward approach to defining the proper memory allocation of the data store components is to use the Data Store `setup` command on hardware that represents the target production platform, especially with regard to process and memory, and the largest heap size that the `setup` tool will allow. After running `setup`, any schema and production database settings should be defined in preparation for the database import using the `import-ldif` tool.

Note: At the moment after an `import-ldif`, the database is at its most optimized state on disk with no inactive records. Over time, the on-disk representation of the database will grow as much as 25-50% as inactive records accumulate before being removed by the server's cleaner thread.

After the database is imported, the server should be started and a configuration change made to the backend. In this scenario, set the *prime-method* to "preload" on the userRoot backend configuration. Once the change is made, re-start the Data Store and watch for a successful preload message at the end of startup. If preloading did not complete, the `setup` command should be run again with a larger heap size. If preloading completed successfully, the database cache utilization percentage will be of interest. The `status` command will display something like the following:

```
             --- JE Environment ---
ID     : Cache Full : Cache   : On-Disk : Alert
---------:------------:--------:---------:------
userRoot : 30%      : 1.1 gb : 868.6mb : None
```

Looking at the above output and knowing that the database is fully loaded into cache, the 30% utilization is comfortable cushion for future database growth. In general, it is best to leave at least 10-20% cache headroom available.

During this scenario, it was clear from the `start-ds` output that the database primed completely and our interpretation of the `status` output was sound. To see the state of the database cache with more detail, perform an `ldapsearch` on the backend monitor.

Automatic DB Cache Percentages

The setup process automatically tunes the percentage of the `db-cache-percent` property for the userRoot backend based on the maximum configured JVM heap size.

Table 2: Percentage Assigned to db-cache-percent Property

Maximum Heap Size	DB Cache Percent
Greater than or equal to 16 GB	75 * (MaxHeapSize-2GB) / MaxHeapSize
Greater than or equal to 8 GB	75 * (MaxHeapSize-1GB) / MaxHeapSize
Greater than or equal to 3 GB	Set to 50%
Else	Set to 25%

Automatic Memory Allocation

If the Memory Tuning feature is enabled during setup, the `setup` algorithm determines the maximum JVM heap size based on the total amount of available system memory. If Memory Tuning is not selected, the server allocates a maximum JVM heap of 256 MB. The Data Store also allows you to specify the maximum heap size during the setup process. You can enable Memory Tuning during the setup process by clicking the check box in the graphical installer (seen in *To Install the Data Store using the GUI*), selecting the feature during the interactive command-line mode (seen in *Setting Up the Data Store in Interactive Mode*), adding the `--jvmTuningParameter` option using the `setup` tool in non-interactive command-line mode (seen in *Installing the Data Store in Non-Interactive Mode*), or regenerating the java properties file with `bin/dsjavaproperties` and the `--jvmTuningParameter` options (seen in *JVM Properties for Server and Command-Line Tools* page 75).

If Memory Tuning is selected, the server can allocate the maximum JVM heap depending on the total system memory. The following table displays the automatically allocated maximum JVM heap memory based on available system memory.

Table 3: Allocated Max JVM Memory if Tuning is Enabled

Available Memory	Allocated JVM Memory
16 GB or more using a 64-bit JVM	The maximum JVM heap size will be set to 70% of total system memory. If the maximum JVM heap size is less than or equal to 128GB of memory (which should be the case for systems with up to 160 GB of memory), then the initial heap size will be set to equal the maximum heap size. If the maximum heap size is greater than 128GB, then the initial heap size will be set to 128GB to work around an apparent bug in the JVM.
6 GB#16 GB using a 64-bit JVM	total system memory - 4 GB
4 GB–6 GB using a 64-bit JVM	2 GB
2 GB–4 GB	512 MB
1 GB–2 GB	256 MB
Less than 1 GB	128 MB

Automatic Memory Allocation for the Command-Line Tools

At setup, the Data Store automatically allocates memory to each command-line utility based upon the maximum JVM heap size. The server sets each command-line utility in the `config/java.properties` with `-Xmx/Xms` values depending on the expected memory needs of the tools. Because some tools can be invoked as a server task while the server is online, there are two definitions of the tool in the `config/java.properties` file: one with .online and one with .offline added to the name. The online invocations of the tools typically require minimal memory as the task is performed within the Data Store's JVM. The offline invocations of the tools, for example, `import-ldif.offline` and `rebuild-index.offline`, can require the same amount of memory that is needed by the Data Store.

Beyond the offline tool invocations, some tools, such as `ldap-diff` and `verify-index`, may need more than the minimal memory if large databases are involved. The table below lists the tools that are expected to have more than the minimal memory needs along with the rules for defining the default heap size.

Table 4: Default Memory Allocation to the Command-Line Tools

Command-Line Tools	Allocated JVM Memory
start-ds, import-ldif (offline), rebuild-index (offline)	MaxHeapSize
backup (offline), dbtest export-ldif (offline), ldap-diff, restore (offline), scramble-ldif, summarize-access-log, verify-index	If Max System Memory is: ➢ Greater than or equal to 16 GB: set Heap to 3 GB ➢ Greater than or equal to 8 GB: set Heap to 1 GB ➢ Greater than or equal to 4 GB: set Heap to 512 MB ➢ Under 4 GB: set Heap to 256 MB

Database Preloading

Key to Data Store performance is the ability to maintain the database contents in the database cache within the JVM memory. With a properly sized database cache, a priming method of "preload" directs the server to load the database contents into memory at server startup before accepting the first client connection. The time needed to preload the database is proportional to the database size. To avoid priming, the server can be started with the `start-ds --skipPrime` command. If the priming method is `none` or the `--skipPrime` option is specified at startup, the database cache will slowly build as entries are accessed. This could take several days to reach optimal performance.

The "preload" priming method is suitable for nearly all Data Store deployments. If the size of the database precludes storing the whole database in memory, there are priming alternatives for optimizing server performance. This type of deployment is considered disk-bound since the disk is accessed when processing most operations. See the section Disk-Bound Deployments for more information. The remaining priming options are applicable to these environments.

The Data Store database `prime-method` property configures how the caches get primed, what gets primed (data, internal nodes, system indexes) and where it gets primed (database cache, filesystem cache, or both). The `prime-method` property is a multi-valued option that enables preloading the internal nodes into the database cache before the server starts, and then primes the values in the background by cursoring across the database. For more details, see the UnboundID Data Store Configuration Reference.

The following is a summary of the priming methods:

- **Preload All Data**. Prime the contents of the backend into the database cache.
- **Preload Internal Nodes Only**. Prime only internal database structure information into the database cache, but do not prime any actual data. (This corresponds to the cache-keys-only cache-mode.)
- **Cursor Across Indexes**. Use the `cursor-across-indexes` property to iterate through backend contents. This is similar to (and may be slower than) using the preload mechanism, but it enables priming to happen in the background after the server has started. This is used when shorter start up times are desired, and the slower performance of an uncached database is acceptable until the database is primed.

Configuring Database Preloading

Use the `dsconfig` tool to set the database priming method. If multiple prime methods are used, the order in which they are specified in the configuration is the order in which they will be performed. Changing the preloading option requires re-starting the Data Store. The following procedure shows how to configure database preloading.

To Configure Database Preloading

1. Set the prime method to "preload" to load the database contents from disk into memory when the server starts up. This eliminates the need for the server to gradually prime the database cache using client traffic, and ensures that the server has optimal performance when it starts to receive client connections.

```
$ bin/dsconfig set-backend-prop \
  --backend-name userRoot \
  --set prime-method:preload
```

2. Re-start the Data Store to apply the changes using `bin/stop-ds` and then, `bin/ start-ds`.

To Configure Multiple Preloading Methods

1. To achieve the benefits of preloading without delaying server startup, `prime-method` can be set to `preload-internal-nodes-only`, which caches all of the keys within the database but not the values. The database values themselves can be cached in the background once the server has been started with the `cursor-across-indexes` option.

```
$ bin/dsconfig set-backend-prop \
  --backend-name userRoot \
  --add prime-method:preload-internal-nodes-only \
  --add prime-method:cursor-across-indexes \
  --set background-prime:true
```

2. Re-start the Data Store to apply the changes using `bin/stop-ds` and then, `bin/start-ds`.

To Configure System Index Preloading

1. Some environments have many indexes configured, though only a few are used for performance-sensitive traffic. In this case, server start up time can be reduced by only preloading the necessary indexes into the database at startup.

```
$ bin/dsconfig set-backend-prop --backend-name userRoot \
  --set prime-method:preload \
  --set prime-all-indexes:false \
  --set system-index-to-prime:dn2id \
  --set system-index-to-prime:id2entry
```

```
$ bin/dsconfig set-local-db-index-prop --backend-name userRoot \
  --index-name mail \
  --set prime-index:true
```

```
$ bin/dsconfig set-local-db-index-prop --backend-name userRoot \
  --index-name uid \
  --set prime-index:true
```

```
$ bin/dsconfig set-local-db-index-prop --backend-name userRoot \
  --index-name entryUUID \
  --set prime-index:true
```

2. Restart the Data Store to apply the changes using `bin/stop-ds` and then, `bin/start-ds`.

Databases on Storage Area Networks, Network-Attached Storage, or running in Virtualized Environments

There are several considerations when using network-based storage or storage abstracted by virtualization that are not issues when databases are stored on local disks. A data durability problem occurs when remote storage or the virtualization environment experiences service interruptions, ranging from connectivity loss to total failure from power loss. Data corruption can occur when the storage layer accepts data for writing that is not made durable before a crash occurs. In these cases, a database property can be set that reduces the likelihood of data loss and data corruption. The database property `database-on-virtualized-or-network-storage` can be set on a per-backend environment basis to request all database writes to be written durably to the underlying storage. There may be a performance penalty for enabling this property, but the benefits of faster recovery and less likelihood of data loss from unplanned events outweigh it. The exact overhead of enabling `database-on-virtualized-or-network-storage` will depend on the characteristics of the database, the host filesystem, storage array configuration, and network and virtualization input and output parameters.

To enable `database-on-virtualized-or-network-storage` for each applicable backend, use the following command as an example, which references the configuration for the userRoot backend:

```
$ bin/dsconfig set-global-configuration-prop \
  --set database-on-virtualized-or-network-storage:true
```

This should be set to `false` if the database is on a local disk.

Database Cleaner

Production environments that have a high volume of write operations may require cleaner thread tuning to control the on-disk database size as log files with inactive nodes wait to be cleaned and deleted. The Data Store stores its Oracle® Berkeley DB Java Edition (JE) database files on-disk in the `db` directory. Each JE database log file is labelled `nnnnnnnn.jdb`, where nnnnnnnn is an 8-digit hexadecimal number that starts at 00000000 and is increased by 1 for each file written to disk. JE only appends data to the end of each file and does not overwrite any existing data. JE uses one or more cleaner threads that run in the background to compact the number of JE database (db) files.

The cleaner threads begin by scanning the records in each db file, starting with the file that contains the smallest number of active records. Next, the cleaner threads append any active records to the most recent database file. If a record is no longer active due to modifications or deletions, the cleaner threads leave it untouched. After the db file no longer has active records, the cleaner threads can either delete the file or rename the discarded file. Note that because of this approach to cleaning, the database size on-disk can temporarily increase when cleaning is being performed and files are waiting to be removed.

The Local DB Backend configuration object has two properties that control database cleaning: `db-cleaner-min-utilization` and `db-num-cleaner-threads`. The `db-cleaner-min-`

`utilization` property determines, by percentage, when to begin cleaning out inactive records from the database files. By default, the property is set to 75, which indicates that database cleaning ensures that at least 75% of the total log file space is devoted to live data. Note that this property only affects the on-disk representation of the database and not the in-memory database cache—only live data is ever cached in memory.

The `db-num-cleaner-threads` property determines how many threads are configured for db cleaning. The default single cleaner thread is normally sufficient. However, environments with a high volume of write traffic may need to increase this value to ensure that database cleaning can keep up.

If the number of database files grow beyond your expected guidelines or if the Data Store is experiencing an increased number of update requests, you can increase the number of cleaner threads using the `dsconfig` tool (select **Backend** > **select advanced properties** > **db-num-cleaner-threads**).

Compacting Common Parent DNs

The UnboundID Data Store compacts entry DNs by tokenizing common parent DNs. Tokenizing the common parent DNs allows you to increase space usage efficiency when encoding entries for storage. The Data Store automatically defines tokens for base DNs for the backend (for example, `dc=example,dc=com`). You can also define additional common base DNs that you want to tokenize. For example, use the following configuration to tokenize two branches, `ou=people,dc=example,dc=com` and `ou=customers,dc=example,dc=com`:

```
$ bin/dsconfig set-backend-prop --backend-name userRoot \
  --add "compact-common-parent-dn:ou=people,dc=example,dc=com" \
  --add "compact-common-parent-dn:ou=customers,dc=example,dc=com"
```

Import Thread Count

For most systems, the default setting of 16 threads is sufficient and provides good import performance. On some systems, increasing the import thread count may lead to improved import performance, while selecting a value that is too large can actually cause import performance to degrade. If minimizing LDIF import time is crucial to your deployment, you must determine the optimal number of import threads for your system, which is dependent on both the underlying system and the dataset being imported.

You can use the `dsconfig` command to set the number of import threads as follows:

```
$ bin/dsconfig set-backend-prop --backend-name userRoot --set import-thread:24
```

JVM Properties for Server and Command-Line Tools

The Data Store and tools refer to the `config/java.properties` file for JVM options that include important memory settings. The `java.properties` file sets the default Java arguments for the Data Store and each command-line utility including the default *JAVA_HOME* path.

The `java.properties` is generated at server setup time and defines memory-related JVM settings based on the user-provided value for max heap size if aggressive memory tuning option was selected at setup. Most of the JVM options specified for both server and tools do not need customization after setup. The exception is the `-Xmx/Xms` options, which specify the maximum and initial JVM heap size. See the section on *Memory Allocation and Database Cache* for advice on tailoring the `-Xmx/Xms` values.

Other than altering the heap size of the server process (`start-ds`) or command-line tools, the most common change required to `java.properties` is when it is desired to update the JVM version. A single edit will apply the new JVM to all server and tool use.

Applying Changes Using dsjavaproperties

To apply the changes to the `config/java.properties` file, edit the file manually, and then run the `bin/dsjavaproperties` utility. The `dsjavaproperties` tool uses the information contained in the `config/java.properties` file to generate a `lib/set-java-home` script (or `lib\set-java-home.bat` on Microsoft Windows systems), which is used by the Data Store and all of its supporting tools to identify the Java environment and its JVM settings. During the process, `dsjavaproperties` calculates an MD5 digest of the contents of the `config/java.properties` file and stores the digest in the generated `set-java-home` script.

The `dsjavaproperties` utility also performs some minimal validation whenever the property references a valid Java installation by verifying that `$(java-home)/bin/java` exists and is executable.

If you make any changes to the `config/java.properties` file but forget to run `bin/dsjavaproperties`, the Data Store compares the MD5 digest with the version stored in `set-java-home` and sends a message to standard error if the digests differ:

```
WARNING -- File /ds/UnboundID-DS/config/java.properties has been edited without
running dsjavaproperties to apply the changes
```

To Update the Java Version in the Properties File

To change the version of java that is used by the server and tools, it is necessary to edit the config/java.properties file and apply the change by invoking `bin/dsjavaproperties` with no command line options. Also, the server must be restarted for the change to take affect.

Inside `config/java.properties`, alter the value of `default.java-home` to point to the java correct JRE. Any time the `config/java.properties` file is updated, the `bin/dsjavaproperties` tool must be run to apply the new configuration.

```
$ bin/dsjavaproperties
```

To Regenerate the Java Properties File

The `dsjavaproperties` command provides a `--initialize` option that allows you to regenerate the Java Properties file specifically if you set up the Data Store using standard memory usage but opt for aggressive memory tuning after setup. Rather than reconfigure the Java Properties file by re-running `setup` or manually editing the `java.properties` file, you can regenerate the properties file for aggressive memory tuning. Any existing file will be renamed with a ".old" suffix.

- Run the `dsjavaproperties` command to regenerate the java properties file for aggressive memory tuning:

  ```
  $ bin/dsjavaproperties --initialize --jvmTuningParameter AGGRESSIVE
  ```

JVM Garbage Collection Using CMS

To ensure reliable server performance with Java, the Data Store depends on Java's Concurrent Mark and Sweep process (CMS) for background garbage collection. There are several garbage collection options, with CMS being the ideal choice for consistent system availability. The CMS collector runs as one or more background threads, for the most part, within the JVM, freeing up space in JVM Heap from an area called the Old Generation. One of the criteria used by CMS to determine when to start background garbage collection is a parameter called `CMSInitiatingOccupancyFraction`. This percentage value, which applies to the Old Generation, is a recommendation for the JVM to initiate CMS when data occupancy in Old Generation reaches the threshold.

To understand this CMS property, it is important to know how large the Old Generation is and how much data in the Old Generation is expected to be occupied by the database cache. Ideally, the database cache takes less than 70% of the space available in the Old Generation, and the `CMSInitiatingOccupancyFraction` value of 80 leaves plenty of headroom to prevent the JVM from running out of space in Old Generation due to an inability for CMS to keep up. Because CMS takes processing resources away from the Data Store, it is not recommended to set the `CMSInitiatingOccupancyFraction` at or below the expected database cache size, which would result in the constant running of CMS in the background. See the section on Memory Footprint and Database Cache for a description of determining Old Generation size.

When the CMS collection process cannot keep pace with memory demands in the Old Generation, the JVM will resort to pausing all application processing to allow a full garbage collection. This event, referred to as a *stop-the-world* pause, does not break existing TCP connections or alter the execution of the Data Store requests. The goal in tuning CMS is to prevent the occurrence of these pauses. When one does occur, the Data Store will generate an alert, after the pause, and record the pause time in the error log.

Because determining an ideal `CMSInitiatingOccupancyFraction` can be difficult, the approach we have taken is to warn if the Data Store detects a garbage collection pause by generating a recommended value for the occupancy threshold based on the current amount of memory being consumed by the backend caches. Unfortunately, it is not possible for an administrator to determine the ideal occupancy threshold value in advance. Therefore, to warn of any impending garbage collection pauses, the Data Store calculates a recommended value for the `CMSInitiatingOccupancyFraction` property and exposes it in the JVM Memory Usage monitor entry in the following attribute:

```
recommended-cms-initiating-occupancy-fraction-for-current-data-set
```

Also, when you start the server, you will see an administrative alert indicating the current state of the `CMSInitiatingOccupancyFraction` and its recommended value.

```
$ bin/start-ds [20/April/2012:10:35:25 -0500] category=CORE severity=NOTICE
 msgID=458886
msg="UnboundID Data Store 5.2.0.0 (build 20120418135933Z, R6226) starting up"

... (more output) ...

[20/April/2012:10:35:53 -0500] category=UBID_EXTENSIONS severity=NOTICE
msgID=1880555580 msg="Memory-intensive Data Store
components are configured to consume 71750382 bytes of memory:
['userRoot local DB backend' currently consumes 26991632 bytes and
can grow to a maximum of 64323584 bytes, 'changelog cn=changelog backend'
currently consumes 232204 bytes and can grow to a maximum of 2426798 bytes,
'Replication Changelog Database' currently consumes 376661 bytes and can
grow to a maximum of 5000000 bytes]. The configured value of
CMSInitiatingOccupancyFraction is 36 which is less than the minimum
recommended value (43) for the server's current configuration. Having
this value too low can cause the Concurrent Mark and Sweep garbage
collector to run too often, which can cause a degradation of throughput
and response time. Consider increasing the CMSInitiatingOccupancyFraction
value to at least the minimum value, preferably setting it to the
recommended value of 55 by editing the config/java.properties file,
running dsjavaproperties, and restarting the Data Store.
If the server later detects that this setting actually leads to a
performance degradation, a separate warning message will be logged.
If this server has not yet been fully loaded with data, then you
can disregard this message"

[20/April/2012:10:35:53 -0500] category=CORE severity=NOTICE msgID=458887
msg="The Data Store has started successfully"
```

The Data Store only makes a recommendation if all of the backends are preloaded and the `CMSInitiatingOccupancyFraction` JVM property is explicitly set, which is done automatically. For example, if you installed the Data Store and specified that the database be preloaded (or "primed") at startup, then the Data Store can make a good recommendation for the Data Store when a pause occurs. If the backend database cache is not full and has not been preloaded, then the recommended value may be an inaccurately low value.

Note: The generated value for the Data Store property could change over time with each Data Store build, Java release, or changes in data set. If the current value is fairly close to the recommended value, then there is no need to change the property unless the server experiences a JVM pause.

If the Data Store experiences a JVM garbage collection pause, you can retrieve the recommended value from the server, reset the Data Store property, run `dsjavaproperties`, and restart the server.

To Determine the CMSInitiatingOccupanyFraction

1. If you set the `Preload Database at startup` option during the installation, then skip to step 3. If you are not sure, retrieve the `prime-method` property for the backend as follows:

```
$ bin/dsconfig get-backend-prop --backend-name userRoot \
  --property prime-method
```

2. If the `prime-method` property was not configured, use `bin/dsconfig` to set the property to PRELOAD, and then, restart the Data Store to preload the database cache.

```
$ bin/dsconfig set-backend-prop --backend-name userRoot \
  --set prime-method:preload
```

```
$ bin/stop-ds
$ bin/start-ds
```

3. At startup, you will see an administrative message if the current `CMSInitiatingOccupancyFraction` property is below the recommended value. You can get the recommended value from this message and change it in the `config/java.properties` file in step 5.

4. If you were unable to see the recommended `CMSInitiatingOccupancyFraction` property at startup presented in the previous step, first you must pre-tune the value of the `CMSInitiatingOccupancyFraction` property to ensure that all of the data is imported into the server and preloading is enabled in the backend. Next, retrieve the recommended `CMSInitiatingOccupancyFraction` value by issuing the following search. If the `recommended-cms-initiating-occupancy-fraction-for-current-data-set` is not present, then make sure that the server has been restarted since enabling preload for the backend(s).

```
$ bin/ldapsearch --baseDN "cn=monitor" \
  "(objectclass=ds-memory-usage-monitor-entry)" \
  cms-initiating-occupancy-fraction \
  recommended-cms-initiating-occupancy-fraction-for-current-data-set
```

```
dn: cn=JVM Memory Usage,cn=monitor
cms-initiating-occupancy-fraction:80
recommended-cms-initiating-occupancy-fraction-for-current-data-set:55
```

5. Open the `config/java.properties` file using a text editor, manually edit the `CMSInitiatingOccupancyFraction` or any other property to its recommended value in the `start-ds.java-args` property, and then, save the file when finished. (The following arguments are recommended for a Sun 5440 server. Contact your authorized support provider for specific assistance.):

```
start-ds.java-args=-d64 -server -Xmx20g -Xms20g -XX:MaxNewSize=1g
-XX:NewSize=1g -XXParallelGCThreads=16 -XX:+UseConcMarkSweepGC
-XX:+CMSConcurrentMTEnabled -XX:+CMSParallelRemarkEnabled
-XX:+CMSParallelSurvivorRemarkEnabled -XX:ParallelCMSThreads=8
-XX:CMSMaxAbortablePrecleanTime=3600000
-XX:+CMSScavengeBeforeRemark -XX:RefDiscoveryPolicy=1
-XX:CMSInitiatingOccupancyFraction=55 -XX:+UseParNewGC
-XX:+UseBiasedLocking -XX:+UseLargePages
-XX:+HeapDumpOnOutOfMemoryError
```

   The `-XX:ParallelGCThreads` should be limited to 16 (default) or to 8 for smaller systems. Also, the `-XX:ParallelCMSThreads` should be limited to 8.

6. Run the `bin/dsjavaproperties` command to apply the changes.

```
$ bin/dsjavaproperties
```

7. Restart the Data Store.

Tuning For Disk-Bound Deployments

For best performance, configure the Data Store to fully cache the DIT in the backend database cache. Data Store configuration assumes this scenario. For databases too large to fit in memory, other options are available:

- Configure the server for a disk-bound data set (when the database is stored on an SSD, this configuration yields server performance that is comparable to a fully-cached scenario).
- Use uncached attributes and/or entries as described in the following section.
- Use a Proxy Server in an entry-balancing deployment, which allows all data to be cached in a partitioned environment.

To Tune for Disk-Bound Deployments

To configure the server for a disk-bound configuration, follow these steps:

1. When installing the server, choose the "aggressive" option for JVM memory configuration and to preload the data when the server starts.
2. Set the `default-cache-mode` of the `userRoot` backend to `cache-keys-only`.
3. Set operating system `vm.swappiness` to 0 to protect the Data Store JVM process from an overly aggressive filesystem cache.
4. When the data set is imported with the above settings, verify in the `import-ldif` output that the cached portions of the data set fit comfortably within the database cache.

Uncached Attributes and Entries

Although achieving optimal Data Store performance requires that the entire data set be fully cached, there may be deployments in which fully caching the data set is not possible due to hardware or financial constraints, or in which acceptable performance can be achieved by only caching a portion of the data. The Data Store already provides support for controlling caching on a per-database basis (e.g., to cache only certain indexes and/or system databases), but these features may not provide sufficient control over how memory is used, particularly with regard to which entries are included in the cache, and they do not provide any degree of control over caching only a portion of attributes.

To better address the needs of environments that require partial caching, the Data Store provides two new options: the ability to exclude certain *entries* from the cache, and the ability to exclude certain *attributes* from the cache. The Data Store uses an `uncached-id2entry` database container, which is similar to the `id2entry` database that maps an entry's unique identifier and its encoded representation. The `uncached-id2entry` database contains either complete and/or partial representations of entries that are intended to receive less memory for caching. For example, if an entry has a particulary large attribute and the system has hardware constraints on memory, then you can configure the system to not cache this particular attribute or entry. This functionality is only available for the local DB backend, which uses the Berkeley DB Java Edition database.

The `uncached-id2entry` database can be included in the set of databases to prime, but if priming is to be performed, it will only include internal nodes and not leaf nodes. For example, the internal nodes of the `uncached-id2entry` database will be included in the preload if the `prime-all-indexes` option is set to "true," or if the `system-index-to-prime-internal-nodes-only` option has a value of "`uncached-id2entry`".

Backup/Restore. There are no special considerations for backup and restore with regard to uncached entries and attributes. Backup will successfully save your database contents including uncached entries and attributes. Because of the way the server deals with changes to uncached entry and uncached attribute configuration, there is no problem with restoring a backup that was taken with a different uncached entry configuration than is currently in place for the server. Any entries encoded in a manner that is inconsistent with the current uncached entry or uncached attribute configuration will be properly re-encoded whenever they are updated, or whenever the re-encode entries task is invoked.

Replication. Replication does not propagate information about which portions of entries may have been cached or uncached, nor does it require that different replicas have the same uncached attribute or uncached entry configuration.

LDIF Import/Export. When LDIF content is imported into the server, the uncached attribute and uncached entry configuration is used to determine on a per-entry basis whether some or all of the content for that entry should be written into the `uncached-id2entry` database. The determination is based on the current configuration and is completely independent of and unaware of the configuration that may have been in place when the LDIF data was initially exported. Neither the LDIF import nor export tools provide any options that specifically target only cached or only uncached content, but these tools do provide the ability to include or exclude entries using search filters, or to include or exclude specific attributes.

Server Access Log. Server access log messages may include `uncachedDataAcessed=true` in the result message for any operation in which it was necessary to access uncached data in the course of processing the associated request. For add, delete, modify, or modify DN result messages, `uncachedDataAcessed=true` indicates that at least a portion of the new or updated entry was written into the `uncached-id2entry` database, or that at least a portion of the updated entry was formerly contained in the `uncached-id2entry` database. For compare result messages, it indicates that at least a portion of the target entry was contained in the `uncached-id2entry` database and that data from the uncached portion of the entry was required to evaluate the assertion. For search result messages, it indicates that one or more of the entries evaluated as potential matches contained uncached data, and that data from the uncached portion of at least one entry was needed in determining what data should be returned to the client.

Uncached Entry/Attribute Properties. The Data Store provides three new advanced properties on the Local DB Backend to control the caching mode for the `uncached-id2entry` database:

- **uncached-id2entry-cache-mode**. Specifies the cache mode that is used when accessing the records in the `uncached-id2entry` database. If the system has enough memory available to fully cache the internal nodes for this database, then `cache-keys-only` is recommended, otherwise it is better to select `no-caching` to minimize the amount of memory required for interacting with the `uncached-id2entry` database. For more information, see the *UnboundID Data Store Configuration Reference*.
- **uncached-attribute-criteria**. Specifies the criteria used to identify attributes that are written into the `uncached-id2entry` database, rather than the `id2entry` database. This property is only used for entries in which the associated `uncached-entry-criteria` does not indicate that the entire entry should be uncached. The property applies to all entry writes, including add, soft delete, modify, and modify DN operations, as well as LDIF import and re-encode

processing. Any changes to the property take effect immediately for writes occurring after the change is made. If no value is specified, then all attributes are written into the `id2entry` database.

- **uncached-entry-criteria**. Specifies the criteria used to identify entries that are written into the `uncached-id2entry` database, rather than the `id2entry` database. The property applies to all entry writes, including add, soft delete, modify, and modify DN operations, as well as LDIF import and re-encode processing. Any changes to the property take effect immediately for writes occurring after the change is made. If no value is specified, then all entries are written into the `id2entry` database.

To Configure Uncached Attributes and Entries

The following procedure assumes that the `uncached-id2entry-cache-mode` property is set to the default value, `cache-keys-only`. For more information on the `uncached-id2entry` cache modes, see the *UnboundID Data Store Configuration Reference*.

1. Run `dsconfig` to uncache entries that match the criteria. Here, the filter will uncache all entries that have its location set to "austin" (i.e., `l=austin`).

```
$ bin/dsconfig create-uncached-entry-criteria \
  --criteria-name "Fully Uncached l=austin" --type filter-based \
  --set enabled:true --set "filter:(l=austin)"
```

2. Run `dsconfig` to uncache attributes that match the criteria (`attribute-type: jpegPhoto`). The `--type simple` option indicates that the simple uncached attribute criteria be used to specify the attribute-type that should be uncached, which in this example is `jpegPhoto`. For those entries that are fully stored in the `uncached-id2entry` database container, the uncached attribute will be ignored.

```
$ bin/dsconfig create-uncached-attribute-criteria \
  --criteria-name "Uncached jpegPhoto" --type simple \
  --set enabled:true --set attribute-type:jpegPhoto
```

3. Set the uncached properties for the `userRoot` backend.

```
$ bin/dsconfig set-backend-prop \
  --backend-name userRoot \
  --set "uncached-entry-criteria:Fully Uncached l=austin" \
  --set "uncached-attribute-criteria:Uncached jpegPhoto"
```

4. Run the `re-encode-entries` tool to initiate a task that causes a local DB `userRoot` backend to re-encode all or a specified subset of the entries that it contains. The tool does not alter the entries themselves but provides a useful mechanism for applying significant changes to the way that entries are stored in the backend. The following command initiates a task that re-encodes all fully-cached entries in the `userRoot` backend, rate-limited to no more than 100 entries per second.

```
$ bin/re-encode-entries --hostname directory.example.com --port 389 \
  --bindDN uid=admin,dc=example,dc=com --bindPassword password \
  --backendID userRoot --skipFullyUncachedEntries \
  --skipPartiallyUncachedEntries --ratePerSecond 100
```

Chapter 6 Configuring the Server

The out-of-the-box, initial configuration settings for the UnboundID Data Store provide an excellent starting point for most general-purpose Data Store applications. However, additional tuning might be necessary to meet the performance, hardware, operating system, and memory requirements for your production environment.

The Data Store stores its configuration settings in an LDIF file, `config/config.ldif`. Rather than editing the file directly, the Data Store provides command-line and GUI tools that administrators can use to configure the server. The Data Store also includes tools to create server groups, so that configuration changes can be applied to multiple servers at one time.

This chapter presents the following topics:

Topics:

Accessing the Data Store Configuration

The UnboundID Data Store configuration can be accessed and modified in the following ways:

- **Using the Management Console**. The UnboundID Data Store provides a web-based console for graphical server management and monitoring. The console provides equivalent functionality as the `dsconfig` command for viewing or editing configurations. All configuration changes using this tool are recorded in `logs/config-audit.log`, which also has the equivalent reversion commands should you need to back out of a configuration.
- **Using the dsconfig Command-Line Tool**. The `dsconfig` tool is a text-based menu-driven interface to the underlying configuration. The tool runs the configuration using three operational modes: interactive command-line mode, non-interactive command-line mode, and batch mode. All configuration changes made using this tool are recorded in `logs/config-audit.log`.

About dsconfig Configuration Tool

The `dsconfig` tool is the text-based management tool used to configure the underlying Data Store configuration. The tool has three operational modes: interactive mode, non-interactive mode, and batch mode.

The `dsconfig` tool also offers an offline mode using the `--offline` option, in which the server does not have to be running to interact with the configuration. In most cases, the configuration should be accessed with the server running in order for the server to give the user feedback about the validity of the configuration.

Using dsconfig in Interactive Command-Line Mode

In interactive mode, the `dsconfig` tool offers a filtering mechanism that only displays the most common configuration elements. The user can specify that more expert level objects and configuration properties be shown using the menu system.

Running `dsconfig` in interactive command-line mode provides a user-friendly, menu-driven interface for accessing and configuring the UnboundID Data Store. To start `dsconfig` in interactive command-line mode, simply invoke the `dsconfig` script without any arguments. You will be prompted for connection and authentication information to the Data Store, and then a menu will be displayed of the available operation types.

In some cases, a default value will be provided in square brackets. For example, [389] indicates that the default value for that field is port 389. You can press **Enter** to accept the default. To skip the connection and authentication prompts, provide this information using the command-line options of `dsconfig`.

To Configure the Server Using dsconfig Interactive Mode

1. Launch the `dsconfig` tool in interactive command-line mode.

```
$ bin/dsconfig
```

2. Next, enter the LDAP connection parameters. Enter the Data Store host name or IP address, or press **Enter** to accept the default.

3. Enter the number corresponding to the type of LDAP connection (1 for LDAP, 2 for SSL, 3 for StartTLS) that you are using on the Data Store, or press **Enter** to accept the default (1).

4. Next, type the LDAP listener port number, or accept the default port. The default port is the port number of the server local to the tool.

5. Enter the user bind DN (default, `cn=Directory Manager`) and the bind DN password.

6. On the **Data Store Configuration Console** main menu, type a number corresponding to the configuration that you want to change. Note that the number can change between releases or within the same release, depending on the options selected (for example, in cases where more expert level objects and and properties are displayed).

   In this example, select the number for Backend. Then, set the `db-cache-percent` to 40%. The optimal cache percentage depends on your system performance objectives and must be tuned as determined through analysis. In many cases, the default value chosen by the `setup` utility is sufficient.

7. On the **Backend management** menu, enter the number corresponding to view and edit an existing backend.

8. Select the backend to work with. In this example, using the basic object menu, only one backend that can be viewed in the directory, userRoot. Press **Enter** to accept the default.

9. From the **Local DB Backend** properties menu, type the number corresponding to the `db-cache-percent` property.

10. Enter the option to change the value, and then type the value for the `db-cache-percent` property. In this example, type `40` for "40 %“.

11. Review the changes, and then type `f` to apply them.

    Before you apply the change, the `dsconfig` interactive command-line mode provides an option to view the equivalent non-interactive command based on your menu selections. This is useful in building `dsconfig` script files for configuring servers in non-interactive or batch mode. If you want to view the equivalent `dsconfig` non-interactive command, type `d`. For more information, see *Getting the Equivalent dsconfig Non-Interactive Mode Command*.

12. In the **Backend management** menu, type `q` to quit the `dsconfig` tool.

To View dsconfig Advanced Properties

For most configuration settings, some properties are more likely to be modified than others. The `dsconfig` interactive mode provides an option that hides or shows additional advanced properties that administrators might want to configure.

1. Repeat steps 1–9 in the previous section using `dsconfig` in Interactive Command-Line Mode.

2. From the **Local DB Backend properties** menu, type `a` to display the advanced properties, which toggles any hidden properties.

Using dsconfig Interactive Mode: Viewing Object Menus

Because some configuration objects are more likely to be modified than others, the UnboundID Data Store provides four different object menus that hide or expose configuration objects to the user. The purpose of object levels is to simply present only those properties that an administrator will likely use. The Object type is a convenience feature designed to unclutter menu readability.

The following object menus are available:

- **Basic**. Only includes the components that are expected to be configured most frequently.
- **Standard**. Includes all components in the Basic menu plus other components that might occasionally need to be altered in many environments.
- **Advanced**. Includes all components in the Basic and Standard menus plus other components that might require configuration under special circumstances or that might be potentially harmful if configured incorrectly.
- **Expert**. Includes all components in the Basic, Standard, and Advanced menus plus other components that should almost never require configuration or that could seriously impact the functionality of the server if not properly configured.

To Change the dsconfig Object Menu

1. Repeat steps 1–6 in the section using `dsconfig` in To Install the Data Store in Interactive Mode.

2. On the **UnboundID Data Store configuration** main menu, type **o** (letter “o”) to change the object level. By default, Basic objects are displayed.

3. Enter a number corresponding to a object level of your choice: `1` for Basic, `2` for Standard, `3` for Advanced, `4` for Expert.

4. View the menu at the new object level. Additional configuration options for the Data Store components are displayed.

Using dsconfig Interactive: Viewing Administrative Alerts

The `dsconfig` tool and the web console provide a useful feature that displays notifications for certain operations that require further administrator action to complete the process. If you change a certain backend configuration property, the admin action will appear in two places during a `dsconfig` interactive session: when configuring the property and before you apply the change. For example, if you change the `db-directory` property on the userRoot backend (that is, specify the path to the filesystem path that holds the Oracle Berkeley DB Java Edition backend files), you will see an admin action reminder during one of the steps (shown below).

The admin action alert will also appear as a final confirmation step. The alert allows you to continue and apply the change or back out of the configuration if the resulting action cannot be conducted at the present time. For example, after you type "`f`" to apply the `db-directory` property change, the admin alert message appears:

```
Enter choice [b]: f
One or more configuration property changes require administrative action or
confirmation/notification.

Those properties include:

* db-directory: Modification requires that the Data Store be stopped,
  the database directory manually relocated, and then the Data Store
  restarted. While the Data Store is stopped, the directory and files
  pertaining to this backend in the old database directory must be manually
  moved or copied to the new location.

Continue? Choose 'no' to return to the previous step (yes / no) [yes]:
```

Currently, only a small set of properties display an admin action alert appear in `dsconfig` interactive mode and the web console. For more information on the properties, see the *UnboundID Data Store Configuration Reference*.

Using dsconfig in Non-Interactive Mode

The `dsconfig` non-interactive command-line mode provides a simple way to make arbitrary changes to the Data Store by invoking it from the command line. To use administrative scripts to automate configuration changes, run the `dsconfig` command in non-interactive mode, which is convenient scripting applications. Note, however, that if you plan to make changes to multiple configuration objects at the same time, then the batch mode might be more appropriate.

You can use the `dsconfig` tool to update a single configuration object using command-line arguments to provide all of the necessary information. The general format for the non-interactive command line is:

```
$ bin/dsconfig --no-prompt {globalArgs} {subcommand} {subcommandArgs}
```

The `--no-prompt` argument indicates that you want to use non-interactive mode. The `{sub-command}` is used to indicate which general action to perform. The `{globalArgs}` argument provides a set of arguments that specify how to connect and authenticate to the Data Store. Global arguments can be standard LDAP connection parameters or SASL connection parameters depending on your setup. For example, using standard LDAP connections, you can invoke the `dsconfig` tool as follows:

```
$ bin/dsconfig --no-prompt list-backends \
  --hostname server.example.com \
  --port 389 \
  --bindDN uid=admin,dc=example,dc=com \
  --bindPassword password
```

If your system uses SASL GSSAPI (Kerberos), you can invoke `dsconfig` as follows:

```
$ bin/dsconfig --no-prompt list-backends \
  --saslOption mech=GSSAPI \
  --saslOption authid=admin@example.com \
  --saslOption ticketcache=/tmp/krb5cc_1313 \
  --saslOption useticketcache=true
```

The `{subcommandArgs}` argument contains a set of arguments specific to the particular subcommand that you wish to invoke. To always display the advanced properties, use the `--advanced` command-line option.

Note: Global arguments can appear anywhere on the command line (including before the subcommand, and after or intermingled with subcommand-specific arguments). The subcommand-specific arguments can appear anywhere after the subcommand.

To Configure the Server Using dsconfig Non-Interactive Mode

- Use the `dsconfig` command in non-interactive mode to change the amount of memory used for caching database contents and to specify common parent DNs that should be compacted in the underlying database.

  ```
  $ bin/dsconfig set-backend-prop \
    --backend-name userRoot \
    --set db-cache-percent:40 \
    --add "compact-common-parent-dn:ou=accts,dc=example,dc=com" \
    --add "compact-common-parent-dn:ou=subs,dc=example,dc=com"
  ```

To View a List of dsconfig Properties

1. Use the `dsconfig` command with the `list-properties` option to view the list of all `dsconfig` properties. Remember to add the LDAP connection parameters.

   ```
   $ bin/dsconfig list-properties
   ```

2. Use the `dsconfig` command with the `list-properties` option and the `--complexity <menu level>` to view objects at and below the menu object level. You can also add the `--includeDescription` argument that includes a synopsis and description of each property in the output. Remember to add the LDAP connection parameters.

   ```
   $ bin/dsconfig list-properties --complexity advanced --includeDescription
   ```

3. If the server is offline, you can run the command with the `--offline` option. You do not need to enter the LDAP connection parameters.

   ```
    $ bin/dsconfig list-properties --offline --complexity advanced --includeDescription
   ```

You can also view the `<server-root>/docs/config-properties.txt` that contains the property information provided with the server.

Getting the Equivalent dsconfig Non-Interactive Mode Command

While the `dsconfig` non-interactive command-line mode is convenient for scripting and automating processes, obtaining the correct arguments and properties for each configuration change can be quite time consuming.

To facilitate easy and quick configuration, you can use an option to display the equivalent non-interactive command using `dsconfig` interactive mode. The command displays the equivalent `dsconfig` command to recreate the configuration in a scripted configuration or to more quickly enter any pending changes on the command line for another server instance.

Note: There are two other ways to get the equivalent `dsconfig` command. One way is by looking at the `logs/config-audit.log`. It might be more convenient to set the Data Store up the way you want and then get the `dsconfig` arguments from the log. Another way is by configuring an option using the Management Console. The console shows the equivalent `dsconfig` command prior to applying the change.

To Get the Equivalent dsconfig Non-Interactive Mode Command

1. Using `dsconfig` in interactive mode, make changes to a configuration but do not apply the changes (that is, do not enter "f").

2. Enter `d` to view the equivalent non-interactive command.

3. View the equivalent command (seen below), and then press **Enter** to continue. For example, based on an example in the previous section, changes made to the `db-cache-percent` returns the following:

```
Command line to apply pending changes to this Local DB Backend:
dsconfig set-backend-prop --backend-name userRoot --set db-cache-percent:40
```

   The command does not contain the LDAP connection parameters required for the tool to connect to the host since it is presumed that the command would be used to connect to a different remote host.

Using dsconfig Batch Mode

The UnboundID Data Store provides a `dsconfig` batching mechanism that reads multiple `dsconfig` invocations from a file and executes them sequentially. The batch file provides advantages over standard scripting by minimizing LDAP connections and JVM invocations that normally occur with each `dsconfig` call. Batch mode is the best method to use with setup scripts when moving from a development environment to test environment, or from a test environment to a production environment. The `--no-prompt` option is required with `dsconfig` in batch mode.

If a `dsconfig` command has a missing or incorrect argument, the command will fail and abort the batch process without applying any changes to the Data Store. The `dsconfig` command supports a `--batch-continue-on-error` option which instructs `dsconfig` to apply all changes and skip any errors.

You can view the `logs/config-audit.log` file to review the configuration changes made to the Data Store and use them in the batch file. The batch file can have blank lines for spacing and lines starting with a pound sign (#) for comments. The batch file also supports a "\" line continuation character for long commands that require multiple lines.

The Data Store also provides a `docs/sun-ds-compatibility.dsconfig` file for migrations from Sun/Oracle to UnboundID Data Store machines.

To Configure the Data Store in dsconfig Batch Mode

1. Create a text file that lists each `dsconfig` command with the complete set of properties that you want to apply to the Data Store. The items in this file should be in the same format as those accepted by the `dsconfig` command. The batch file can have blank lines for spacing and lines starting with a pound sign (#) for comments. The batch file also supports a "\" line continuation character for long commands that require multiple lines.

```
# Set the DB cache percent to 40
set-backend-prop --backend-name userRoot --set db-cache-percent:40

# Disable prime-method to none
set-backend-prop --backend-name userRoot --reset prime-method
```

2. Use `dsconfig` with the `--batch-file` option to read and execute the commands.

```
$ bin/dsconfig --hostname host1 --port 1389 \
 --bindDN "uid=admin,dc=example,dc=com" \
 --bindPassword secret --no-prompt \
 --batch-file /path/to/config-batch.txt
```

```
Batch file 'config-batch.txt' contains 2 commands:
Executing: set-backend-prop --port 1389 --bindDN "uid=admin,dc=example,dc=com" \
--bindPassword ****** --no-prompt --backend-name userRoot --set db-cache-percent:40

Executing: set-backend-prop --port 1389 --bindDN "uid=admin,dc=example,dc=com" \
--bindPassword ****** --no-prompt --backend-name userRoot --reset prime-method
```

Using the Configuration API

UnboundID servers provide a Configuration API, which may be useful in situations where using LDAP to update the server configuration is not possible. The API is consistent with the System for Cross-domain Identity Management (SCIM) 2.0 protocol and uses JSON as a text exchange format, so all request headers should allow the application/json content type.

The server includes a servlet extension that provides read and write access to the server's configuration over HTTP. The extension is enabled by default for new installations, and can be enabled for existing deployments by simply adding the extension to one of the server's HTTP Connection Handlers, as follows:

```
$ bin/dsconfig set-connection-handler-prop \
  --handler-name "HTTPS Connection Handler" \
  --add http-servlet-extension:Configuration
```

The API is made available on the HTTPS Connection handler’s host:port in the `/config` context. Due to the potentially sensitive nature of the server’s configuration, the HTTPS Connection Handler should be used for hosting the Configuration extension.

Authentication and Authorization with the Configuration API

Clients must use HTTP Basic authentication to authenticate to the Configuration API. If the username value is not a DN, then it will be resolved to a DN value using the identity mapper associated with the Configuration servlet. By default, the Configuration API uses an identity mapper that allows an entry’s UID value to be used as a username. To customize this behavior, either customize the default identity mapper, or specify a different identity mapper using the Configuration servlet’s `identity-mapper` property. For example:

```
$ bin/dsconfig set-http-servlet-extension-prop \
  --extension-name Configuration \
  --set "identity-mapper:Alternative Identity Mapper”
```

To access configuration information, users must have the appropriate privileges:

- To access the `cn=config` backend, users must have the `bypass-acl` privilege or be allowed access to the configuration using an ACI.
- To read configuration information, users must have the `config-read` privilege.
- To update the configuration, users must have the `config-write` privilege.

Relationship Between the Configuration API and the dsconfig Tool

The Configuration API is designed to mirror the `dsconfig` tool, using the same names for properties and object types. Property names are presented as hyphen case in `dsconfig` and as camel-case attributes in the API. In API requests that specify property names, case is not important. Therefore, `baseDN` is the same as `baseDn`. Object types are represented in hyphen case. API paths mirror what is in `dsconfig`. For example, the `dsconfig list-connection-handlers` command is analogous to the API's `/config/connection-handlers` path. Object types that appear in the schema URNs adhere to a `type:subtype` syntax. For example, a Local DB Backend's schema URN is `urn:unboundid:schemas:configuration:2.0:backend:local-db`. Like the `dsconfig` tool, all configuration updates made through the API are recorded in `logs/config-audit.log`.

The API includes the filter, sort, and pagination query parameters described by the SCIM specification. Specific attributes may be requested using the attributes query parameter, whose value must be a comma-delimited list of properties to be returned, for example `attributes=baseDN,description`. Likewise, attributes may be excluded from responses by specifying the `excludedAttributes` parameter.

Operations supported by the API are those typically found in REST APIs:

HTTP Method	Description	Related dsconfig Example
GET	Lists the properties of an object when used with a path representing an object, such as `/config/global-configuration` or `/config/`	`get-backend-prop`, `list-backends`, `get-global-configuration-prop`

HTTP Method	Description	Related dsconfig Example
	`backends/userRoot`. Can also list objects when used with a path representing a parent relation, such as `/config/backends`.	
POST	Creates a new instance of an object when used with a relation parent path, such as `/config/backends`.	`create-backend`
PUT	Replaces the existing properties of an object. A PUT operation is similar to a PATCH operation, except that the PATCH identifies the difference between an existing target object and a supplied source object. Only those properties in the source object are modified in the target object. The target object is specified using a path, such as `/config/backends/userRoot`.	`set-backend-prop`, `set-global-configuration-prop`
PATCH	Updates the properties of an existing object when used with a path representing an object, such as `/config/backends/userRoot`.	`set-backend-prop`, `set-global-configuration-prop`
DELETE	Deletes an existing object when used with a path representing an object, such as `/config/backends/userRoot`.	`delete-backend`

The OPTIONS method can also be used to determine the operations permitted for a particular path.

Object names, such as `userRoot` in the Description column, must be URL-encoded for use in the path segment of a URL. For example, `%20` must be used in place of spaces, and `%25` is used in place of the percent (%) character. The URL for accessing the HTTP Connection Handler object is:

```
/config/connection-handlers/http%20connection%20handler
```

GET Example

The following is a sample GET request for information about the `userRoot` backend:

```
GET /config/backends/userRoot
Host: example.com:5033
Accept: application/scim+json
```

The response:

```
{
  "schemas": [
    "urn:unboundid:schemas:configuration:2.0:backend:local-db"
  ],
   "id": "userRoot",
   "meta": {
     "resourceType": "Local DB Backend",
     "location": "http://localhost:5033/config/backends/userRoot"
   },
   "backendID": "userRoot2",
   "backgroundPrime": "false",
   "backupFilePermissions": "700",
   "baseDN": [
     "dc=example2,dc=com"
   ],
   "checkpointOnCloseCount": "2",
   "cleanerThreadWaitTime": "120000",
   "compressEntries": "false",
   "continuePrimeAfterCacheFull": "false",
   "dbBackgroundSyncInterval": "1 s",
   "dbCachePercent": "10",
   "dbCacheSize": "0 b",
   "dbCheckpointerBytesInterval": "20 mb",
   "dbCheckpointerHighPriority": "false",
   "dbCheckpointerWakeupInterval": "1 m",
   "dbCleanOnExplicitGC": "false",
   "dbCleanerMinUtilization": "75",
   "dbCompactKeyPrefixes": "true",
   "dbDirectory": "db",
   "dbDirectoryPermissions": "700",
   "dbEvictorCriticalPercentage": "0",
   "dbEvictorLruOnly": "false",
   "dbEvictorNodesPerScan": "10",
   "dbFileCacheSize": "1000",
   "dbImportCachePercent": "60",
   "dbLogFileMax": "50 mb",
   "dbLoggingFileHandlerOn": "true",
   "dbLoggingLevel": "CONFIG",
   "dbNumCleanerThreads": "0",
   "dbNumLockTables": "0",
   "dbRunCleaner": "true",
   "dbTxnNoSync": "false",
   "dbTxnWriteNoSync": "true",
   "dbUseThreadLocalHandles": "true",
   "deadlockRetryLimit": "10",
   "defaultCacheMode": "cache-keys-and-values",
   "defaultTxnMaxLockTimeout": "10 s",
   "defaultTxnMinLockTimeout": "10 s",
   "enabled": "false",
   "explodedIndexEntryThreshold": "4000",
   "exportThreadCount": "0",
   "externalTxnDefaultBackendLockBehavior": "acquire-before-retries",
   "externalTxnDefaultMaxLockTimeout": "100 ms",
   "externalTxnDefaultMinLockTimeout": "100 ms",
   "externalTxnDefaultRetryAttempts": "2",
   "hashEntries": "false",
   "id2childrenIndexEntryLimit": "66",
   "importTempDirectory": "import-tmp",
   "importThreadCount": "16",
   "indexEntryLimit": "4000",
   "isPrivateBackend": "false",
   "javaClass": "com.unboundid.directory.server.backends.jeb.BackendImpl",
   "jeProperty": [
     "je.cleaner.adjustUtilization=false",
     "je.nodeMaxEntries=32"
   ],
   "numRecentChanges": "50000",
   "offlineProcessDatabaseOpenTimeout": "1 h",
   "primeAllIndexes": "true",
   "primeMethod": [
     "none"
   ],
   "primeThreadCount": "2",
   "primeTimeLimit": "0 ms",
   "processFiltersWithUndefinedAttributeTypes": "false",
   "returnUnavailableForUntrustedIndex": "true",
   "returnUnavailableWhenDisabled": "true",
   "setDegradedAlertForUntrustedIndex": "true",
   "setDegradedAlertWhenDisabled": "true",
   "subtreeDeleteBatchSize": "5000",
   "subtreeDeleteSizeLimit": "5000",
   "uncachedId2entryCacheMode": "cache-keys-only",
   "writabilityMode": "enabled"
}
```

GET List Example

The following is a sample GET request for all local backends:

```
GET /config/backends/
Host: example.com:5033
Accept: application/scim+json
```

The response (which has been shortened):

```
{
  "schemas": [
    "urn:ietf:params:scim:api:messages:2.0:ListResponse"
  ],
  "totalResults": 24,
  "Resources": [
    {
      "schemas": [
        "urn:unboundid:schemas:configuration:2.0:backend:ldif"
      ],
      "id": "adminRoot",
      "meta": {
        "resourceType": "LDIF Backend",
        "location": "http://localhost:5033/config/backends/adminRoot"
      },
      "backendID": "adminRoot",
      "backupFilePermissions": "700",
      "baseDN": [
        "cn=admin data"
      ],
      "enabled": "true",
      "isPrivateBackend": "true",
      "javaClass": "com.unboundid.directory.server.backends.LDIFBackend",
      "ldifFile": "config/admin-backend.ldif",
      "returnUnavailableWhenDisabled": "true",
      "setDegradedAlertWhenDisabled": "false",
      "writabilityMode": "enabled"
    },
    {
      "schemas": [
        "urn:unboundid:schemas:configuration:2.0:backend:trust-store"
      ],
      "id": "ads-truststore",
      "meta": {
        "resourceType": "Trust Store Backend",
        "location": "http://localhost:5033/config/backends/ads-truststore"
      },
      "backendID": "ads-truststore",
      "backupFilePermissions": "700",
      "baseDN": [
        "cn=ads-truststore"
      ],
      "enabled": "true",
      "javaClass": "com.unboundid.directory.server.backends.TrustStoreBackend",
      "returnUnavailableWhenDisabled": "true",
      "setDegradedAlertWhenDisabled": "true",
      "trustStoreFile": "config/server.keystore",
      "trustStorePin": "********",
      "trustStoreType": "JKS",
      "writabilityMode": "enabled"
    },
    {
      "schemas": [
        "urn:unboundid:schemas:configuration:2.0:backend:alarm"
      ],
      "id": "alarms",
      "meta": {
        "resourceType": "Alarm Backend",
        "location": "http://localhost:5033/config/backends/alarms"
      },
  ...
```

PATCH Example

Configuration can be modified using the HTTP PATCH method. The PATCH request body is a JSON object formatted according to the SCIM patch request. The Configuration API, supports a subset of possible values for the path attribute, used to indicate the configuration attribute to modify.

The configuration object's attributes can be modified in the following ways. These operations are analogous to the `dsconfig modify-[object]` options.

- An operation to set the single-valued `description` attribute to a new value:

```
{
  "op" : "replace",
  "path" : "description",
  "value" : "A new backend."
}
```

is analogous to:

```
$ dsconfig set-backend-prop
  --backend-name userRoot \
  --set "description:A new backend"
```

- An operation to add a new value to the multi-valued `jeProperty` attribute:

```
{
  "op" : "add",
  "path" : "jeProperty",
  "value" : "je.env.backgroundReadLimit=0"
}
```

is analogous to:

```
$ dsconfig  set-backend-prop --backend-name userRoot \
  --add je-property:je.env.backgroundReadLimit=0
```

- An operation to remove a value from a multi-valued property. In this case, path specifies a SCIM filter identifying the value to remove:

```
{
  "op" : "remove",
  "path" : "[jeProperty eq \"je.cleaner.adjustUtilization=false\"]"
}
```

is analogous to:

```
$ dsconfig set-backend-prop --backend-name userRoot \
  --remove je-property:je.cleaner.adjustUtilization=false
```

- A second operation to remove a value from a multi-valued property, where the `path` specifies both an attribute to modify, and a SCIM filter whose attribute is value:

```
{
  "op" : "remove",
  "path" : "jeProperty[value eq \"je.nodeMaxEntries=32\"]"
}
```

is analogous to:

```
$ dsconfig set-backend-prop --backend-name userRoot \
  --remove je-property:je.nodeMaxEntries=32
```

- An option to remove one or more values of a multi-valued attribute. This has the effect of restoring the attribute's value to its default value:

```
{
  "op" : "remove",
  "path" : "id2childrenIndexEntryLimit"
}
```

is analogous to:

```
$ dsconfig set-backend-prop --backend-name userRoot \
  --reset id2childrenIndexEntryLimit
```

The following is the full example request. The API responds with the entire modified configuration object, which may include a SCIM extension attribute `urn:unboundid:schemas:configuration:messages` containing additional instructions:

```
PATCH /config/backends/userRoot
Host: example.com:5033
Accept: application/scim+json

{
  "schemas" : [ "urn:ietf:params:scim:api:messages:2.0:PatchOp" ],
  "Operations" : [ {
    "op" : "replace",
    "path" : "description",
    "value" : "A new backend."
  }, {
    "op" : "add",
    "path" : "jeProperty",
    "value" : "je.env.backgroundReadLimit=0"
  }, {
    "op" : "remove",
    "path" : "[jeProperty eq \"je.cleaner.adjustUtilization=false\"]"
  }, {
    "op" : "remove",
    "path" : "jeProperty[value eq \"je.nodeMaxEntries=32\"]"
  }, {
    "op" : "remove",
    "path" : "id2childrenIndexEntryLimit"
  } ]
}
```

Example response:

```
{
 "schemas": [
   "urn:unboundid:schemas:configuration:2.0:backend:local-db"
 ],
 "id": "userRoot2",
 "meta": {
   "resourceType": "Local DB Backend",
   "location": "http://example.com:5033/config/backends/userRoot2"
 },
 "backendID": "userRoot2",
 "backgroundPrime": "false",
 "backupFilePermissions": "700",
 "baseDN": [
   "dc=example2,dc=com"
 ],
 "checkpointOnCloseCount": "2",
 "cleanerThreadWaitTime": "120000",
 "compressEntries": "false",
 "continuePrimeAfterCacheFull": "false",
 "dbBackgroundSyncInterval": "1 s",
 "dbCachePercent": "10",
 "dbCacheSize": "0 b",
 "dbCheckpointerBytesInterval": "20 mb",
 "dbCheckpointerHighPriority": "false",
 "dbCheckpointerWakeupInterval": "1 m",
 "dbCleanOnExplicitGC": "false",
 "dbCleanerMinUtilization": "75",
 "dbCompactKeyPrefixes": "true",
 "dbDirectory": "db",
 "dbDirectoryPermissions": "700",
 "dbEvictorCriticalPercentage": "0",
 "dbEvictorLruOnly": "false",
 "dbEvictorNodesPerScan": "10",
 "dbFileCacheSize": "1000",
 "dbImportCachePercent": "60",
 "dbLogFileMax": "50 mb",
 "dbLoggingFileHandlerOn": "true",
 "dbLoggingLevel": "CONFIG",
 "dbNumCleanerThreads": "0",
 "dbNumLockTables": "0",
 "dbRunCleaner": "true",
 "dbTxnNoSync": "false",
 "dbTxnWriteNoSync": "true",
 "dbUseThreadLocalHandles": "true",
 "deadlockRetryLimit": "10",
 "defaultCacheMode": "cache-keys-and-values",
 "defaultTxnMaxLockTimeout": "10 s",
 "defaultTxnMinLockTimeout": "10 s",
 "description": "123",  "enabled": "false",
 "explodedIndexEntryThreshold": "4000",
 "exportThreadCount": "0",
 "externalTxnDefaultBackendLockBehavior": "acquire-before-retries",
 "externalTxnDefaultMaxLockTimeout": "100 ms",
 "externalTxnDefaultMinLockTimeout": "100 ms",
 "externalTxnDefaultRetryAttempts": "2",
 "hashEntries": "false",
 "importTempDirectory": "import-tmp",
 "importThreadCount": "16",
 "indexEntryLimit": "4000",
 "isPrivateBackend": "false",
 "javaClass": "com.unboundid.directory.server.backends.jeb.BackendImpl",
 "jeProperty": [  "\"je.env.backgroundReadLimit=0\""
 ],
 "numRecentChanges": "50000",
 "offlineProcessDatabaseOpenTimeout": "1 h",
 "primeAllIndexes": "true",
 "primeMethod": [
   "none"
 ],
 "primeThreadCount": "2",
 "primeTimeLimit": "0 ms",
 "processFiltersWithUndefinedAttributeTypes": "false",
 "returnUnavailableForUntrustedIndex": "true",
 "returnUnavailableWhenDisabled": "true",
 "setDegradedAlertForUntrustedIndex": "true",
 "setDegradedAlertWhenDisabled": "true",
 "subtreeDeleteBatchSize": "5000",
 "subtreeDeleteSizeLimit": "5000",
 "uncachedId2entryCacheMode": "cache-keys-only",
 "writabilityMode": "enabled",
 "urn:unboundid:schemas:configuration:messages:2.0": {
   "requiredActions": [
     {
       "property": "jeProperty",
       "type": "componentRestart",
       "synopsis": "In order for this modification to take effect,
          the component must be restarted, either by disabling and
          re-enabling it, or by restarting the server"
     },
     {
       "property": "id2childrenIndexEntryLimit",
       "type": "other",
       "synopsis": "If this limit is increased, then the contents
          of the backend must be exported to LDIF and re-imported to
          allow the new limit to be used for any id2children keys
          that had already hit the previous limit."
     }
   ]
 }
}
```

Configuration API Paths

The Configuration API is available under the /config path. A full listing of supported sub-paths is available by accessing the base `/config/ResourceTypes` endpoint:

```
GET /config/ResourceTypes
Host: example.com:5033
Accept: application/scim+json
```

Sample response (abbreviated):

```
{
  "schemas": [
    "urn:ietf:params:scim:api:messages:2.0:ListResponse"
  ],
  "totalResults": 520,
  "Resources": [
    {
      "schemas": [
        "urn:ietf:params:scim:schemas:core:2.0:ResourceType"
      ],
      "id": "dsee-compat-access-control-handler",
      "name": "DSEE Compat Access Control Handler",
      "description": "The DSEE Compat Access Control
              Handler provides an implementation that uses syntax
              compatible with the Sun Java System Directory Server
              Enterprise Edition access control handler.",
      "endpoint": "/access-control-handler",
      "meta": {
        "resourceType": "ResourceType",
        "location": "http://example.com:5033/config/ResourceTypes/dsee-compat-access-
control-handler"
      }
    },
    {
      "schemas": [
        "urn:ietf:params:scim:schemas:core:2.0:ResourceType"
      ],
      "id": "access-control-handler",
      "name": "Access Control Handler",
      "description": "Access Control Handlers manage the
              application-wide access control. The server's access
              control handler is defined through an extensible
              interface, so that alternate implementations can be created.
              Only one access control handler may be active in the server
                        at any given time.",
      "endpoint": "/access-control-handler",
      "meta": {
        "resourceType": "ResourceType",
        "location": "http://example.com:5033/config/ResourceTypes/access-control-
handler"
      }
    },
    {
 ...
```

The response's `endpoint` elements enumerate all available sub-paths. The path `/config/access-control-handler` in the example can be used to get a list of existing access control handlers, and create new ones. A path containing an object name such as `/config/backends/{backendName}`, where `{backendName}` corresponds to an existing backend (such as `userRoot`) can be used to obtain an object's properties, update the properties, or delete the object.

Some paths reflect hierarchical relationships between objects. For example, properties of a local DB VLV index for the `userRoot` backend are available using a path like `/config/backends/userRoot/local-db-indexes/uid`. Some paths represent singleton objects, which have properties but cannot be deleted nor created. These paths can be differentiated from others by their singular, rather than plural, relation name (for example `global-configuration`).

Sorting and Filtering Objects

The Configuration API supports SCIM parameters for filter, sorting, and pagination. Search operations can specify a SCIM filter used to narrow the number of elements returned. See the SCIM specification for the full set of operations for SCIM filters. Clients can also specify sort parameters, or paging parameters. Include or exclude attributes can be specified in both get and list operations.

GET Parameter	Description
filter	Values can be simple SCIM filters such as `id eq "userRoot"` or compound filters like `meta.resourceType eq "Local DB Backend"` and `baseDn co "dc=exmple,dc=com"`.
sortBy	Specifies a property value by which to sort.

GET Parameter	Description
sortOrder	Specifies either `ascending` or `descending` alphabetical order.
startIndex	1-based index of the first result to return.
count	Indicates the number of results per page.

Updating Properties

The Configuration API supports the HTTP PUT method as an alternative to modifying objects with HTTP PATCH. With PUT, the server computes the differences between the object in the request with the current version in the server, and performs modifications where necessary. The server will never remove attributes that are not specified in the request. The API responds with the entire modified object.

Request:

```
PUT /config/backends/userRoot
Host: example.com:5033
Accept: application/scim+json
{
  "description" : "A new description."
}
```

Response:

```
{
  "schemas": [
    "urn:unboundid:schemas:configuration:2.0:backend:local-db"
  ],
  "id": "userRoot",
  "meta": {
    "resourceType": "Local DB Backend",
    "location": "http://example.com:5033/config/backends/userRoot"
  },
  "backendID": "userRoot",
  "backgroundPrime": "false",
  "backupFilePermissions": "700",
  "baseDN": [
    "dc=example,dc=com"
  ],
  "checkpointOnCloseCount": "2",
  "cleanerThreadWaitTime": "120000",
  "compressEntries": "false",
  "continuePrimeAfterCacheFull": "false",
  "dbBackgroundSyncInterval": "1 s",
  "dbCachePercent": "25",
  "dbCacheSize": "0 b",
  "dbCheckpointerBytesInterval": "20 mb",
  "dbCheckpointerHighPriority": "false",
  "dbCheckpointerWakeupInterval": "30 s",
  "dbCleanOnExplicitGC": "false",
  "dbCleanerMinUtilization": "75",
  "dbCompactKeyPrefixes": "true",
  "dbDirectory": "db",
  "dbDirectoryPermissions": "700",
  "dbEvictorCriticalPercentage": "5",
  "dbEvictorLruOnly": "false",
  "dbEvictorNodesPerScan": "10",
  "dbFileCacheSize": "1000",
  "dbImportCachePercent": "60",
  "dbLogFileMax": "50 mb",
  "dbLoggingFileHandlerOn": "true",
  "dbLoggingLevel": "CONFIG",
  "dbNumCleanerThreads": "1",
  "dbNumLockTables": "0",
  "dbRunCleaner": "true",
  "dbTxnNoSync": "false",
  "dbTxnWriteNoSync": "true",
  "dbUseThreadLocalHandles": "true",
  "deadlockRetryLimit": "10",
  "defaultCacheMode":
  "cache-keys-and-values",
  "defaultTxnMaxLockTimeout": "10 s",
  "defaultTxnMinLockTimeout": "10 s",
  "description": "abc",
  "enabled": "true",
  "explodedIndexEntryThreshold": "4000",
  "exportThreadCount": "0",
  "externalTxnDefaultBackendLockBehavior":
  "acquire-before-retries",
  "externalTxnDefaultMaxLockTimeout": "100 ms",
  "externalTxnDefaultMinLockTimeout": "100 ms",
  "externalTxnDefaultRetryAttempts": "2",
  "hashEntries": "true",
  "importTempDirectory": "import-tmp",
  "importThreadCount": "16",
  "indexEntryLimit": "4000",
  "isPrivateBackend": "false",
  "javaClass": "com.unboundid.directory.server.backends.jeb.BackendImpl",
  "numRecentChanges": "50000",  "offlineProcessDatabaseOpenTimeout": "1 h",
  "primeAllIndexes": "true",
  "primeMethod": [
    "none"
  ],
  "primeThreadCount": "2",
  "primeTimeLimit": "0 ms",
  "processFiltersWithUndefinedAttributeTypes": "false",
  "returnUnavailableForUntrustedIndex": "true",
  "returnUnavailableWhenDisabled": "true",
  "setDegradedAlertForUntrustedIndex": "true",
  "setDegradedAlertWhenDisabled": "true",
  "subtreeDeleteBatchSize": "5000",
  "subtreeDeleteSizeLimit": "100000",
  "uncachedId2entryCacheMode": "cache-keys-only",
  "writabilityMode": "enabled"
}
```

Administrative Actions

Updating a property may require an administrative action before the change can take effect. If so, the server will return `200 Success`, and any actions are returned in the `urn:unboundid:schemas:configuration:messages:2.0` section of the JSON response that represents the entire object that was created or modified.

For example, changing the `jeProperty` of a backend will result in the following:

```
"urn:unboundid:schemas:configuration:messages:2.0": {
    "required-actions": [
      {
       "property": "baseContextPath",
       "type": ""componentRestart",
       "synopsis": "In order for this modification to take effect, the component
                  must be restarted, either by disabling and re-enabling it, or
                  by restarting the server"
      },
      {
        "property": {
        "type": "other",
        "synopsis": "If this limit is increased, then the
                 contents of the backend must be exported to LDIF
                 and re-imported to allow the new limit to be used
                 for any id2children keys that had already hit the
                 previous limit."
      }
    ]
  }
```

Updating Servers and Server Groups

Servers can be configured as part of a server group, so that configuration changes that are applied to a single server, are then applied to all servers in a group. When managing a server that is a member of a server group, creating or updating objects using the Configuration API requires the `applyChangeTo` query attribute. The behavior and acceptable values for this parameter are identical to the `dsconfig` parameter of the same name. A value of `single-server` or `server-group` can be specified. For example:

```
http://localhost:8082/config/backends/userRoot?applyChangeTo=single-server
```

Configuration API Responses

Clients of the API should examine the HTTP response code in order to determine the success or failure of a request. The following are response codes and their meanings:

Response Code	Description	Response Body
200 Success	The requested operation succeeded, with the response body being the configuration object that was created or modified. If further actions are required, they are included in the `urn:unboundid:schemas:configuration:messages:2.0` object.	List of objects, or object properties, administrative actions.
204 No Content	The requested operation succeeded and no further information has been provided, such as in the case of a DELETE operation.	None.
400 Bad Request	The request contents are incorrectly formatted or a request is made for an invalid API version.	Error summary and optional message.
401 Unauthorized	User authentication is required. Some user agents such as browsers may respond by prompting for credentials. If the request had specified credentials in an Authorization header, they are invalid.	None.
403 Forbidden	The requested operation is forbidden either because the user does not have sufficient privileges or some other constraint such as an object is edit-only and cannot be deleted.	None.
404 Not Found	The requested path does not refer to an existing object or object relation.	Error summary and optional message.
409 Conflict	The requested operation could not be performed due to the current state of the configuration. For example, an attempt was made to create an object that already exists, or an attempt was made to delete an object that is referred to by another object.	Error summary and optional message.
415 Unsupported Media Type	The request is such that the Accept header does not indicate that JSON is an acceptable format for a response.	None.
500 Server Error	The server encountered an unexpected error. Please report server errors to customer support.	Error summary and optional message.

An application that uses the Configuration API should limit dependencies on particular text appearing in error message content. These messages may change, and their presence may depend on server configuration. Use the HTTP return code and the context of the request to create a client error message. The following is an example encoded error message:

```
{
 "schemas": [
   "urn:ietf:params:scim:api:messages:2.0:Error"
 ],
 "status": 404,
 "scimType": null,
 "detail": "The Local DB Index does not exist."
}
```

Configure the Server Using the Management Console

The UnboundID Data Store provides a graphical web console for server management and monitoring that has the same functionality as that of the `dsconfig` command. When logging on to the Management Console, the console does not persistently store any credentials for authenticating to the Data Store but uses the credentials provided by the user when logging in. When managing multiple data store instances, the provided credentials must be valid for each instance.

For information on installing the Management Console, see *Installing the Management Console*.

To Log onto the Management Console

To log into the console, you can either use a DN (for example, `cn=admin,dc=example,dc=com`) or provide the name of an administrator, which is stored under `cn=admin` data, such as admin or `cn=admin2,cn=Administrators,cn=Admin Data`. See *Configuring a Global Administrator* for instructions.

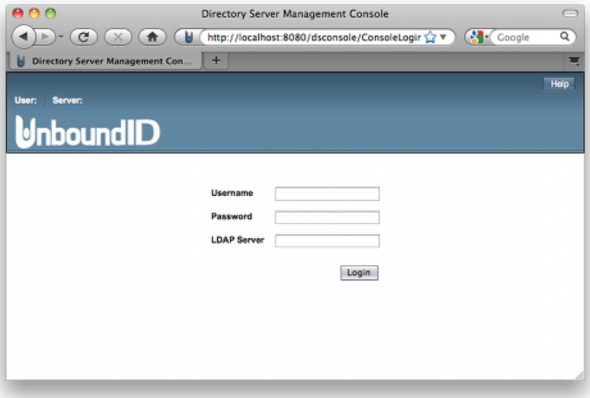
1. Start the Data Store.

   ```
   $ bin/start-ds
   ```

2. Start the servlet container.

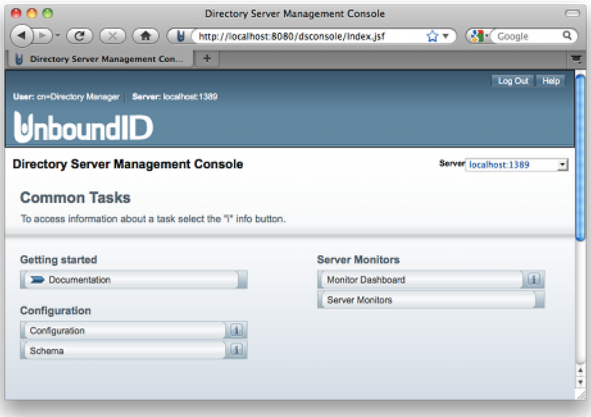
3. Open a browser to http://hostname:8080/dsconsole/.

4. Enter the root user DN (or any authorized administrator user name) and password, and then click **Login**.

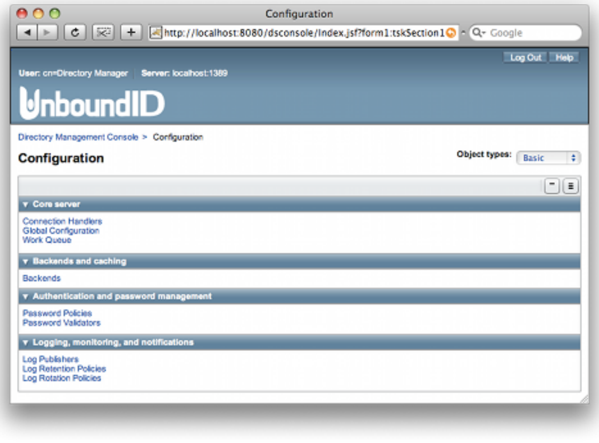

Directory Server Management Console
http://localhost:8080/dsconsole/ConsoleLogin
Help
User: Server:
UnboundID
Username
Password
LDAP Server
Login

The console does not persistently store any credentials for accessing the Data Store. Instead, it uses the credentials provided by the user when logging into the console. When managing multiple data store instances, the provided credentials must be valid at each instance.

5. View the Configuration menu. By default, the console displays the Basic object type properties. You can change the object menu using the Object Types drop-down list.

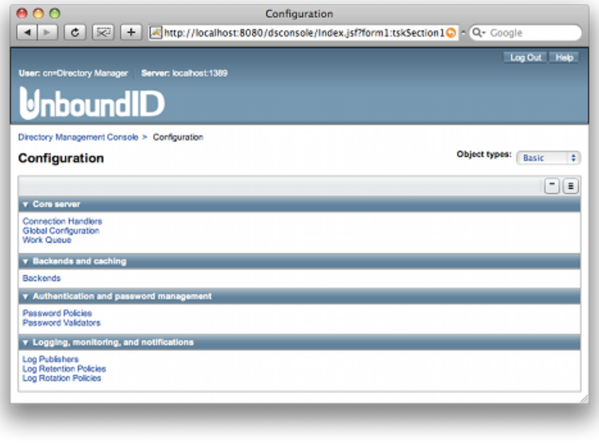

Directory Server Management Console
http://localhost:8080/dsconsole/index.jsf
Log Out Help
User: cn=Directory Manager Server: localhost:1389
UnboundID
Directory Server Management Console
Server localhost:1389
Common Tasks
To access information about a task select the "i" info button.
Getting started
Documentation
Configuration
Configuration
Schema
Server Monitors
Monitor Dashboard
Server Monitors

6. On the Management Console, click **Configuration**.

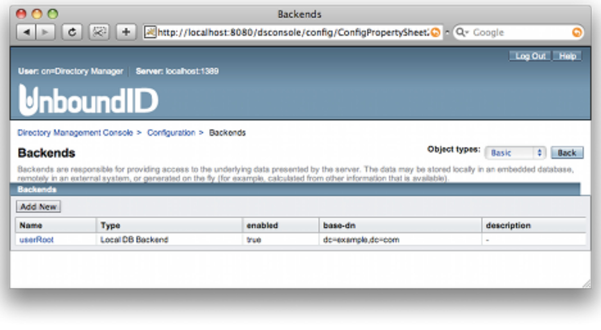


To Configure the Server Using the Console

1. Log into the Management Console. Click **Configuration** to open the **Configuration** menu, and then click **Backends**.



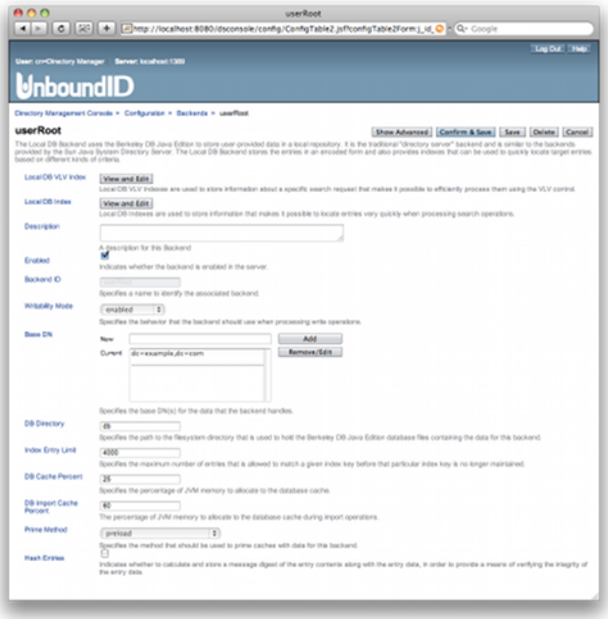
2. In the **Backends** menu, click the backend to work with. For this example, only one backend is displayed. Click userRoot.


Backends
http://localhost:8080/dsconsole/config/ConfigPropertySheet.
Google
Log Out
Help
User: cn=Directory Manager
Server: localhost:1389
UnboundID
Directory Management Console > Configuration > Backends
Backends
Object types:
Basic
Back
Backends
Add New

Backends are responsible for providing access to the underlying data presented by the server. The data may be stored locally in an embedded database, remotely in an external system, or generated on the fly (for example, calculated from other information that is available).

Name	Type	enabled	base-dn	description
userRoot	Local DB Backend	true	dc=example,dc=com	-

3. Change or enter values in the `userRoot` configuration. For this example, change the `DB Cache Percent` value to 40, and then click **Confirm & Save** to apply the change without further confirmation.



User: cn=Directory Manager | Server: localhost:1389

Directory Management Console > Configuration > Backends > userRoot

userRoot

The Local DB Backend uses the Berkeley DB Java Edition to store user-provided data in a local repository. It is the traditional "directory server" backend and is similar to the backends provided by the Sun Java System Directory Server. The Local DB Backend stores the entries in an encoded form and also provides indexes that can be used to quickly locate target entries based on different kinds of criteria.

Local DB VLV Index: Local DB VLV Indexes are used to store information about a specific search request that makes it possible to efficiently process them using the VLV control.

Local DB Index: Local DB Indexes are used to store information that makes it possible to locate entries very quickly when processing search operations.

Description: A description for this Backend

Enabled: ✓ Indicates whether the backend is enabled in the server.

Backend ID: Specifies a name to identify the associated backend.

Writability Mode: enabled — Specifies the behavior that the backend should use when processing write operations.

Base DN: New / Current: dc=example,dc=com — Specifies the base DN(s) for the data that the backend handles.

DB Directory: db — Specifies the path to the filesystem directory that is used to hold the Berkeley DB Java Edition database files containing the data for this backend.

Index Entry Limit: 4000 — Specifies the maximum number of entries that is allowed to match a given index key before that particular index key is no longer maintained.

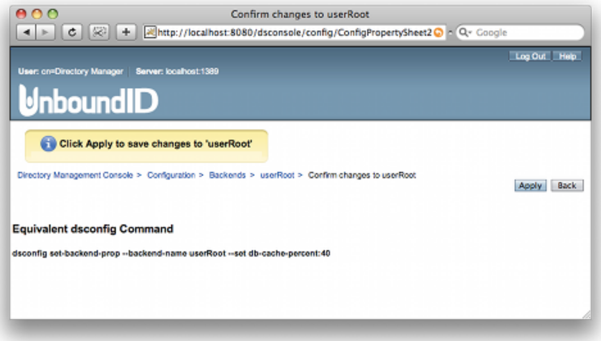
DB Cache Percent: 25 — Specifies the percentage of JVM memory to allocate to the database cache.

DB Import Cache Percent: 60 — The percentage of JVM memory to allocate to the database cache during import operations.

Prime Method: preload — Specifies the method that should be used to prime caches with data for this backend.

Hash Entries: Indicates whether to calculate and store a message digest of the entry contents along with the entry data, in order to provide a means of verifying the integrity of the entry data.

4. Click **Apply** to save the changes. Note that you can see the equivalent non-interactive command-line command on this page. If the property has any associated admin action requirements, such as a system or component restart, it will appear on this page:


Confirm changes to userRoot
http://localhost:8080/dsconsole/config/ConfigPropertySheet2
Google
Log Out
Help
UnboundID
Apply
Back

User: cn=Directory Manager | Server: localhost:1389

Click Apply to save changes to 'userRoot'

Directory Management Console > Configuration > Backends > userRoot > Confirm changes to userRoot

Equivalent dsconfig Command

```
dsconfig set-backend-prop --backend-name userRoot --set db-cache-percent:40
```

Generating a Summary of Configuration Components

The Data Store provides a `config-diff` tool that generates a summary of the configuration in a local or remote data store instance. The tool is useful when comparing configuration settings on the data store instance when troubleshooting issues or when verifying configuration settings on newly-added servers to your network. The tool can interact with the local configuration regardless of whether the server is running or not.

Run the `config-diff --help` option to view other available tool options.

To Generate a Summary of Configuration Components

- Run the `config-diff` tool to generate a summary of the configuration components on the data store instance. The following command runs a summary on a local online server.

```
$ bin/config-diff
```

- The following example compares the current configuration of the local server to the baseline, pre-installation configuration, ignoring any changes that could be made by the installer, and writes the output to the `configuration-steps.dsconfig` file. This provides a script that can be used to configure a newly installed server identically to the local server:

```
$ bin/config-diff --sourceLocal \
  --sourceBaseline \
  --targetLocal \
  --exclude differs-after-install \
  --outputFile configuration-steps.dsconfig
```

About Root User, Administrator, and Global Administrators

The Data Store provides three different classes of administrator accounts: root user, administrator, and global administrator. The root user is the LDAP-equivalent of a UNIX super-user account and inherits its privileges from the default root user privilege set (see *Default Root Privileges*). The root user "account" is an entry that is stored in the server's configuration under the `cn=Root DNs,cn=config` and bypasses access control evaluation. This account has full access to the entire set of data in the Directory Information Tree (DIT) as well as full access to the server configuration and its operations. One important difference between other vendors' servers and the Data Store's implementation is that the root user's rights are granted through a set of privileges. This allows the Data Store to have multiple root users on its system if desired; however, the normal practice is to set up administrator user entries. Also, by default, the Root User has no resource limits.

The administrator user can have a full set of root user privileges but often has a subset of these privileges to limit the accessible functions that can be performed. The administrators entries typically have limited access to the entire set of data in the directory information tree (DIT), which is controlled by access control instructions. These entries reside in the backend configuration (for example, `uid=admin,dc=example,dc=com`) and are replicated between servers in a replication topology. In some cases, administrator user accounts may be unavailable when the server enters lockdown mode unless the administrator is given the lock-down mode privilege.

A global administrator is primarily responsible for managing configuration server groups and can be used to log in to the Management Console. A configuration server group is an administration domain that allows you to synchronize configuration changes to one or all of the servers in the group. For example, you can set up a group when configuring a replication topology, where configuration changes to one server can be applied to all of the servers at one time. Global Administrator(s) entries are stored in the `cn=admin data` backend along with other admin backend data and are always replicated between servers in a replication topology. These users can be assigned privileges like other admin users but are typically used to manage the data under `cn=admin data` and `cn=config`.

Managing Root Users Accounts

The UnboundID Data Store provides a default root user, `cn=Directory Manager`, that is stored in the server's configuration file (for example, under `cn=Root DNs,cn=config`). The root user is the LDAP-equivalent of a UNIX super-user account and inherits its read-write privileges from the default root privilege set. Root user entries are stored in the server’s configuration and not in backend data. Root users have access to all of the data in the Data Store.

To limit full access to all of the Data Store, we recommend that you create separate administrator user accounts with limited privileges so that you can identify the administrator responsible for a particular change. Having separate user accounts for each administrator also makes it possible to enable password policy functionality (such as password expiration, password history, and requiring secure authentication) for each administrator.

Default Root Privileges

The UnboundID Data Store contains a privilege subsystem that allows for a more fine-grained control of privilege assignments. The following set of root privileges are available to each root user DN:

Table 5: Default Root Privileges

Privilege	Description
audit-data-security	Allows the associated user to execute data security auditing tasks.
backend-backup	Allows the user to perform backend backup operations.
backend-restore	Allows the user to perform backend restore operations.
bypass-acl	Allows the user to bypass access control evaluation.
config-read	Allows the user to read the server configuration.
config-write	Allows the user to update the server configuration.
disconnect-client	Allows the user to terminate arbitrary client connections.
ldif-export	Allows the user to perform LDIF export operations.
ldif-import	Allows the user to perform LDIF import operations.
lockdown-mode	Allows the user to request a server lockdown.
modify-acl	Allows the user to modify access control rules.
password-reset	Allows the user to reset user passwords but not their own. The user must also have privileges granted by access control to write the user password to the target entry.
privilege-change	Allows the user to change the set of privileges for a specific user, or to change the set of privileges automatically assigned to a root user.
server-restart	Allows the user to request a server restart.
server-shutdown	Allows the user to request a server shutdown.

Privilege	Description
soft-delete-read	Allows the user access to soft-deleted entries.
stream-values	Allows the user to perform a stream values extended operation that obtains all entry DNs and/or all values for one or more attributes for a specified portion of the DIT.
third-party-task	Allows the associated user to invoke tasks created by third-party developers.
unindexed-search	Allows the user to perform an unindexed search in the Oracle Berkeley DB Java Edition backend.
update-schema	Allows the user to update the server schema.
use-admin-session	Allows the associated user to use an administrative session to request that operations be processed using a dedicated pool of worker threads.

The Data Store provides other privileges that are not assigned to the root user DN by default but can be added using the `ldapmodify` tool (see Modifying Individual Root User Privileges) for more information.

Table 6: Other Available Privileges

Privilege	Description
bypass-read-aci	Allows the associated user to bypass access control checks performed by the server for bind, compare, and search operations. Access control evaluation may still be enforced for other types of operations.
jmx-notify	Allows the associated user to subscribe to receive JMX notifications.
jmx-read	Allows the associated user to perform JMX read operations.
jmx-write	Allows the associated user to perform JMX write operations.

To View the Default Root User Privileges Using dsconfig

The root DN accounts are the only user accounts that are stored within the Data Store's configuration under `cn=Root DNs,cn=config`. You can view the default privileges automatically granted to root users using the `dsconfig` tool.

- Use `dsconfig` to view the root DN.

```
$ bin/dsconfig get-root-dn-prop
```

To Modify the Root User Password

Root users are governed by the Root Password Policy and by default, their passwords never expire. However, in the event that you want to change a root user's password, you can use the `ldappasswordmodify` tool.

1. Open a text editor and create a text file containing the new password. In this example, name the file `rootuser.txt`.

```
$ echo password > rootuser.txt
```

2. Use `ldappasswordmodify` to change the root user’s password.

```
$ bin/ldappasswordmodify --port 1389 --bindDN "cn=Directory Manager" \
  --bindPassword secret --newPasswordFile rootuser.txt
```

3. Remove the text file.

```
$ rm rootuser.txt
```

To Create a Root User

You can create another root user by adding an entry under `cn=Root DNs,cn=config`. Whether the new root DN inherits the default set of root privileges is determined by the value of `ds-cfg-inherit-default-root-privileges`. Data under `cn=Root DNs,cn=config` is not replicated. Therefore the following steps need to be repeated on every system.

1. Open a text editor, and create a file containing the root user entry.

```
dn: cn=Data Admin,cn=Root DNs,cn=config
objectClass: top
objectClass: person
objectClass: organizationalPerson
objectClass: inetOrgPerson
objectClass: ds-cfg-root-dn-user
userPassword: password
cn: Data Admin
sn: Admin
ds-cfg-alternate-bind-dn: cn=Data Admin
givenName: Data
ds-cfg-inherit-default-root-privileges: false
ds-privilege-name: bypass-acl
ds-privilege-name: password-reset
ds-privilege-name: update-schema
ds-privilege-name: unindexed-search
ds-privilege-name: use-admin-session
ds-privilege-name: soft-delete-read
```

2. Use `ldapmodify` to add the entry.

```
$ bin/ldapmodify --port 1389 --bindDN "cn=Directory Manager" \
  --bindPassword secret --defaultAdd --filename "rootuser.ldif"
```

Modifying Individual Root User Privileges

All root users automatically inherit the default root privileges defined in the `default-root-privilege-name` configuration property. However, you can give individual root users additional privileges that are not included in the set of default root privileges. You can also remove default root privileges from individual root users.

Modifying the privileges of the root user can be accomplished by adding the `ds-privilege-name` operational attribute to the entry for the root user. Any values containing a privilege name will grant that privilege to the user in addition to the set of default root privileges. Any values containing a minus sign followed by a privilege name will remove that privilege from that root user, even if it is included in the set of default root privileges.

1. Open a text editor, and create a file containing the changes to the root user entry. The following example grants the `proxied-auth` privilege and removes the `server-shutdown` and `server-restart` privileges.

```
dn: cn=Directory Manager2,cn=Root DNs,cn=config
changetype: modify
add: ds-privilege-name
ds-privilege-name: proxied-auth
ds-privilege-name: -server-shutdown
ds-privilege-name: -server-restart
```

2. Use `ldapmodify` to apply the change.

```
$ bin/ldapmodify --port 1389 --bindDN "cn=Directory Manager" \
  --bindPassword secret --filename "modifyRootUserPrivileges.ldif"
```

Configuring Administrator Accounts

An administrator account is any account in the user backend that is assigned one or more privileges, or given access to read and write operations beyond that of a normal user entry. The privilege mechanism is the same as that used for Root DN accounts and allows individual privileges to be assigned to an administrator entry.

Typically, administrator user entries are controlled by access control evaluation to limit access to the entire set of data in the Directory Information Tree (DIT). Fine-grained read and write access can be granted using the access control definitions available via the `aci` attribute. Administrator entries reside in the backend configuration (for example, `uid=admin,dc=example,dc=com`) and are replicated between servers in a replication topology.

The following examples show how to configure administrator accounts. The first procedure shows how to set up a single, generic `uid=admin,dc=example,dc=com` account with limited privileges. Note that if you generated sample data at install, you can view an example `uid=admin` entry using `ldapsearch`. The second example shows a more realistic example, where the user is part of the Administrators group. Note that both examples are based on a simple DIT. Actual deployment cases depends on your schema.

To Set Up a Single Administrator Account

1. Create an LDIF file with an example Administrator entry.

```
dn: uid=admin,dc=example,dc=com
objectClass: person
objectClass: inetOrgPerson
objectClass: organizationalPerson
objectClass: top
givenName: Admin
uid: admin
cn: Admin User
sn: User
userPassword: password
```

2. Then add the entry using the `ldapmodify` tool.

```
$ bin/ldapmodify --defaultAdd --filename admin.ldif
```

3. Create another LDIF file to add the access control instruction (ACI) to the root suffix, or base DN to give full access to the new administrator. The ACI grants full access to all

user attributes, but not to operational attributes. If you want to grant access to operational attributes as well as user attributes, use `(targetattr = "*||+")` in the access control instruction.

```
dn: dc=example,dc=com
changetype: modify
add: aci
aci: (targetattr = "*")
  (version 3.0; acl "Grant full access for the admin user";
    allow (all) userdn="ldap:///uid=admin,dc=example,dc=com";)
```

4. Then add the entry using the `ldapmodify` tool.

```
$ bin/ldapmodify --filename admin.ldif
```

5. Verify the additions using `ldapsearch`. The first command searches for the entry that contains `uid=Admin` and returns it if the search is successful. The second command searches for the base DN and returns only those operational attributes, including access control instructions, associated with the entry.

```
$ bin/ldapsearch --baseDN dc=example,dc=com "(uid=admin)"

$ bin/ldapsearch --baseDN dc=example,dc=com --searchScope base "(objectclass=*)" "+"
```

6. Add specific privileges to the Admin account. In this example, add the `password-reset` privilege to the admin account from the command line. After typing the privileges, press **CTRL-D** to process the modify operation.

```
$ bin/ldapmodify
dn: uid=admin,dc=example,dc=com
changetype: modify
add: ds-privilege-name
ds-privilege-name: password-reset
```

```
Processing MODIFY request for uid=admin,dc=example,dc=com
MODIFY operation successful for DN uid=admin,dc=example,dc=com
```

7. Assign a password policy for the Admin account. For example, create an "Admin Password Policy", then add the password policy to the account.

```
$ bin/dsconfig create-password-policy \
  --policy-name "Admin Password Policy" \
  --set "description:Password policy for administrators" \
  --set password-attribute:userpassword \
  --set "default-password-storage-scheme:Salted SHA-1" \
  --set password-change-requires-current-password:true \
  --set force-change-on-reset:true \
  --set "max-password-age:25w 5d" \
  --set grace-login-count:3
  --no-prompt
```

8. Apply the password policy to the account. In this example, the password policy is being added from the command line. The following `ldapmodify` command should be executed with a bind DN that has sufficient rights, such as a Root DN.

```
$ bin/ldapmodify
dn: uid=admin,dc=example,dc=com
changetype: modify
add: ds-pwp-password-policy-dn
ds-pwp-password-policy-dn: cn=Admin Password Policy,cn=Password Policies,cn=config
```

To Set Up an Administrator Group

The following example shows how to set up a group of administrators that have access rights to the whole Data Store. The example uses a static group using the `GroupOfUniqueNames` object class.

1. Create an LDIF file with an example Administrator group, and save it as `admin-group.ldif`.

```
dn: ou=Groups,dc=example,dc=com
objectClass: organizationalunit
objectClass: top
ou: Groups

dn: cn=Dir Admins,ou=Groups,dc=example,dc=com
objectClass: groupofuniquenames
objectClass: top
uniqueMember: uid=user.0, ou=People, dc=example,dc=com
uniqueMember: uid=user.1, ou=People, dc=example,dc=com
cn: Dir Admins
ou: Groups
```

2. Then, add the entries using the `ldapmodify` tool.

```
$ bin/ldapmodify --defaultAdd --filename admin-group.ldif
```

3. Create another LDIF file to add the access control instruction (ACI) to the root suffix, or base DN to provide full access to the Data Store to the new administrator. Save the file as `admin-aci.ldif`.

```
dn: dc=example,dc=com
changetype: modify
add: aci
aci: (target="ldap:///dc=example,dc=com")
  (targetattr != "aci")
  (version 3.0; acl "allow all Admin group";
    allow(all) groupdn = "ldap:///cn=Dir Admins,ou=Groups,dc=example,dc=com";)
```

4. Then, add the ACI using the `ldapmodify` tool:

```
$ bin/ldapmodify --filename admin-aci.ldif
```

5. Verify the additions using `ldapsearch`. The first command searches for the entry that contains `cn=Dir Admins` and returns it if the search is successful. The second command searches for the base DN and returns only those operational attributes, including access control instructions, associated with the entry.

```
$ bin/ldapsearch --baseDN dc=example,dc=com "(cn=Dir Admins)"

$ bin/ldapsearch --baseDN dc=example,dc=com --searchScope base \
  "(objectclass=*)" "+"
```

6. Add specific privileges to each Admin account using an LDIF file, saved as `admin-priv.ldif`. In this example, add the `password-reset` privilege to the `user.0` admin account from the command line. Add the privilege using the `ldapmodify` tool. Repeat the process for the other administrators configured in the Admin group.

```
dn: uid=user.0,ou=People,dc=example,dc=com
changetype: modify
add: ds-privilege-name
```

```
ds-privilege-name: password-reset

$ bin/ldapmodify --filename admin-priv.ldif
```

```
Processing MODIFY request for uid=user.0,dc=example,dc=com
MODIFY operation successful for DN uid=user.0,dc=example,dc=com
```

7. Assign a password policy for the Admin account using an LDIF file, saved as `admin-pwd-policy.ldif`. For example, create an "Admin Password Policy", then add the password policy to the account. Apply the password policy to the account using the `ldapmodify` tool.

```
dn: uid=user.0,dc=example,dc=com
changetype: modify
add: ds-pwp-password-policy-dn
ds-pwp-password-policy-dn: cn=Admin Password Policy,cn=Password Policies,cn=config

$ bin/ldapmodify --filename admin-pwd-policy.ldif
```

Configuring a Global Administrator

A global administrator is responsible for managing configuration server groups or can be used to log in to the Management Console. A configuration server group is an administration domain that allows you to synchronize configuration changes to one or all of the servers in the group. For example, you can set up a group when configuring a replication topology, where configuration changes to one server can be applied to all of the servers at a time.

Global Administrator(s) are stored in the `cn=admin` data backend. These entries along with other admin backend data are always replicated between servers in a replication topology. Global Administrators can be assigned privileges like other admin users but are typically used to manage the data under `cn=admin` data and `cn=config`. You can create new global administrators and remove existing global administrators using the `dsframework` tool. The global administrator entries are located in the `cn=Administrators,cn=admin` data branch. Once you have set up a global admin, you can use it to log on to the Management Console. For example, the Management Console accepts the root user DN (for example, cn=Directory Manager), the global admin ID (for example, admin2), or the full global admin DN (for example, `cn=admin2,cn=Administrators,cn=Admin Data`).

By default, the `dsframework` tool connects to any registered server interface when querying for configuration and status-related information. To connect over SSL or StartTLS, the `dsframework set-server-properties` command can be used to set the `preferredSecurity` property (possible values: `none`, `ssl`, or `starttls`). This feature allows the administrator to have control over which security protocol that the tool should use for such queries. To view the server properties, use the `dsframework list-server-properties` command.

To Create a Global Administrator

1. Use `dsframework` to create a new global administrator.

```
$ bin/dsframework create-admin-user \
  --userID admin2 --set password:secret
```

2. To verify the creation of the new administrator, use the `list-admin-users` subcommand with `dsframework`.

```
$ bin/dsframework list-admin-users
id: admin2
id: admin
```

To Remove a Global Administrator

1. Use `dsframework` to delete an existing global administrator.

```
$ bin/dsframework delete-admin-user --userID admin2
```

2. To verify the deletion of the global administrator, use the `list-admin-users` option with `dsframework`.

```
$ bin/dsframework list-admin-users
id: admin
```

Configuring Server Groups

The UnboundID Data Store provides a mechanism for setting up administrative domains that synchronize configuration changes among servers in a server group. After you have set up a server group, you can make an update on one server using `dsconfig`, then you can apply the change to the other servers in the group using the `--applyChangeTo server-group` option of the `dsconfig` non-interactive command. If you want to apply the change to one server in the group, use the `--applyChangeTo single-server` option. When using `dsconfig` in interactive command-line mode, you will be asked if you want to apply the change to a single server or to all servers in the server group.

About the Server Group Example

You can create an administrative server group using the `dsframework` tool. The general process is to create a group, register each server, add each server to the group, and then set a global configuration property to use the server group. If you are configuring a replication topology, then you must configure the replicas to be in a server group as outlined in Replication Configuration.

The following example procedure adds three Data Store instances into the server group labelled "group-one". The commands are run on server1.example.com.

Server	Host Name	LDAP Port
instance 1	server1.example.com	1389
instance 2	server2.example.com	2389
instance 3	server3.example.com	3389

To Create a Server Group

1. Create a group called "group-one" using `dsframework`.

```
$ bin/dsframework create-group --groupName group-one \
  --description "Server Group One"
```

2. Register each data store that you want to add to the server group. If you have set up replication between a set of servers, these server entries will have already been created by the `dsreplication enable` command.

```
$ bin/dsframework register-server \
  --serverID server1.example.com:1389 \
  --set hostname:server1.example.com \
  --set ldapport:1389 --set ldapEnabled:true

$ bin/dsframework register-server \
  --serverID server2.example.com:2389 \
  --set hostname:server2.example.com \
  --set ldapport:2389 --set ldapEnabled:true

$ bin/dsframework register-server \
  --serverID server3.example.com:3389 \
  --set hostname:server3.example.com \
  --set ldapport:3389 --set ldapEnabled:true
```

3. Add each data store to the group.

```
$ bin/dsframework add-to-group \
  --groupName group-one \
  --memberName server1.example.com:1389

$ bin/dsframework add-to-group \
  --groupName group-one \
  --memberName server2.example.com:2389

$ bin/dsframework add-to-group \
  --groupName group-one \
  --memberName server3.example.com:3389
```

4. Set a global configuration property using the `dsconfig` tool.

```
$ bin/dsconfig set-global-configuration-prop \
  --set configuration-server-group:group-one
```

5. Test the server group. In this example, enable the log publisher for each data store in the group, server-group, by using the `--applyChangeTo server-group` option.

```
$ bin/dsconfig set-log-publisher-prop \
  --publisher-name "File-Based Audit Logger" \
  --set enabled:true \
  --applyChangeTo server-group
```

6. View the property on the first data store instance.

```
$ bin/dsconfig get-log-publisher-prop \
  --publisher-name "File-Based Audit Logger" \
  --property enabled
```

```
Property : Value(s)
---------:---------
enabled : true
```

7. Repeat the step 6 on the second and third data store instance.

8. Test the server group by disabling the log publisher on the first data store instance by using the `--applyChangeTo single-server`.

```
$ bin/dsconfig set-log-publisher-prop \
  --publisher-name "File-Based Audit Logger" \
  --set enabled:disabled \
  --applyChangeTo single-server
```

9. View the property on the first data store instance. The first data store instance should be disabled.

```
$ bin/dsconfig get-log-publisher-prop \
  --publisher-name "File-Based Audit Logger" \
  --property enabled
```

```
Property : Value(s)
---------:---------
enabled : false
```

10. View the property on the second data store instance. Repeat this step on the third data store instance to verify that the property is still enabled on that server.

```
$ bin/dsconfig get-log-publisher-prop \
  --publisher-name "File-Based Audit Logger" \
  --property enabled
```

```
Property : Value(s)
---------:---------
enabled : true
```

Configuring Client Connection Policies

Client connection policies help distinguish what portions of the DIT the client can access. They also enforce restrictions on what clients can do in the server. A client connection policy specifies criteria for membership based on information about the client connection, including client address, protocol, communication security, and authentication state and identity. The client connection policy, however, does not control membership based on the type of request being made.

Every client connection is associated with exactly one client connection policy at any given time, which is assigned to the client when the connection is established. The choice of which client connection policy to use will be reevaluated when the client attempts a bind to change its authentication state or uses the StartTLS extended operation to convert an insecure connection to a secure one. Any changes you make to the client connection policy do not apply to existing connections. The changes only apply to new connections.

Client connections are always unauthenticated when they are first established. If you plan to configure a policy based on authentication, you must define at least one client connection policy with criteria that match unauthenticated connections.

Once a client has been assigned to a policy, you can determine what operations they can perform. For example, your policy might allow only SASL bind operations. Client connection policies are also associated with one or more subtree views, which determine the portions of the

DIT a particular client can access. For example, you might configure a policy that prevents users connecting over the extranet from accessing configuration information. The client connection policy is evaluated in addition to access control, so even a root user connecting over the extranet would not have access to the configuration information.

Understanding the Client Connection Policy

Client connection policies are based on two things:

- **Connection criteria**. The connection criteria are used in many areas within the server. They are used by the client connection policies, but they can also be used in other instances when the server needs to perform matching based on connection-level properties, such as filtered logging. A single connection can match multiple connection criteria definitions.
- **Evaluation order index**. If multiple client connection policies are defined in the server, then each of them must have a unique value for the **evaluation-order-index** property. The client connection policies are evaluated in order of ascending evaluation order index. If a client connection does not match the criteria for any defined client connection policy, then that connection will be terminated.

If the connection policy matches a connection, then the connection is assigned to that policy and no further evaluation occurs. If, after evaluating all of the defined client connection policies, no match is found, the connection is terminated.

When a Client Connection Policy is Assigned

A client connection policy can be associated with a client connection at the following times:

- When the connection is initially established. This association occurs exactly once for each client connection.
- After completing processing for a StartTLS operation. This association occurs at most once for a client connection, because StartTLS cannot be used more than once on a particular connection. You also may not stop using StartTLS while keeping the connection active.
- After completing processing for a bind operation. This association occurs zero or more times for a client connection, because the bind request can be processed many times on a given connection.

StartTLS and bind requests will be subject to whatever constraints are defined for the client connection policy that is associated with the client connection at the time that the request is received. Once they have completed, then subsequent operations will be subject to the constraints of the new client connection policy assigned to that client connection. This policy may or may not be the same client connection policy that was associated with the connection before the operation was processed. That is, any policy changes do not apply to existing connections and will be applicable when the client reconnects.

All other types of operations will be subject to whatever constraints are defined for the client connection policy used by the client connection at the time that the request is received. The client connection policy assigned to a connection never changes as a result of processing any operation other than a bind or StartTLS. So, the server will not re-evaluate the client connection policy for the connection in the course of processing an operation. For example, the client connection policy will never be re-evaluated for a search operation.

Restricting the Type of Search Filter Used by Clients

You can restrict the types of search filters that a given client may be allowed to use to prevent the use of potentially expensive filters, like range or substring searches. You can use the `allowed-filter-type` property to provide a list of filter types that may be included in the search requests from clients associated with the client connection policy. This setting will only be used if search is included in the set of allowed operation types. This restriction will only be applied to searches with a scope other than `baseObject`, such as searches with a scope of `singleLevel`, `wholeSubtree`, or `subordinateSubtree`.

The `minimum-substring-length` property can be used to specify the minimum number of non-wildcard characters in a substring filter. Any attempt to use a substring search with an element containing fewer than this number of bytes will be rejected. For example, the server can be configured to reject filters like `"(cn=a*)"` and `"(cn=ab*)"`, but to allow `"(cn=abcde*)"`. This property setting will only be used if search is included in the set of allowed operation types and at least one of `sub-initial`, `sub-any`, or `sub-final` is included in the set of allowed filter types.

There are two primary benefits to enforcing a minimum substring length:

- Allowing very short substrings can require the server to perform more expensive processing. The search requires a lot more server effort to assemble a candidate entry list for short substrings because the server has to examine a lot more index keys.
- Allowing very short substrings makes it easier for a client to put together a series of requests to retrieve all the data from the server (a process known as "trawling"). If a malicious user wants to obtain all the data from the server, then it is easier to issue 26 requests like `"(cn=a*)"`, `"(cn=b*)"`, `"(cn=c*)"`, ..., `"(cn=z*)"` than if the user is required to do something like `"(cn=aaaaa*)"`, `"(cn=aaaab*)"`, `"(cn=aaaac*)"`, ..., `"(cn=zzzzz*)"`.

Setting Resource Limits

Your client connection policy can specify resource limits, helping to ensure that no single client monopolizes server resources. You can limit the total number of connections to a server from a particular client or from clients that match specified criteria. You can also limit the duration of the connection.

A client connection policy may only be used to enforce additional restrictions on a client connection. You can never use it to grant a client capabilities that it would not otherwise have.

Any change to any of these new configuration properties will only impact client connections that are assigned to the client connection policy after the change is made. Any connection associated with the client connection policy before the configuration change was made will continue to be subject to the configuration that was in place at the time it was associated with that policy.

Table 7: Resource Limiting Properties

Property	Description
maximum-concurrent-connections	Specifies the maximum number of client connections that can be associated with that client connection policy at any given time. The default value of zero indicates that no limit will be enforced. If the server already has the maximum number of connections associated with a client connection policy, then any attempt to associate another connection with that policy (e.g., newly-established connections or an existing connection that has done something to change its client connection policy, such as perform a bind or StartTLS operation) will cause that connection to be terminated.
terminate-connection	Specifies that any client connection for which the client connection policy is selected (whether it is a new connection or an existing connection that is assigned to the client connection policy after performing a bind or StartTLS operation) will be immediately terminated. This property can be used to define criteria for connections that you do not want to be allowed to communicate with the Data Store.
maximum-connection-duration	Specifies the maximum length of time that a connection associated with the client connection policy can remain established to the Data Store, regardless of the amount of activity on that connection. A value of "0 seconds" (default) indicates that no limit will be enforced. If a connection associated with the client connection policy has been established for longer than this time, then it will be terminated.
maximum-idle-connection-duration	Specifies the maximum length of time that a connection associated with the client connection policy can remain established with the Data Store without any requests in progress. A value of "0 seconds" (default) indicates that no additional limit will be enforced on top of whatever idle time limit might already be in effect for an associated connection. If a nonzero value is provided, then the effective idle time limit for any client connection will be the smaller of the `maximum-idle-connection-duration` from the client connection policy and the idle time limit that would otherwise be in effect for that client. This property can be used to apply a further restriction on top of any value that may be enforced by the `idle-time-limit` global configuration property (which defines a default idle time limit for client connections) or the `ds-rlim-idle-time-limit` operational attribute (which may be included in a user entry to override the default idle time limit for that user).
maximum-operation-count-per-connection	Specifies the maximum number of operations that a client associated with the client connection policy will be allowed to request. A value of zero (default) indicates that no limit will be enforced. If a client attempts to request more than this number of operations on the same connection, then that connection will be terminated.
maximum-concurrent-operations-per-connection	Specifies the maximum number of operations that may be active at any time from the same client. This limit is only applicable to clients that use asynchronous operations with multiple outstanding requests at any given time. A value of zero (default) indicates that no limit will be enforced. If a client already has the maximum number of outstanding requests in progress and issues a new request, then that request will be delayed and/or

Property	**Description**
	rejected based on the value of the `maximum-concurrent-operation-wait-time-before-rejecting` property.
maximum-concurrent-operation-wait-time-before-rejecting	Specifies the maximum length of time that a client connection should allow an outstanding operation to complete if the maximum number of concurrent operations for a connection are already in progress when a new request is received on that connection. A value of “0 seconds” (default) indicates that any new requests received while the maximum number of outstanding requests are already in progress for that connection will be immediately rejected. If an outstanding operation completes before this time expires, then the server may be allowed to process that operation. If the time expires, the new request will be rejected.
allowed-request-control	Specifies the OIDs of the request controls that clients associated with the client connection policy will be allowed to use. If any allowed-request-control OIDs are specified, then any request which includes a control not in that set will be rejected. If no `allowed-request-control` values are specified (default), then any control whose OID is not included in the set of denied-request-control values will be allowed.
denied-request-control	Specifies the OIDs of the request controls that clients associated with the client connection policy will not be allowed to use. If there are any `denied-request-control` values, then any request containing a control whose OID is included in that set will be rejected. If there are no `denied-request-control` values (default), then any request control will be allowed if the `allowed-request-control` property is also empty, or only those controls whose OIDs are included in the set of `allowed-request-control` values will be allowed if at least one `allowed-request-control` value is provided.
allowed-filter-type	Specifies the types of components which may be used in filters included in search operations with a non-base scope that are requested by clients associated with the client connection policy. Any non-base scoped search request whose filter contains a component not included in this set will be rejected. The set of possible filter types include: ➢ and ➢ or ➢ not ➢ equality ➢ sub-initial ➢ sub-any ➢ sub-final ➢ greater-or-equal ➢ less-or-equal ➢ approximate-match ➢ extensible-match By default, all filter types will be allowed. Also note that no restriction will be placed on the types of filters which may be used in searches with a base scope.
allow-unindexed-searches	Specifies whether clients associated with the client connection policy will be allowed to request searches which cannot be efficiently processed using the

Property	Description
	configured set of indexes. Note that clients will still be required to have the `unindexed-search` privilege, so this option will not grant the ability to perform unindexed searches to clients that would not have otherwise had that ability, but it may be used to prevent clients associated with the client connection policy from requesting unindexed searches when they might have otherwise been allowed to do so. By default, this has a value of "true", indicating that any client associated with the client connection policy that has the `unindexed-search` privilege will be allowed to request unindexed searches.
minimum-substring-length	Specifies the minimum number of bytes, which may be present in any sub-Initial, subAny, or subFinal element of a substring search filter component in a search with a non-baseObject scope. A value of one (which is the default) indicates that no limit will be enforced. This property may be used to prevent clients from issuing overly-vague substring searches that may require the Installing the Data Store to examine too many entries over the course of processing the request.
maximum-search-size-limit	Specifies the maximum number of entries that may be returned from any single search operation requested by a client associated with this client connection policy. Note that this property only specifies a maximum limit and will never increase any limit that may already be in effect for the client via the `size-limit` global configuration property or the `ds-rlim-size-limit` operational attribute. A value of zero (default) indicates that no additional limit will be enforced on top of whatever size limit might already be in effect for an associated connection. If a nonzero value is provided, then the effective maximum size limit for any search operation requested by the client will be the smaller of the size limit from that search request, the `maximum-search-size-limit` from the client connection policy, and the size limit that would otherwise be in effect for that client.

Defining the Operation Rate

You can configure the maximum operation rate for individual client connections as well as collectively for all connections associated with a client connection policy. If the operation rate limit is exceeded, the Data Store may either reject the operation or terminate the connection. You can define multiple rate limit values, making it possible to fine tune limits for both a long term average operation rate and short term operation bursts. For example, you can define a limit of one thousand operations per second and one million operations per day, which works out to an average of less than twelve operations per second, but with bursts of up to one thousand operations per second.

Rate limit strings should be specified as a maximum count followed by a slash and a duration. The count portion must contain an integer, and may be followed by a multiplier of k (to indicate that the integer should be interpreted as thousands), m (to indicate that the integer should be interpreted as millions), or g (to indicate that the integer should be interpreted as billions). The duration portion must contain a time unit of milliseconds (ms), seconds (s), minutes (m), hours (h), days (d), or weeks (w), and may be preceded by an integer to specify a quantity for that unit.

For example, the following are valid rate limit strings:

- 1/s (no more than one operation over a one-second interval)
- 10K/5h (no more than ten thousand operations over a five-hour interval)
- 5m/2d (no more than five million operations over a two-day interval)

You can provide time units in many different formats. For example, a unit of seconds can be signified using s, sec, sect, second, and seconds.

Client Connection Policy Deployment Example

In this example scenario, we assume the following:

- Two external LDAP clients are allowed to bind to the Data Store.
- Client 1 should be allowed to open only 1 connection to the server.
- Client 2 should be allowed to open up to 5 connections to the server.

Defining the Connection Policies

We need to set a per-client connection policy limit on the number of connections that may be associated with a particular client connection policy. We have to define at least two client connection policies, one for each of the two clients. Each policy must have different connection criteria for selecting the policy with which a given client connection should be associated.

Because the criteria is based on authentication, we must create a third client connection policy that applies to unauthenticated clients, because client connections are always unauthenticated as soon as they are established and before they have sent a bind request. Plus, clients are not required to send a bind request as their first operation.

Therefore, we define the following three client connection policies:

- **Client 1 Connection Policy**, which only allows client 1, with an evaluation order index of 1.
- **Client 2 Connection Policy**, which only allows client 2, with an evaluation order index of 2.
- **Unauthenticated Connection Policy**, which allows unauthenticated clients, with an evaluation order index of 3.

We define simple connection criteria for the Client 1 Connection Policy and the Client 2 Connection Policy with the following properties:

- The `user-auth-type` must not include none, so that it will only apply to authenticated client connections.
- The `included-user-base-dn` should match the bind DN for the target user. This DN may be full DN for the target user, or it may be the base DN for a branch that contains a number of users that you want treated in the same way.

To create more generic criteria that match more than one user, you could list the DNs of each of the users explicitly in the `included-user-base-dn` property. If there is a group that contains all of the pertinent users, then you could instead use the `[all|any|not-all|not-any]-included-user-group-dn` property to apply to all members of that group. If the entries for all of the users match a particular filter, then you could use the `[all|any|not-all|not-any]-included-user-filter` property to match them.

How the Policy is Evaluated

Whenever a connection is established, the server associates the connection with exactly one client connection policy. The server does this by iterating over all of the defined client connection policies in ascending order of the evaluation order index. Policies with a lower evaluation order index value will be examined before those with a higher evaluation order index value. The first policy that the server finds whose criteria match the client connection will be associated with that connection. If no client connection policy is found with criteria matching the connection, then the connection will be terminated.

So, in our example, when a new connection is established, the server first checks the connection criteria associated with the Client 1 Connection Policy because it has the lowest evaluation order index value. If it finds that the criteria do not match the new connection, the server then checks the connection criteria associated with the Client 2 Connection Policy because it has the second lowest evaluation order index. If these criteria do not match, the server finally checks the connection criteria associated with the Unauthenticated Connection Policy, because it has the third lowest evaluation order index. It finds a match, so the client connection is associated with the Unauthenticated Connection Policy.

After the client performs a bind operation to authenticate to the server, then the client connection policies will be re-evaluated. If client 2 performs the bind, then the Client 1 Connection Policy will not match but the Client 2 Connection Policy will, so the connection will be re-associated with that client connection policy. Whenever a connection is associated with a client connection policy, the server will check to see if the maximum number of client connections have already been associated with that policy. If so, then the newly-associated connection will be terminated.

For example, Client 1 opens a new connection. Because it is a new connection not yet associated with connection criteria, it is assigned to the Unauthenticated Connection Policy. Client 1 then sends a bind request. The determination of whether the bind operation is allowed is made based on the constraints defined in the Unauthenticated Connection Policy, because it is the client connection policy already assigned to the client connection. Once the bind has completed, then the server will reevaluate the client connection policy against the connection criteria associated with Client 1 Connection Policy, because it has the lowest evaluation order index. The associated connection criteria match, so processing stops and the client connection is assigned to the Client 1 Connection Policy.

Next, Client 2 opens a new connection. Because it is a new connection not yet associated with connection criteria, it is assigned to the Unauthenticated Connection Policy. When Client 2 sends a bind request, the operation is allowed based on the constraints defined in the Unauthenticated Connection Policy. Once the bind is complete, the client connection is evaluated against the connection criteria associated with Client 1 Connection Policy, because it has the lowest evaluation order index. The associated connection criteria do not match, so the client 2 connection is evaluated against the connection criteria associated with Client 2 Connection Policy, because it has the next lowest evaluation order index. The associated connection criteria match, so processing stops and the client connection is assigned to Client 2 Connection Policy.

Client 1 sends a search request. The Client 1 Connection Policy is used to determine whether the search operation should be allowed, because this is the client connection policy assigned to the client connection for client 1. The connection is not reevaluated, before or after processing the search operation.

To Configure a Client Connection Policy Using the Console

1. Open the Management Console. Provide a username and password, and then click **Login**.
2. In the **Core Server** section, click **Client Connection Policies**. If you do not see **Client Connection Policies** on the menu, change the Object Types filter to **Standard**.
3. Click **Add New** to add a new policy.
4. Enter a Policy ID. If you want to base your new client connection policy on an existing policy, select it from the **Template** menu.
5. Configure the properties of the client connection policy. To enable the policy, select **Enabled**.
6. Enter the order in which you want the new policy to be evaluated in the **Evaluation Order Index** box, and then click **Continue**. A policy with a lower index is evaluated before a policy with a higher index. The Data Store uses the first evaluated policy that applies to a client connection.
7. Select the connection criteria that match the client connection for this policy. Click **View and edit** to change the criteria. Click **Select New** to add new criteria. Select the operations allowed for clients that are members of this connection group. Use the **Add and Remove** buttons to make operations available to clients. Specify the extended operations that clients are allowed and denied to use.
8. Enter the type of authorization allowed and the SASL mechanisms that are allowed and denied in response to client requests.
9. Check the **Include Backend Subtree Views** check box if you want to automatically include the subtree views of backends configured in the Data Store. You can also choose to include and exclude specific base DNs using the appropriate fields.
10. Once you have finished configuring the properties of your client connection policy, click **Confirm then Save** to review the `dsconfig` command equivalent and save your changes. Click **Save Now** to save your changes without first reviewing the `dsconfig` output.

To Configure a Client Connection Policy Using dsconfig

You can configure a client connection policy using the `dsconfig` tool in interactive mode from the command line. You can access the **Client Connection Policy** menu on the **Standard objects** menu.

1. Use the `dsconfig` tool to create and configure a client connection policy. Specify the host name, connection method, port number, and bind DN as described in previous procedures.

2. On the **Data Store configuration console** main menu, change to the **Standard objects** menu by entering `o` and then entering the number for the Standard menu.

3. On the **Data Store configuration console** main menu, enter the number associated with **Client Connection Policy**.

4. On the **Client Connection Policy management** menu, type the number corresponding to **Create a new connection policy**.

5. Enter `n` to create a new client connection policy from scratch.

6. Next, enter a name for the new client connection policy.

7. On the **Enabled Property** menu, select true to enable the connection policy.

8. On the **Evaluation-Order Property** menu, type a value between 0 and 2147483647 to set the evaluation order for the policy. A client connection policy with a lower evaluation-order will be evaluated before one with a higher number. For this example, type `9999`.

9. On the **Client Connection Policy** menu, review the configuration. If you want to make any further modifications, enter the number corresponding to the property. Enter `f` to finish the creation of the client connection policy.

   Any changes that you make to the client connection policy do not apply to existing connections. They will only apply to new connections.

Restricting Server Access Based on Client IP Address

Another common use case is to limit client access to the Data Store. Two methods are available:

- **Connection Handlers**. You can limit the IP addresses using the LDAP or LDAPS connection handlers. The connection handlers provide an `allowed-client` property and a `denied-client` property. The `allowed-client` property specifies the set of allowable address masks that can establish connections to the handler. The `denied-client` property specifies the set of address masks that are not allowed to establish connections to the handler.

- **Client Connection Policies**. You can take a more fine-grained approach by restricting access by configuring a new Client Connection Policy, then create a new connection criteria and associate it with the connection policy. Connection criteria define sets of criteria for grouping and describing client connections based on a number of properties, including the protocol, client address, connection security, and authentication state for the connection. Each client connection policy may be associated with zero or more Connection Criteria, and server components may use Connection Criteria to indicate which connections should be processed and what kind of processing should be performed (e.g., to select connections and/or operations for filtered logging, or to classify connections for network groups).

To Restrict Server Access Using the Connection Handlers

- Use `dsconfig` to set the `allowed-client` property for the LDAP connection handler. You should specify the address mask for the range of allowable IP addresses that can establish connections to the Data Store. You should also specify the loopback address, 127.0.0.1, so that you will still be able to configure the server using the `dsconfig` tool on the local host.

```
$ bin/dsconfig set-connection-handler-prop \
  --handler-name "LDAP Connection Handler" \
  --set "allowed-client:10.6.1.*" \
  --set allowed-client:127.0.0.1
```

To Restrict Server Access Using Client Connection Policies

1. Create a simple connection criteria. The following example uses the `dsconfig` tool in non-interactive mode. It allows only the Data Store's IP address and loopback to have access.

   ```
   $ bin/dsconfig set-connection-criteria-prop \
     --criteria-name allowed-ip-addrs \
     --add included-client-address:10.6.1.80 \
     --add included-client-address:127.0.0.1
   ```

2. Assign the criteria to the client connection policy. After you have run the following command, access is denied to remote IP addresses. The Data Store does not require a restart.

   ```
   $ bin/dsconfig set-client-connection-policy-prop \
     --policy-name new-policy \
     --set connection-criteria:allowed-ip-addrs
   ```

3. Add a remote IP range to the criteria. For this example, add 10.6.1.*. Access from any remote servers is allowed. The Data Store does not require a restart.

   ```
   $ bin/dsconfig set-connection-criteria-prop \
     --criteria-name allowed-ip-addrs \
     --add "included-client-address:10.6.1.*"
   ```

4. To restore default behavior, you can remove the criteria from the connection policy. The Data Store does not require a restart. Remember to include the LDAP or LDAPS connection parameters (e.g., hostname, port, bindDN, bindPassword) with the `dsconfig` command.

   ```
   $ bin/dsconfig set-client-connection-policy-prop \
     --policy-name new-policy --remove connection-criteria:allowed-ip-addrs
   ```

To Automatically Authenticate Clients that Have a Secure Communication Channel

The Data Store provides an option to automatically authenticate clients that have a secure communication channel (either SSL or StartTLS) and presented their own certificate. This option is disabled by default, but when enabled, the net effect will be as if the client issued a SASL EXTERNAL bind request on that connection.

This option will be ignored if the client connection is already authenticated (e.g., because it is using StartTLS but the client had already performed a bind before the StartTLS request). If the bind attempt fails, then the connection will remain unauthenticated but usable. If the client subsequently sends a bind request on the connection, then it will be processed as normal and any automatic authentication will be destroyed.

- Run the following `dsconfig` command.

  ```
  $ bin/dsconfig set-connection-handler-prop \
    --handler-name "LDAPS Connection Handler" \
    --set "auto-authenticate-using-client-certificate:true"
  ```

Securing the Server with Lockdown Mode

The Data Store provides tools to enter and leave lockdown mode if the server requires a security lockdown. In lockdown mode, only users with the `lockdown-mode` privilege can perform operations, while those without the privilege are rejected. Root users have this privilege by default; other administrators can be given this privilege.

The Data Store can be manually placed into lockdown mode to perform some administrative operation while ensuring that other client requests are not allowed to access any data in the server. In addition, some configuration problems (particularly problems that could lead to inadvertent exposure of sensitive information, like an access control rule that cannot be properly parsed) cause the server to place itself in lockdown mode, so that an administrator can manually correct the problem. Lockdown mode does not persist across restarts. The data store can be taken out of lockdown mode by using either the `leave-lockdown-mode` tool or by restarting the server. If administrators want to start a server in lockdown mode, they can use the `start-ds --lockdownMode` option.

Any client request to the Data Store in lockdown mode receives an "Unavailable" response.

To Manually Enter Lockdown Mode

- Use `enter-lockdown-mode` to begin a lockdown mode.

```
$ bin/enter-lockdown-mode
```

To Leave Lockdown Mode

- Use `leave-lockdown-mode` to end lockdown mode.

```
$ bin/leave-lockdown-mode
```

To Start a Server in Lockdown Mode

- Use the `--lockdownMode` option with the `start-ds` tool to start a server in lockdown mode.

```
$ bin/start-ds --lockdownMode
```

Configuring Maximum Shutdown Time

During shutdown, some database checkpointing and cleaning threads may remain active even after the default time period on systems with very large or very busy database backends. If checkpointing or cleaning is aborted prematurely, it could possible lead to significantly longer startup times for the Data Store. The Data Store provides an option for administrators to set the maximum time a shutdown process should take. When a shutdown process is initiated, the server begins stopping all of its internal components and waits up to 5 minutes for all threads to complete before exiting.

Administrators can use the `dsconfig` tool to increase the maximum shutdown time to allow database operations to complete.

To Configure the Maximum Shutdown Time

- Use the `dsconfig` tool to increase the maximum shutdown time for your system. The following command increases the maximum shutdown time from 5 minutes to 6 minutes. The command allows time values of w (weeks), d (days), h (hours), m (minutes), s (seconds), ms (milliseconds).

  ```
  $ bin/dsconfig set-global-configuration-prop --set "maximum-shutdown-time:6 m"
  ```

  Remember to include the LDAP or LDAPS connection parameters (e.g., host name, port, bindDN and bindDN password) with the `dsconfig` command.

  The `maximum-shutdown-time` property can also be changed using the `dsconfig` tool in interactive mode. From the main menu, select **Global Configuration**, and then select the option to display advanced properties.

Working with Referrals

A referral is a redirection mechanism that tells client applications that a requested entry or set of entries is not present on the Data Store but can be accessed on another server. Referrals can be used when entries are located on another server. The Data Store implements two types of referrals depending on the requirement.

- **Referral on Update Plug-in**. The Data Store provides a Referral on Update Plug-in to create any referrals for update requests (add, delete, modify, or modDN operations) on read-only servers. For example, given two replicated data store where one server is a master (read-write) and the other, a read-only server, you can configure a referral for any client update requests on the second data store to point to the master server. If a client application sends an add request, for example, on the second data store, the data store responds with a referral that indicates any updates should be made on the master server. All read requests on the read-only server will be processed as normal.
- **Smart Referrals**. The Data Store supports smart referrals that map an entry or a specific branch of a DIT to an LDAP URL. Any client requests (reads or writes) targeting at or below the branch of the DIT will send a referral to the server designated in the LDAP URL.

Specifying LDAP URLs

Referrals use LDAP URLs to redirect a client application’s request to another server. LDAP URLs have a specific format, described in RFC 4516 and require that all special characters be properly escaped and any spaces indicated as "%20". LDAP URLs have the following syntax:

```
ldap[s]://hostname:port/base-dn?attributes?scope?filter
```

where

- *ldap[s]* indicates the type of LDAP connection to the Data Store. If the Data Store connects over a standard, non-encrypted connection, then ldap is used; if it connects over SSL, then ldaps is used. Note that any search request initiated by means of an LDAP URL is anonymous by default, unless an LDAP client provides authentication.
- *hostname* specifies the host name or IP address of the Data Store.
- *port* specifies the port number of the Data Store. If no port number is provided, the default LDAP port (389) or LDAPS port (636) is used.
- *base-dn* specifies the distinguished name (DN) of an entry in the DIT. The Data Store uses the base DN as the starting point entry for its searches. If no base DN is provided, the search begins at the root of the DIT.
- *attributes* specifies those attributes for which the Data Store should search and return. You can indicate more than one attribute by providing a comma-separated list of attributes. If no attributes are provided, the search returns all attributes.
- *scope* specifies the scope of the search, which could be one of the following: `base` (only search the specified base DN entry), `one` (only search one level below the specified base DN), `sub` (search the base entry and all entries below the specified base DN). If no scope is provided, the server performs a base search.
- *filter* specifies the search filter to apply to entries within the scope of the search. If no filter is provided, the server uses `+`.

Creating Referrals

You can create a smart referral by adding an entry with the referral and `extensibleObject` object classes or adding the object classes to a specific entry. The referral object class designates the entry as a referral object. The `extensibleObject` object class allows you to match the target entry by matching any schema attribute. The following example shows how to set up a smart referral if a portion of a DIT is located on another server.

To Create a Referral

1. Create an LDIF file with an entry that contains the `referral` and `extensibleObject` object classes.

```
dn: ou=EngineeringTeam1,ou=People,dc=example,dc=com
objectClass: top
objectClass: referral
objectClass: extensibleObject
ou: Engineering Team1
ref: ldap://server2.example.com:6389/ou=EngineeringTeam1,ou=People,dc=example,dc=com
```

2. On the first server, add the referral entry using the `ldapmodify` command.

```
$ bin/ldapmodify --defaultAdd --fileName referral-entry.ldif
```

3. Verify the addition by searching for a user.

```
$ bin/ldapsearch --baseDN ou=People,dc=example,dc=com "(uid=user.4)"
```

```
SearchReference(referralURLs={ldap://server2.example.com:6389/
 ou=EngineeringTeam1,ou=People,dc=example,dc=com??sub?})
```

To Modify a Referral

- Use `ldapmodify` with the `manageDSAIT` control to modify the `ref` attribute on the referral entry.

```
$ bin/ldapmodify --control manageDSAIT
dn: ou=EngineeringTeam1,ou=People,dc=example,dc=com
changetype: modify
replace: ref
ref: ldap://server3.example.com/ou=EngineeringTeam1,ou=People,dc=example,dc=com
```

To Delete a Referral

- Use `ldapdelete` with the `manageDSAIT` control to delete the referral entry.

```
$ bin/ldapdelete \
  --control manageDSAIT "ou=EngineeringTeam1,ou=People,dc=example,dc=com"
```

Configuring a Read-Only Server

The UnboundID Data Store provides a means to configure a hub-like, read-only data store for legacy systems that require it. The read-only data store participates in replication but cannot respond to any update requests from an external client. You can configure the Data Store by setting the writability mode to internal-only, which makes the server operate in read-only mode. Read-only mode data stores can process update operations from internal operations but reject any write requests from external clients. Because the Data Store cannot accept write requests, you can configure the server to send a referral, which redirects a client's request to a master server. The client must perform the operation again on the server named in the referral.

Note: For Implementers of Third Party Extensions. Many Server SDK extensions use the `InternalConnection` interface to process operations in the server, rather than issuing LDAP requests over the network. If an extension does so in response to an external update request, then any Data Store using that extension will effectively respond to external update requests, even though the Data Store is configured to operate in read-only mode, as described above. One possible workaround is to split the extension into two extensions, one for reads and one for writes, then disabling (or not deploying) the write-only extension when configuring a Data Store in read-only mode.

To Configure a Read-Only Server

1. Install two replicating data stores. See *Replication Configuration* for various ways to set up your servers.

2. On the second server, use the `dsconfig` command to set the writability mode of the server to internal-only.

```
$ bin/dsconfig set-global-configuration-prop \
  --set writability-mode:internal-only
```

3. On the second server, use the `dsconfig` tool to create a referral that instructs the server to redirect client write requests under `dc=example,dc=com` to server1.example.com:1389. The referral itself is defined as a plugin of type `Referral on Update`. This command sets up the server to process read operations but redirects all write operations under `dc=example,dc=com` to another server.

```
$ bin/dsconfig create-plugin --plugin-name "Refer Updates" \
  --type referral-on-update \
  --set enabled:true \
  --set referral-base-url:ldap://server1.example.com:1389/ \
  --set "base-dn:dc=example,dc=com"
```

4. To test the referral, attempt to modify an entry and confirm that the server responds with the result code of 10. The resulting message is available in the server's access log.

```
$ bin/ldapmodify -p 2389 -D "cn=Directory Manager" -w password
dn: uid=user.12,ou=People,dc=example,dc=com
changetype:modify
replace:telephoneNumber
telephoneNumber: +1 408 555 1155
```

```
[06/Aug/2012:15:28:21.468 -0400] MODIFY
RESULT conn=86 op=1 msgID=1 requesterIP="127.0.0.1"
dn="uid=user.12,ou=People,dc=example,dc=com" resultCode=10
referralURLs="ldap://server1.example.com:1389/uid=user.12,
ou=People,dc=example,dc=com" etime=0.223
```

Configuring HTTP Access for the Data Store

Although most clients communicate with the UnboundID Data Store using LDAP, the server also provides support for an HTTP connection handler that uses Java servlets to serve content to clients over HTTP. UnboundID offers an extension that uses this HTTP connection handler to add support for the System for Cross-domain Identity Management (SCIM) protocol. Third-party developers can also use the Server SDK to write extensions that leverage this HTTP support.

The following sections describe how to configure HTTP servlet extensions and how to configure an HTTP connection handler.

Configuring HTTP Servlet Extensions

To use the HTTP connection handler, you must first configure one or more servlet extensions. Servlet extensions are responsible for obtaining Java servlets (using the Java Servlet 3.0 specification as described in JSR 315) and registering them to be invoked using one or more context paths. If you plan to deploy the SCIM extension, then you should follow the instructions in Chapter 24, "*Managing the SCIM Servlet Extension*." For custom servlet extensions created using the Server SDK, the process varies based on whether you are using a Java-based or Groovy-scripted extension.

Web Application Servlet Extensions

A Web application may be deployed either as a WAR file that has been packaged according to the standard layout and containing a web.xml deployment descriptor, or from a directory containing the application's source components arranged in the standard layout.

When deploying a Web application from a directory, you may specify the location of the `web.xml` deployment descriptor if it is not in the standard location. You may also specify the directory used by the server for temporary files. At runtime the web application has access to the server classes.

Java-based Servlet Extensions

For Java-based extensions, first use the Server SDK to create and build the extension bundle as described in the Server SDK documentation. Then, install it using the `manage-extension` tool as follows:

```
$ bin/manage-extension --install/path/to/extension.zip
```

The Java-based extension may then be configured for use in the server using `dsconfig` or the web-based administration console. Create a new Third Party HTTP Servlet Extension, specifying the fully-qualified name for the `HTTPServletExtension` subclass in the `extension-class` property, and providing any appropriate arguments in the `extension-argument` property.

Groovy-Scripted Extensions

For Groovy-scripted extensions, place the necessary Groovy scripts in the appropriate directory (based on the package for those scripts) below the `lib/groovy-scripted-extensions` directory. Then, create a new Groovy Scripted HTTP Servlet Extension, specifying the fully-qualified Groovy class name for the `script-class` property, and providing any appropriate arguments in the `script-argument` property.

Configuring HTTP Operation Loggers

Servlet extensions may write error log messages in the same way as any other kind of server component, but interaction with HTTP clients will not be recorded in the server access log. However, if a servlet extension performs internal operations to interact with data held in the data store, then those operations may be captured in the access log. To capture information about communication with HTTP clients, you must configure one or more HTTP operations loggers.

By default, the server comes with a single HTTP operation logger implementation, which uses the standard W3C common log format. It records messages in a format like the following:

```
127.0.0.1 - - [01/Jan/2012:00:00:00 -0600]"GET/hello HTTP/1.1" 200 113
```

The log message contains the following elements:

- The IP address of the client that issued the request.
- The RFC 1413 (ident) identity of the client. Because the ident protocol is not typically provided by HTTP clients, the HTTP connection handler never requests this information. This identity will always be represented as a dash to indicate that information is not available.
- The authenticated identity determined for the request by HTTP authentication, or a dash to indicate that the request was not authenticated.
- The time that the request was received.
- The request issued by the client, including the HTTP method, path and optional query string, and the HTTP protocol version used.
- The integer representation of the HTTP status code for the response to the client.
- The number of bytes included in the body of the response to the client.

To configure an HTTP operation logger to use this common log format, create a new instance of a Common Log File HTTP Operation Log Publisher object, specifying the path and name for the active log file to be written and the rotation and retention policies that should be used to manage the log files. In general, properties for Common Log File HTTP Operation Log Publisher objects have the same meaning and use as they do for other kinds of loggers.

You can use the Server SDK to create custom Java-based or Groovy-scripted HTTP operation loggers using the Third Party HTTP Operation Log Publisher and Groovy Scripted HTTP Operation Log Publisher object types.

Example HTTP Log Publishers

When troubleshooting HTTP Connection Handler issues, administrators should first look at the logs to determine any potential problems. The following section shows some `dsconfig` commands and their corresponding log files.

Default Configuration Example. You can configure a default detailed HTTP Log Publisher with default log rotation and retention policies as follows:

```
$ bin/dsconfig create-log-publisher \
  --publisher-name "HTTP Detailed Access Logger" \
  --type detailed-http-operation \
  --set enabled:true \
  --set log-file:logs/http-detailed-access \
  --set "rotation-policy:24 Hours Time Limit Rotation Policy" \
  --set "rotation-policy:Size Limit Rotation Policy" \
  --set "retention-policy:File Count Retention Policy" \
  --set "retention-policy:Free Disk Space Retention Policy" \
  --set "retention-policy:Size Limit Retention Policy"
```

The corresponding log file provides access information below. The log message contains the following elements:

➢ The time that the request was received.
➢ The request ID issued by the client, including the IP address, port, HTTP method, and URL.
➢ The authorization type, request content type, and status code.
➢ The response content length.
➢ The redirect URI.
➢ The response content type.

The HTTP log file is shown as follows:

```
[23/Feb/2012:01:19:45 -0600] RESULT requestID=4300604 from="10.5.1.10:53269"
method="GET" url="https://10.5.1.129:443/Gimel/Users/uid=user.402914,ou=People,
dc=gimel" authorizationType="Basic" requestContentType="application/json"
statusCode=200 etime=4.145 responseContentLength=1530 redirectURI="https://
x2270-11.example.lab:443/Gimel/Users/uid=user.402914,ou=people,dc=gimel"
responseContentType="application/json"
[23/Feb/2012:01:19:45 -0600] RESULT requestID=4300605 from="10.5.1.10:53269"
method="PUT" url="https://10.5.1.129:443/Gimel/Users/uid=user.207585,ou=people,
dc=gimel" authorizationType="Basic" requestContentType="application/json"
statusCode=200 etime=4.872 responseContentLength=1532 redirectURI="https://
x2270-11.example.lab:443/Gimel/Users/uid=user.207585,ou=people,dc=gimel"
responseContentType="application/json"
[23/Feb/2012:11:31:18 -0600] RESULT requestID=4309872 from="10.5.1.10:3
```

Configuration with Request/Response Header Names and Values. The following example adds request/response header names and values, including the "Content-Type" request header, which is normally suppressed by default.

```
$ bin/dsconfig set-log-publisher-prop \
  --publisher-name "HTTP Detailed Access Logger" \
  --set log-request-headers:header-names-and-values \
  --remove suppressed-request-header-name:Content-Type \
  --set log-response-headers:header-names-and-values
```

The following is a log example of a query request by a SCIM Server using the property, `scim-query-rate`. The log message contains the basic log elements shown in the first example plus the following additional information:

➢ The request header for the host, http method, content type, connection, user agent.
➢ The response header for the access-control credentials.

```
[23/Oct/2012:11:39:41-0600] RESULT requestID=4665307 from="10.5.0.20:56044"
method="GET" url="https://10.5.1.129:443/Beth/Users?attributes=userName,title,
emails,urn:scim:schemas:extension:custom:1.0:descriptions,urn:scim:schemas:
extension:enterprise:1.0:manager,groups,urn:scim:schemas:extension:custom:1.0:
blob&filter=userName+eq+%22user.18935%22" requestHeader="Host: x2270-11.example.
lab:443" requestHeader="Accept: application/json" requestHeader="Content-Type:
application/json" requestHeader="Connection: keep-alive"
requestHeader="User-Agent: Wink Client v1.1.2" authorizationType="Basic"
requestContentType="application/json" statusCode=200 etime=140.384
```

```
responseContentLength=11778 responseHeader="Access-Control-Allow-Credentials:
true" responseContentType="application/json"
```

Another log example shows an example user creation event. The client is curl.

```
[23/Oct/2012:11:50:11-0600] RESULT requestID=4802791 from="10.8.1.229:52357"
method="POST" url="https://10.2.1.113:443/Aleph/Users/" requestHeader="Host: x2270-
11.example.lab" requestHeader="Expect: 100-continue" requestHeader="Accept: applica-
tion/xml" requestHeader="Content-Type: application/xml" requestHeader="User-Agent:
curl/7.21.4 (universal-apple-darwin11.0) libcurl/7.21.4 OpenSSL/0.9.8r zlib/1.2.5"
authorizationType="Basic" requestContentType="application/xml" requestContent-
Length=1773 statusCode=201 etime=11.598 responseContentLength=1472 redirec-
tURI="https://x2270-11.example.lab:443/Aleph/Users/b2cef63c-5e46-11e1-974b-
60334b1a0d7a" responseContentType="application/xml"
```

The final example shows a user deletion request. The client is the UnboundID Sync Server.

```
[23/Oct/2012:11:38:06-0600] RESULT requestID=4610261 from="10.5.1.114:34558"
method="DELETE" url="https://10.2.1.113:443/Aleph/Users/b8547525-24e0-41ae-b66b-
0b441800de70" requestHeader="Host: x2270-11.example.lab:443" requestHeader="Accept:
application/json" requestHeader="Content-Type: application/json" requestHeader="Con-
nection: keep-alive" requestHeader="User-Agent: UnboundID-Sync-3.6.0.0 (Build
20121022173845Z, Revision 11281)" authorizationType="Basic" requestContentType="appli-
cation/json" statusCode=200 etime=10.615 responseContentLength=0
```

Configuring HTTP Connection Handlers

HTTP connection handlers are responsible for managing the communication with HTTP clients and invoking servlets to process requests from those clients. They can also be used to host web applications on the server. Each HTTP connection handler must be configured with one or more HTTP servlet extensions and zero or more HTTP operation log publishers.

If the HTTP Connection Handler cannot be started (for example, if its associated HTTP Servlet Extension fails to initialize), then this will not prevent the entire Data Store from starting. The Data Store's `start-ds` tool will output any errors to the error log. This allows the Data Store to continue serving LDAP requests even with a bad servlet extension.

The configuration properties available for use with an HTTP connection handler include:

- **listen-address**. Specifies the address on which the connection handler will listen for requests from clients. If not specified, then requests will be accepted on all addresses bound to the system.
- **listen-port**. Specifies the port on which the connection handler will listen for requests from clients. Required.
- **use-ssl**. Indicates whether the connection handler will use SSL/TLS to secure communications with clients (whether it uses HTTPS rather than HTTP). If SSL is enabled, then `key-manager-provider` and `trust-manager-provider` values must also be specified.
- **http-servlet-extension**. Specifies the set of servlet extensions that will be enabled for use with the connection handler. You can have multiple HTTP connection handlers (listening on different address/port combinations) with identical or different sets of servlet extensions. At least one servlet extension must be configured.
- **http-operation-log-publisher**. Specifies the set of HTTP operation log publishers that should be used with the connection handler. By default, no HTTP operation log publishers will be used.

- **key-manager-provider**. Specifies the key manager provider that will be used to obtain the certificate presented to clients if SSL is enabled.
- **trust-manager-provider**. Specifies the trust manager provider that will be used to determine whether to accept any client certificates presented to the server.
- **num-request-handlers**. Specifies the number of threads that should be used to process requests from HTTP clients. These threads are separate from the worker threads used to process other kinds of requests. The default value of zero means the number of threads will be automatically selected based on the number of CPUs available to the JVM.
- **web-application-extension**. Specifies the Web applications to be hosted by the server.

To Configure an HTTP Connection Handler

An HTTP connection handler has two dependent configuration objects: one or more HTTP servlet extensions and optionally, an HTTP log publisher. The HTTP servlet extension and log publisher must be configured prior to configuring the HTTP connection handler. The log publisher is optional but in most cases, you want to configure one or more logs to troubleshoot any issues with your HTTP connection.

1. The first step is to configure your HTTP servlet extensions. The following example uses the ExampleHTTPServletExtension in the Server SDK.

```
$ bin/dsconfig create-http-servlet-extension \
  --extension-name "Hello World Servlet" \
  --type third-party \
  --set "extension-
class:com.unboundid.directory.sdk.examples.ExampleHTTPServletExtension" \
  --set "extension-argument:path=/" \
  --set "extension-argument:name=example-servlet"
```

2. Next, configure one or more HTTP log publishers. The following example configures two log publishers: one for common access; the other, detailed access. Both log publishers use the default configuration settings for log rotation and retention.

```
$ bin/dsconfig create-log-publisher \
  --publisher-name "HTTP Common Access Logger" \
  --type common-log-file-http-operation \
  --set enabled:true \
  --set log-file:logs/http-common-access \
  --set "rotation-policy:24 Hours Time Limit Rotation Policy" \
  --set "rotation-policy:Size Limit Rotation Policy" \
  --set "retention-policy:File Count Retention Policy" \
  --set "retention-policy:Free Disk Space Retention Policy"

$ bin/dsconfig create-log-publisher \
  --publisher-name "HTTP Detailed Access Logger" \
  --type detailed-http-operation \
  --set enabled:true \
  --set log-file:logs/http-detailed-access \
  --set "rotation-policy:24 Hours Time Limit Rotation Policy" \
  --set "rotation-policy:Size Limit Rotation Policy" \
  --set "retention-policy:File Count Retention Policy" \
  --set "retention-policy:Free Disk Space Retention Policy"
```

3. Configure the HTTP connection handler by specifying the HTTP servlet extension and log publishers. Note that some configuration properties can be later updated on the fly while others, like `listen-port`, require that the HTTP Connection Handler be disabled, then re-enabled for the change to take effect.

```
$ bin/dsconfig create-connection-handler \
  --handler-name "Hello World HTTP Connection Handler" \
  --type http \
  --set enabled:true \
  --set listen-port:8443 \
  --set use-ssl:true \
  --set "http-servlet-extension:Hello World Servlet" \
  --set "http-operation-log-publisher:HTTP Common Access Logger" \
  --set "http-operation-log-publisher:HTTP Detailed Access Logger" \
  --set "key-manager-provider:JKS" \
  --set "trust-manager-provider:JKS"
```

4. By default, the HTTP connection handler has an advanced monitor entry property, `keep-stats`, that is set to TRUE by default. You can monitor the connection handler using the `ldapsearch` tool.

```
$ bin/ldapsearch --baseDN "cn=monitor" \
  "(objectClass=ds-http-connection-handler-statistics-monitor-entry)"
```

To Configure an HTTP Connection Handler for Web Applications

1. Create the Web application servlet extension.

```
$ bin/dsconfig create-web-application-extension \
  --extension-name "Hello Web Application" \
  --set "base-context-path:/hello-app" \
  --set "document-root-directory:/opt/hello-web-app"
```

2. By default, the HTTP connection handler has an advanced monitor entry property, `keep-stats`, that is set to TRUE by default. You can monitor the connection handler using the `ldapsearch` tool.

```
$ bin/ldapsearch --baseDN "cn=monitor" \
  "(objectClass=ds-http-connection-handler-statistics-monitor-entry)"
```

Domain Name Service (DNS) Caching

If needed, two global configuration properties can be used to control the caching of hostname-to-numeric IP address (DNS lookup) results returned from the name resolution services of the underlying operating system. Use the `dsconfig` tool to configure these properties.

- **network-address-cache-ttl** – Sets the Java system property `networkaddress.cache.ttl`, and controls the length of time in seconds that a hostname-to-IP address mapping can be cached. The default behavior is to keep resolution results for one hour (3600 seconds). This setting applies to the server and all extensions loaded by the server.
- **network-address-outage-cache-enabled** – Caches hostname-to-IP address results in the event of a DNS outage. This is set to true by default, meaning name resolution results are cached. Unexpected service interruptions may occur during planned or unplanned maintenance, network outages or an infrastructure attack. This cache may allow the server to function during a DNS outage with minimal impact. This cache is not available to server extensions.

IP Address Reverse Name Lookups

UnboundID servers do not explicitly perform numeric IP address-to-hostname lookups. However, address masks configured in Access Control Lists (ACIs), Connection Handlers, Connection Criteria, and Certificate handshake processing may trigger implicit reverse name lookups. For more information about how address masks are configured in the server, review the following information for each server:

- ACI dns: bind rules under *Managing Access Control* (Data Store and Proxy Servers)
- `ds-auth-allowed-address`: *Adding Operational Attributes that Restrict Authentication* (Data Store)
- Connection Criteria: *Restricting Server Access Based on Client IP Address* (Data Store and Proxy Servers)
- Connection Handlers: restrict server access using Connection Handlers (Configuration Reference Guide for all servers)

Working with the Referential Integrity Plug-in

Referential integrity is a plug-in mechanism that maintains the DN references between an entry and a group member attribute. For example, if you have a group entry consisting of member attributes specifying the DNs of printers, you can enable the referential integrity plug-in to ensure that the group entry is automatically removed if a printer entry is removed from the Data Store.

The Referential Integrity Plug-in is disabled by default. When enabled, the plug-in performs integrity updates on the specified attributes (for example, member or uniquemember) after a delete, modify DN, or a rename (i.e., subordinate modifyDN) operation is logged to the `logs/referint` file. If an entry is deleted, the plug-in checks the log file and makes the corresponding change to the associated group entry.

Three important points about the Referential Integrity Plug-in:

- All specified attributes that are configured for Referential Integrity must be indexed.
- On replicated servers, the Referential Integrity Plug-in configuration is not propagated to other replicas; therefore, you must manually enable the plug-in on each replica.
- The plug-in settings must also be identical on all machines.
- Subtree delete operations are not allowed if the referential integrity plugin is enabled and configured to operate in synchronous mode. It must be configured to operate in asynchronous mode (by specifying a nonzero update interval) if subtree delete operations will be performed.

To Enable the Referential Integrity Plug-in

1. Determine the attributes needed for your system. By default, the `member` and the `uniquemember` attributes are set for the plug-in.

2. Run the `dsconfig` tool to enable the Referential Integrity Plug-in.

```
$ bin/dsconfig set-plugin-prop --plugin-name "Referential Integrity" \
  --set enabled:true
```

Working with the Unique Attribute Plug-in

The Unique Attribute plug-in is used to enforce uniqueness constraints on the values of one or more attributes across a portion of the Data Store. The plug-in checks for uniqueness prior to an add, modify, or modify DN request and will instruct the server to reject the request if a constraint violation is found.

The plug-in is disabled by default as it can affect performance in heavy write load environments. Once the plug-in is enabled, it does not check for attribute uniqueness on existing entries, but only on new ADD, MODIFY, or MODDN operations. However, administrators can use the `identify-unique-attribute-conflicts` tool to ensure that no such conflicts exist in the data.

Important: All attributes for which uniqueness should be enforced should be indexed for equality in all backends.

Attribute uniqueness can be enforced in replicated environments in which each replica contains the complete set of data for which to provide uniqueness, regardless of whether clients communicate directly with the server or interact with it through a Proxy Server. In such environments, all servers should have identical uniqueness configurations. Note that it is not possible to *completely* prevent conflicts that arise from simultaneous writes on separate replicas. However, such conflicts will be detected after the changes have been replicated and will trigger administrative alert notifications.

For proxied environments that do not have the complete set of data on all servers (e.g., environments that use entry balancing or that store different portions of the DIT on different servers), you can implement the Global Uniqueness Attribute Plug-in on the Proxy Server, instead of enabling the attribute uniqueness plug-in on the Data Store. For more information, see the UnboundID Proxy Server Administration Guide.

To Enable the Unique Attribute Plug-in

1. Determine which attributes must be unique in your data.

2. Run the `dsconfig` tool to enable the plug-in. By default, the plug-in type property is set to `postsynchronizationadd`, `postsynchronizationmodify`, `postsynchronizationmodifydn`, `preoperationadd`, `preoperationmodify`, and `preopertionmodifydn`. If you want to set one plug-in type, use the `--set plugin-type:<operation-type>` option. For example, use `--set plugin-type:preoperationadd` with the following command if you only want to check for attribute uniqueness prior to ADD operation.

```
$ bin/dsconfig set-plugin-prop --plugin-name "UID Unique Attribute" \
  --set enabled:true
```

Configuring Uniqueness Across Attribute Sets

Attribute uniqueness can be configured across a set of attributes using the `multiple-attribute-behavior` property. The `multiple-attribute-behavior` property can take the following values:

- **unique-within-each-attribute -** If multiple attributes are specified, then uniqueness will be enforced for all values of each attribute, but the same value may appear in different attributes (in the same entry or in different entries). For example, assume you have an existing entry that has attributes, `telephoneNumber=123-456-7890` and `mobile=123-456-7891`. If you set the uniqueness plugin to have `--set "multiple-attribute-behavior:unique-within-each-attribute"` and add:
  - ➢ An entry with a `telephoneNumber` value that matches the `telephoneNumber` attribute in the existing entry, then the add request will fail.
  - ➢ An entry with a `mobile` value that matches the `mobile` attribute in the existing entry, then that too will fail.
  - ➢ An entry with the same `telephoneNumber` and `mobile` attribute values (e.g., 123-456-7893) but differ from the values in the existing entry, then the add request will succeed.
- **unique-across-all-attributes-including-in-same-entry -** If multiple attributes are specified, then uniqueness will be enforced across all of those attributes, so that if a value appears in one of those attributes, that value may not be present in any other of the listed attributes in the same entry, nor in any of the listed attributes in other entries. For example, assume you have an existing entry that has attributes, `telephoneNumber=123-456-7890` and `mobile=123-456-7891`. If you set the uniqueness plugin to have `--set "multiple-attribute-behavior:unique-across-all-attributes-including-in-same-entry"` and add:
  - ➢ An entry with a `telephoneNumber` value (e.g., 123-456-7890) that matches the `telephoneNumber` attribute in an existing entry, then the add request will fail.
  - ➢ An entry with a `mobile` value that matches the `mobile` attribute in an existing entry, then that too will fail.
  - ➢ An entry with a `mobile` value (e.g., 123-456-7890) that matches the `telephoneNumber` attribute in an existing entry, then that will fail.
  - ➢ An entry with a `telephoneNumber` value (e.g., 123-456-7891) that matches the `mobile` attribute in an existing entry, then that too will fail.

- ➢ An entry with the same `telephoneNumber` and `mobile` attribute values (e.g., 123-456-7893) but differ from the values in an existing entry, then the add request will fail.

- **unique-across-all-attributes-except-in-same-entry -** If multiple attributes are specified, then uniqueness will be enforced across all of those attributes, so that if a value appears in one of those attributes, that value may not be present in any of the listed attributes in other entries. However, the same value may appear in multiple attributes in the same entry. For example, assume you have an existing entry that has attributes, `telephoneNumber=123-456-7890` and `mobile=123-456-7891`. If you set the uniqueness plugin to have `--set "multiple-attribute-behavior:unique-across-all-attributes-except-in-same-entry"` and add:

  - ➢ An entry with a `telephoneNumber` value (e.g., 123-456-7890) that matches the `telephoneNumber` attribute in an existing entry, then the add request will fail.
  - ➢ An entry with a `mobile` value that matches the `mobile` attribute in the existing entry, then that too will fail.
  - ➢ An entry with a `mobile` value (e.g., 123-456-7890) that matches the `telephoneNumber` attribute in an existing entry, then that will fail.
  - ➢ An entry with a `telephoneNumber` value (e.g., 123-456-7891) that matches the `mobile` attribute in an existing entry, then that will fail.
  - ➢ An entry with the same `telephoneNumber` and `mobile` attribute values (e.g., 123-456-7893) but differ from the values in an existing entry, then the add request will succeed.

To Enable Uniqueness Across Attribute Sets

- Use `dsconfig` to configure the UID Unique Attribute plug-in to apply across multiple attributes. The `multiple-attribute-behavior` property is set to "`unique-within-each-attribute`", which indicates that uniqueness will be enforced for all values of each attribute (e.g., `telephoneNumber=123-456-7890` and `mobile=123-456-7891`), but the same value (e.g., either 123-456-7890 or 123-456-7891) may appear in different attributes in the same entry or in different entries.

```
$ dsconfig create-plugin \
  --plug-in "Unique telephoneNumber and mobile" \
  --type "unique-attribute" \
  --set "enabled:true" \
  --set "type:telephoneNumber" \
  --set "type:mobile" \
  --set "multiple-attribute-behavior:unique-within-each-attribute" \
  --no-prompt
```

Working with the Last Access Time Plug-In

The Last Access Time plug-in is used to record the timestamp of the last activity targeting an entry. The plug-in updates the `ds-last-access-time` attribute of the entry when it is accessed by an add, bind, compare, modify, modify DN, or search operation.

The plug-in can be used with the Data Store Uncached Attribute Criteria, or any application that needs to determine how recently an entry has been accessed. The plug-in also enables defining request criteria to limit the scope of tracking the last access time. The `max-search-result-entries-to-update` property also prevents mass updates of `ds-last-access-time` when searches contain many results, but may not reflect end-user access. Consider the following when using this plug-in:

- The plugin should be enabled on all servers that have the same configuration.
- An updated `ds-last-access-time` attribute value is replicated like any other change to an entry.
- The `ds-last-access-time` attribute is not returned from a search, unless included in the attributes list explicitly, or given the "+" specification for operational attributes.
- The `ds-last-access-time` value format is `yyyyMMddHHmmss.SSS'Z'`, which provides millisecond-level accuracy, such as `20131207144135.821Z`.
- The `ds-last-access-time` attribute can be indexed with a local database index. The ordering index type is the most relevant, but may require a higher index entry limit (default is 4000) to accommodate searches for entries that have not been accessed in a long period of time. The ordering index type, with a short time range or high index entry limit, will result in indexed search results for requests such as `(ds-last-access-time>=20131207144135.821Z)`.

Important: Deployments prior to version 4.5 using the last access time plug-in should disable the plug-in before upgrading, and then re-enable the plug-in once the update is complete. If servers are running different versions, the `last-access-time` updates may occur with a higher frequency than intended.

Supporting Unindexed Search Requests

By default, the Data Store denies all unindexed search requests, except for those issued by the bind DNs that have the `unindexed-search` privilege. This default behavior keeps the server from tying up worker threads on time-consuming, unindexed searches. However, you can turn off the enforcement of the `unindexed-search` privilege to allow any client to perform an unindexed search. To do this, set the `disabled-privilege` global configuration property to `unindexed-search` as follows:

```
$ bin/dsconfig set-global-configuration-prop \
  --set disabled-privilege:unindexed-search
```

If you choose to allow unindexed searches, you may want to cap the maximum number of concurrent unindexed search requests using the `maximum-concurrent-unindexed-searches` global configuration property. You configure this property using `dsconfig` as follows:

```
$ bin/dsconfig set-global-configuration-prop \
  --set maximum-concurrent-unindexed-searches:2
```

You can limit unindexed search privileges for particular clients using the allow-unindexedsearches property of the Client Connection Policy. For more information about configuring Client Connection Policies, see “Configuring Client Connection Policies”.

Sun/Oracle Compatibility

For companies that are migrating from a Sun/Oracle server to the UnboundID Data Store, the UnboundID Data Store provides a `dsconfig` batch file, `sun-ds-compatibility.dsconfig`, which describes the various components that can be configured to make the server exhibit behavior closer to a Sun/Oracle configuration.

Administrators can use the `sun-ds-compatibility.dsconfig` batch file to apply the Data Store's configuration with the necessary `dsconfig` commands. Simply uncomment the example commands listed in the file, and then run the `dsconfig` command specifying the batch file. Note that this batch file is not comprehensive and must be used together with the `migrate-sun-ds-config` tool, located in the `bin` folder (or `bat` folder for Windows systems) during the migration process. Both the tool and the batch file overlap in some areas but provide good initial migration support from the Sun/Oracle server to an UnboundID server.

Another useful tool is the `migrate-ldap-schema` tool in the `bin` folder (or `bat` folder for Windows systems), which migrates schema information from an existing LDAP server onto this instance. All attribute type and object class definitions that are contained in the source LDAP server will be added to the targeted instance or written to a schema file.

To Configure the Data Store for Sun/Oracle Compatibility

1. From the Data Store server root directory, open the `sun-ds-compatibility.dsconfig` file in the `docs` folder. You can use a text editor to view the file.

2. Read the file completely.

3. Apply any changes to the file by removing the comment symbol at any `dsconfig` command example, and then applying the `dsconfig` command specifying the batch file.

```
$ bin/dsconfig --no-prompt --bindDN "cn=Directory Manager" \
  --bindPassword "password" --batch-file /path/to/dsconfig/file
```

4. Run the `migrate-ldap-schema` tool to move the schema definitions on the source server to the destination UnboundID server.

```
$ bin/migrate-ldap-schema
```

5. Next, run the `migrate-sun-ds-config` tool to see what differences exist in the UnboundID configuration versus the Sun/Oracle configuration. On the UnboundID Data Store, run the following command:

```
$ bin/migrate-sun-ds-config
```

6. Test the server instance for further settings that may not have been set with the batch file, the `migrate-ldap-schema` tool, or the `migrate-sun-ds-config` tool.

7. If you notice continued variances in your configuration, contact your authorized support provider.

Chapter 7 Configuring Soft Deletes

The UnboundID Data Store (version 3.2.4 or later) supports a *soft-delete* feature that preserves a deleted entry's attribute and uniqueness characteristics to allow it to be undeleted or permanently removed at a later date.

This chapter introduces the following topics:

Topics:

About Soft Deletes

The standard implementation of an LDAP server allows for adding, renaming, modifying, searching, comparing, and deleting one or more entries. The DELETE operation is, by specification, a destructive operation that permanently removes an entry and its attributes in a Directory Information Tree (DIT) but records the changes in access, and optionally, audit and change logs. During the DELETE operation, any associations such as references and group memberships are severed to reflect the entry that is removed. Meta attributes like operational attributes, which may be unique to an entry like `entryUUID`, will be lost or be different if the same entry is re-added to the Data Store.

There are cases, however, where a company may want to preserve their deleted entries to allow for possible undeletion at a later date. For example, a company may want to retain account and subscriber entries for their users (e.g., customers, employees, or partners) who leave but later rejoin. Artifacts that a user creates such as account histories, web pages, notes, may be tracked and recovered while a user is deleted or when the user returns as an active customer.

To facilitate this use case, the Data Store supports a feature called *soft deletes*, which preserves a deleted entry’s attributes and entry uniqueness characteristics to allow the entry to be undeleted or permanently removed at a later date. A delete request may result in a soft delete either by the client explicitly requesting a soft delete or by the request matching criteria defined in an active soft delete policy. The soft-deleted entries are renamed by prefixing an `entryUUID` operational attribute to the DN and adding an auxiliary object class, `ds-soft-delete-entry`, to the entry, which saves the entry in a hidden state. All active references and group memberships are then removed. Once in this hidden state, soft-deleted entries are inaccessible to clients under normal operating conditions. Only clients with the `soft-delete-read` privilege will be allowed to interact with soft-deleted entries.

To allow soft deletes, the Data Store’s attribute uniqueness function has been relaxed to allow for the co-existence of a soft-deleted entry and an active entry with identical naming attributes, such as `uid`. For example, if a user John Smith was soft deleted but a different John Smith was added to the user accounts system, both entries could reside in the DIT without conflict: one in a soft-deleted state; the other, in an active state. The Data Store extends this capability further by allowing multiple users with the same DN, who would normally conflict if active, to reside in the soft-deleted state.

Soft-deleted entries can be restored with an Undelete operation. However, the same uniqueness constraints that apply when adding a new user to the Data Store are enforced when a soft-deleted entry is undeleted. Returning to the previous example, John Smith was soft deleted but a different John Smith with the same `uid` as the original John Smith was added later to the system. If the original John Smith was undeleted from its soft-deleted state, it would result in a conflict with the active John Smith entry. Administrators will need to modify the DN of the soft-deleted entry to avoid such conflicts.

Administrators can permanently remove a soft-deleted entry by performing a regular DELETE operation on it. This operation, called a *hard delete*, permanently removes a soft-deleted entry from the server. Also, note that you can also permanently remove a regular non-soft-deleted entry using a hard delete. This is useful when the server is configured with a soft-delete policy that would otherwise turn a regular delete request into a soft delete.

The Data Store provides tool arguments that can use the Soft Delete Request Control, a Hard Delete Request Control, and other controls necessary to process these operations. Procedures to show how to use these options are presented later in this section.

For replicated topologies, when a participating data store soft deletes an entry, it notifies the other replicas in the topology to soft delete the same entry on its respective machine. The changelog backend also records these entries by annotating them using an attribute that indicates its soft-deleted state. Modification and hard deletes of soft-deleted entries are not recorded by default in the changelog but can be enabled in the server. For maximum compatibility, it is highly recommended that all servers in the replication cluster support Soft Deletes and have identical Soft Delete configurations.

General Tips on Soft Deletes

There are some general tips about soft deletes that administrators should be aware of:

- **LDAP SDK and Server SDK**. The LDAP SDK and Server SDK both fully supports soft-deletes.
- **Possible Performance Impact for Searching Regular Entries and Soft-Deleted Entries**. There is little performance difference between retrieving a regular entry and a soft-deleted entry, respectively. However, there may be a performance impact when a search operation has to match criteria (such as, `uid=john.smith`) for both active entries and soft-deleted entries. For example, if there is one active `uid=john.smith` entry and two soft-deleted `uid=john.smith` entries, it may take the server a little more time to retrieve and try to match the criteria before it can return the results.
- **Soft Delete for Uncached Attributes and Entries**. The soft delete feature fully supports uncached attributes and uncached entries. See the section on *Uncached Attributes and Entries* for more information about the feature.
- **Soft Delete for Leaf Nodes Only**. Soft-deletion of any parent entry is not allowed. Likewise, soft-deleted entries that have soft-deleted sub-entries are not allowed.
- **Attempting to Soft-Delete a Soft-Deleted Entry Fails**. There are two available state options for soft-deletes: administrators can permanently delete a soft-deleted entry or undelete the entry. An administrator cannot soft-delete an already soft-deleted entry, which returns an `UNWILLING_TO_PERFORM` result code.
- **Soft-Deleted Users Have No Privileges**. Soft-deleted users do not have the ability to bind to the Data Store or have authentication access. They cannot change their passwords and cannot undelete themselves. Also, soft-deleted entries cannot be used as an authorization identity using the proxied authorization or immediate client control. It is important to note that the soft-delete process does not destroy privilege assignment. If a soft-deleted entry is undeleted, the restored entry will retain the same privileges it originally had before being soft deleted. (One possible exception to this are those privileges assigned by virtual attributes that no longer match the newly-undeleted entry; those entries do not retain their original privileges.)
- **Soft-Deleted Entries Not Accessible by Other Means**. Soft-deleted entries may not be accessible from alternate access methods like SCIM.

- **Soft-Deleted Entries Can Be Modified but Not Renamed**. Administrators can search for all soft-deleted entries and the original source entry attributes can be updated as long as the administrators has modify privileges and access to the `soft-delete-read` privilege. Any attempt to rename a soft-deleted entry using a MODIFY DN operation will result in an `UNWILLING_TO_PERFORM` result code.
- **Replication**. Replication will have access to the LDAP operations with Soft Delete controls. These operations are transmitted, processed, and replayed as high-level requests, which are re-played on remote replicated servers. The replication conflict-resolution mechanism handles soft-deleted entries like any regular entries. For example, if a soft delete is executed independently on two servers then replicated, this results in a replication conflict. For maximum compatibility, it is highly recommended that all servers in a replication cluster support Soft Deletes and have identical Soft Delete configuration.
- **Transactions**. Soft-deletes are supported in transactions. The processing workflow uses the transactions mechanism and maintains the context information necessary to rollback failures to soft delete or undelete.
- **Soft-Deletes Through the Proxy Server**. There is no special configuration steps to configure Soft Deletes on the Proxy Server. The soft-deleted entry is routed directly to the underlying Data Store. There is one exception: in an entry-balancing deployment, the Proxy Server is responsible for routing the soft-deleted entry to the Data Store containing the originally soft-deleted item. Also, as with standard entry-balanced deployments, it is not possible to undelete (using MODDN) an entry to a different Data Store.
- **Export-LDIF**. The default behavior is to include soft-deleted entries as part of the `export-ldif` operation. If soft-deleted entries are to be excluded from export, administrators can use the `--excludeSoftDeleteEntries` option to filter out the entries.
- **Proxied Authorization**. The Soft Delete feature can be used with users who have proxied authorization privileges.
- **Ignored by Data Sync Server Sync Pipes**. For customers using the UnboundID Data Sync Server, soft-deleted entries are not synchronized by the server. Modifications or deletes of a soft-deleted entry are ignored by the Data Sync Server, and do not appear in the changelog by default. An actual soft delete operation appears to the changelog as a regular DELETE, and an actual undelete operation appears in the changelog as a regular ADD.
- **Referential Integrity Plugin Does Not Restore Membership**. References to a deleted DN are not restored by the referential integrity plugin upon undeletion of a soft-deleted entry. For example, if you have referential integrity enabled and you soft-delete a DN that is a member of a static group, the referential integrity plugin will remove this DN from the group's list of members. When you undelete the soft-deleted entry, the plugin will not add the entry back to the group.
- **Criteria-Selected or Explicitly-Requested Purging of Soft Deletes**. The Soft Delete Policy configuration supports two new properties, `soft-delete-retention-time` and `soft-delete-retain-number-of-entries` that performs purging of soft deleted entries. See the section on *Configuring Soft-Delete Automatic Purging*.
- **Assigning Access to Controls to Non-Root Users Administrators**. By default, the root user account (e.g., `cn=Directory Manager`) has access to all of the controls needed to run the Soft Delete operations. For non-root users, you must grant access to these Soft

Delete controls using access control rules. An example is shown in step 1 of the section, *To Configure Soft Deletes as a Global Configuration*. The following Soft Delete Controls are available to non-root users:

- ➢ **Soft Delete Request Control**. Allows the user to perform a soft delete operation. The OID for the control is 1.3.6.1.4.1.30221.2.5.20.
- ➢ **Soft Delete Response Control**. Allows the server to hold the DN of the soft-deleted entry that results from a soft delete request. The OID for the control is 1.3.6.1.4.1.30221.2.5.21.
- ➢ **Hard Delete Request Control**. Allows the user to run a hard delete operation on the entry, regardless if it is a regular or soft-deleted entry. The OID for the control is 1.3.6.1.4.1.30221.2.5.22.
- ➢ **Undelete Request Control**. Allows the user to undelete a soft-deleted entry using an ADD request. The OID for this control is 1.3.6.1.4.1.30221.2.5.23.
- ➢ **Soft-Deleted Entry Access Request Control**. Allows the user to search for any soft-deleted entries. The OID for this control is 1.3.6.1.4.1.30221.2.5.24. Note that a bind DN with the `stream-values` privilege can perform operations that can reveal soft-deleted entries, even if that bind DN does not have permission to use the Soft-Deleted Entry Access Request Control. For example, if a user can successfully run `dump-dns` or `ldap-diff`, then that user can get a list of soft-deleted entry DNs or soft-deleted entry contents via the output of one of those tools.

Configuring Soft Deletes on the Server

Soft deletes are configured on the Data Store in several ways:

- **Using a Soft-Delete Policy and Global Configuration Property**. You can configure soft deletes by creating a soft-delete policy and a global configuration property. The soft-delete policy enables the feature on the server, while the global configuration property sets the controls used for the soft-delete requests. To enter a soft delete request, the `ldapmodify` or `ldapdelete` command requires the `--useSoftDelete` option. A delete request that does not have the `--useSoftDelete` option is treated as a hard delete, which permanently removes the entry.

- **Using Connection Criteria**. You can configure soft deletes by defining connection criteria within a client connection policy. Any clients that meet the criteria will have their deletes processed as soft deletes.

- **Using Request Criteria**. You can configure soft deletes by defining request criteria within a client connection policy. Any client requests that meet the criteria will have their deletes processed as soft deletes. Note that you can define both connection criteria and request criteria. Both criteria are exclusive and can exist within a soft-delete policy. In this case, the connection criteria is processed first, then the request criteria.

Configuring Soft Deletes as a Global Configuration

You can configure the soft delete feature by creating a soft-delete policy and then setting the configuration property on the server. The presence of the soft-delete policy enables the feature on the server and allows the global configuration property to send the necessary soft-delete requests.

This configuration setting requires that the `--useSoftDelete` option be used together with the `ldapmodify` or `ldapdelete` commands to send the delete using the Soft Delete Request Control. Without the `--useSoftDelete` option, any delete will be processed as a hard delete.

To Configure Soft Deletes as a Global Configuration

1. Create a non-root user admin account, such as `uid=admin,dc=example,dc=com`. See steps 1 and 3 in the Configuring Administrator Accounts section for more information. The following LDIF adds ACI's to the `uid=admin,dc=example,dc=com` entry to allow access to user and operational attributes as well as access to the controls necessary to carry out the Soft Delete operations. The LDIF also adds the `soft-delete-read` privilege, which allows the user to access soft-deleted entries. Add the LDIF file using the `ldapmodify` tool.

```
dn: dc=example,dc=com
changetype: modify
add: aci
aci: (targetattr="*||+")
      (version 3.0; acl "Allow admins to read and write all user and operational
       attributes";
       allow (all) userdn="ldap:///uid=admin,dc=example,dc=com";)
aci: (targetcontrol="1.3.6.1.4.1.30221.2.5.20||1.3.6.1.4.1.30221.2.5.21")
      (version 3.0; acl "Allow admins to use the Soft Delete Request Control and
       Soft Delete Response Control";
       allow (read) userdn="ldap:///uid=admin,dc=example,dc=com";)
aci: (targetcontrol="1.3.6.1.4.1.30221.2.5.22")
      (version 3.0; acl "Allow admins to use the Hard Delete Request Control";
       allow (read) userdn="ldap:///uid=admin,dc=example,dc=com";)
aci: (targetcontrol="1.3.6.1.4.1.30221.2.5.23")
      (version 3.0; acl "Allow admins to use the Undelete Request Control";
       allow (read) userdn="ldap:///uid=admin,dc=example,dc=com";)
aci: (targetcontrol="1.3.6.1.4.1.30221.2.5.24")
      (version 3.0; acl "Allow admins to use the Soft-Deleted Entry Access Request
       Control";
       allow (read) userdn="ldap:///uid=admin,dc=example,dc=com";)

$ bin/ldapmodify --fileName add-admin-aci.ldif
```

2. Create another LDIF file and assign the `soft-delete-read` privilege to the authorized user. Add the file to the server using the `ldapmodify` tool. You'll need to include bind credentials with the `ldapmodify` command.

```
dn: uid=admin,dc=example,dc=com
changeType: modify
add: ds-privilege-name
ds-privilege-name: soft-delete-read

$ bin/ldapmodify --fileName add-admin-priv.ldif
```

3. Configure a soft delete policy using the `dsconfig` command. The soft delete configuration option requires a soft-delete policy, which effectively enables the feature on the server. This is a required step.

```
$ bin/dsconfig create-soft-delete-policy \
  --policy-name default-soft-delete-policy
```

4. Configure the soft delete as a global configuration property using the `dsconfig` command. The command sets up the soft-delete controls necessary to send them as a request. This is a required step.

```
$ bin/dsconfig set-global-configuration-prop \
  --set soft-delete-policy:default-soft-delete-policy
```

After a successful modification, the server issues a warning that soft deletes are not enabled and that administrative action may be needed to prune older soft-deleted entries if resources are limited. For more information on setting up soft deletes, see “Configuring Soft Deletes by Connection Criteria”.

```
One or more configuration property changes require administrative action or
confirmation/notification. Those properties include:

 * soft-delete-policy:  Presently the server does not have an automatic purging
   capability for soft deleted entries. The administrator must
   periodically monitor and determine if too many soft deleted entries are
   consuming resources and must be pruned.

The Global Configuration was modified successfully
```

5. Delete an entry to test the soft delete feature. You must use the `--useSoftDelete` (or the short form, `-s`) option with the `ldapdelete` or `ldapmodify` to send the delete using a Soft Delete Request Control. The control renames the entry, prefixes an `entryUUID` operational attribute to the DN, and hides the entry by adding an auxiliary object class, `ds-soft-delete-entry`. If you do not include the `--useSoftDelete` option, the server processes the delete as a hard delete, which permanently removes the entry unless soft deletes is enabled. Upon a successful soft delete operation, the server returns the DN of the newly soft-deleted entry.

```
$ bin/ldapdelete --useSoftDelete uid=user.1,ou=People,dc=example,dc=com
```

```
Processing DELETE request for uid=user.1,ou=People,dc=example,dc=com
DELETE operation successful for DN uid=user.1,ou=People,dc=example,dc=com
Soft-deleted entry DN:
entryUUID=4e9b7847-edcb-3791-b11b-7505f4a55af4+uid=user.1,ou=People,dc=exam-
ple,dc=com
```

Note:

Once an entry has been soft deleted, it is possible for an LDAP client to create an entry with the same DN as the original user entry DN. For example, if you soft-delete an entry (e.g., `uid=user.3,ou=People,dc=example,dc=com`), you can create a new entry using the same DN as the original entry, `uid=user.3,ou=People,dc=example,dc=com`. If the soft-deleted entry is undeleted at a later date, then a conflict will occur.

Searching for Soft Deletes

Soft-deleted entries are excluded from normal LDAP searches because they represent "deleted" entries. The `ldapsearch` tool has been updated to support these types of searches. If you want the option to search for soft-deleted entries, there are three ways to do so:

- **Base-Level Search on a Soft-Deleted entry by DN**. Use `ldapsearch` and specify the base DN of the specific soft-deleted entry that you are searching for.

- **Filtered Search by `soft-delete-entry` object class**. To search for all soft-deleted entries, use `ldapsearch` with a filter on the `ds-soft-delete-entry` objectclass.
- **Soft-Delete-Entry-Access Control**. You can use the Soft Delete Entry Access Control with the LDAP search to return soft-deleted entries. The `ldapsearch` tool provides a shortcut option, `--includeSoftDeletedEntries`, that sends the control to the server for processing. The control allows for the following search possibilities:
  - ➢ Return only soft-deleted entries.
  - ➢ Return non-deleted entries along with soft-deleted entries.
  - ➢ Return only soft-deleted entries in undeleted form.

To Run a Base-Level Search on a Soft-Deleted Entry

- Run `ldapsearch` using the base DN of the specified soft-deleted entry.

```
$ bin/ldapsearch \
  --baseDN entryUUID=4e9b7847-edcb-3791-
b11b-7505f4a55af4+uid=user.1,ou=People,dc=example,dc=com \
  --searchScope base "(objectClass=*)"
```

```
# Soft-deleted entry DN:
# entryUUID=4e9b7847-edcb-3791-
b11b-7505f4a55af4+uid=user.1,ou=People,dc=example,dc=com
dn: entryUUID=4e9b7847-edcb-3791-
b11b-7505f4a55af4+uid=user.1,ou=People,dc=example,dc=com
objectClass: top
objectClass: person
objectClass: organizationalPerson
objectClass: inetOrgPerson
objectClass: ds-soft-delete-entry
postalAddress: Aartjan Aalders$59748 Willow Street$Green Bay, TN 66239
postalCode: 66239
description: This is the description for Aartjan Aalders.
uid: user.1
userPassword: {SSHA}RdBCwQ2kIw57LukRthjrFBS/oFylJARnmTnorA==
employeeNumber: 1
initials: AKA
givenName: Aartjan
pager: +1 197 025 3730
mobile: +1 890 430 9077
cn: Aartjan Aalders
sn: Aalders
telephoneNumber: +1 094 100 7524
street: 59748 Willow Street
homePhone: +1 332 432 4295
l: Green Bay
mail: user.3@maildomain.net
st: TN
```

To Run a Filtered Search by soft-delete-entry Object Class

- Run `ldapsearch` to retrieve all soft-deleted entries using the `ds-soft-delete-entry` object class. The following command retrieves all soft-deleted entries on the server

```
$ bin/ldapsearch --baseDN dc=example,dc=com \
  "(objectclass=ds-soft-delete-entry)"
```

To Run a Search using the Soft Delete Entry Access Control

The following examples use the `--includeSoftDeleteEntries` `{with-non-deleted-entries | without-non-deleted-entries | deleted-entries-in-undeleted-form}` option, which uses the Soft Delete Entry Access Control. You could also use the `--control` option with the Soft Delete Entry Access Control symbolic name, `softdeleteentryaccess`, or the `--control` option with the actual Soft Delete Entry Access Control OID, `1.3.6.1.4.1.30221.2.5.24`.

- **Return Only Soft-Deleted Entries**. Run `ldapsearch` using the `--includeSoftDeletedEntries` option with the value of `without-non-deleted-entries` to return only soft-deleted entries.

```
$ bin/ldapsearch --baseDN dc=example,dc=com \
  --includeSoftDeletedEntries without-non-deleted-entries \
  --searchScope sub "(objectclass=*)"
```

- **Return Non-Deleted Entries Along with Soft-Deleted Entries**. Run `ldapsearch` using the `--includeSoftDeletedEntries` option with the value of with-non-deleted-entries to return non-deleted entries along with soft-deleted entries.

```
$ bin/ldapsearch --baseDN dc=example,dc=com \
  --includeSoftDeletedEntries with-non-deleted-entries \
  --searchScope sub "(objectclass=*)"
```

- **Return Only Soft-Deleted Entries in Undeleted Form**. Run `ldapsearch` using the `--includeSoftDeletedEntries` option with the value of `deleted-entries-in-undeleted-form` to return only soft-deleted entries in undeleted form. Some applications require access to all entries in the server, including both active and soft-deleted entries. The following command returns all entries that were soft-deleted but presents it in a form that is similar to a regular entry with the soft-delete DN in comments. This regular entry format does not show the actual soft-deleted DN but displays it in an "undeleted" form even though it is not actually "undeleted". Also, the object class, `ds-soft-delete-entry`, is not displayed:.

```
$ bin/ldapsearch --baseDN dc=example,dc=com \
  --includeSoftDeletedEntries deleted-entries-in-undeleted-form \
  --searchScope sub "(ds-soft-delete-from-dn=*)"

# Soft-deleted entry DN:
# entryUUID=2b5511e2-7616-389b-ab0c-025c805ad32c+uid=user.14,ou=People,dc=exam-
ple,dc=com
dn: uid=user.14,ou=People,dc=example,dc=com
objectClass: top
objectClass: person
objectClass: organizationalPerson
objectClass: inetOrgPerson
postalAddress: Abdalla Abdou$78929 Hillcrest Street$Elmira, ME 93080
postalCode: 93080
description: This is the description for Abdalla Abdou.
uid: user.14
userPassword: {SSHA}7GkzWiMiU12m5m+xBV+ZsoX3gVacMcRtSwDTFg==
employeeNumber: 14
initials: AFA
givenName: Abdalla
pager: +1 307 591 4870
mobile: +1 401 069 1289
cn: Abdalla Abdou
sn: Abdou
telephoneNumber: +1 030 505 6190
street: 78929 Hillcrest Street
homePhone: +1 119 487 2328
l: Elmira
mail: user.14@maildomain.net
st: ME
```

Undeleting a Soft-Deleted Entry Using the Same RDN

To undelete a soft-deleted entry, use `ldapmodify` with the `--allowUndelete` option and target the specific soft-deleted entry that you want to restore. In an LDIF file or from the command line, specify the `dn:<target entry>` attribute, which is the DN that the entry will be undeleted *to* and the `ds-undelete-from-dn` attribute, which is the entry that will be undeleted *from*. An undelete requires the `add` changetype so that the entry can be re-added to the server.

To Undelete a Soft-Deleted Entry Using the Same RDN

- Use `ldapmodify` with the `--allowUndelete` option and target the specific soft-deleted entry that you want to restore. The `--allowUndelete` option sends the Soft Undelete Request Control to the server. The first DN is the entry to undelete to and the `ds-undelete-from-dn` is the soft-delete entry to undelete from.

```
$ bin/ldapmodify --allowUndelete
dn: uid=user.1,ou=People,dc=example,dc=com
changetype:add
ds-undelete-from-dn: entryUUID=4e9b7847-edcb-3791-b11b-
7505f4a55af4+uid=user.1,ou=People,dc=example,dc=com
```

Undeleting a Soft-Deleted Entry Using a New RDN

In some cases, the original RDN, `uid=user.1`, may have been allocated to a new user, which is allowed while the entry is in a soft-deleted state. To properly undelete this entry, you need to specify a new RDN value that the entry should be restored with. In this case, specifying the RDN of `uid=user.5` will undelete the original entry but with the new DN in the example below. In addition, the `uid` attribute on the entry will be updated with the new value of `user.5` as well. All other attributes of the users entry including the `entryUUID` will remain unchanged.

To Undelete a Soft-Deleted-Entry Using a New RDN

1. Use `ldapmodify` to undelete a soft-deleted entry that has an original RDN, `uid=user.1`, to a new RDN, `uid=user.5`. You will need to ensure that the DN that you are undeleting the entry to does not already exist as this will lead to an "entry already exists" error if you specify a DN that already exists in the Data Store as a normal entry.

```
$ bin/ldapmodify --allowUndelete
dn: uid=user.5,ou=People,dc=example,dc=com
changetype:add
ds-undelete-from-dn: entryUUID=4e9b7847-edcb-3791-
b11b-7505f4a55af4+uid=user.1,ou=People,dc=example,dc=com
```

2. View the results using `ldapsearch`. You will notice the RDN and the `uid` attribute has changed.

```
dn: uid=user.5,ou=People,dc=example,dc=com
objectClass: top
```

```
objectClass: person
objectClass: organizationalPerson
objectClass: inetOrgPerson
postalAddress: Aartjan Aalders$59748 Willow Street$Green Bay, TN 66239
postalCode: 66239
description: This is the description for Aartjan Aalders.
uid: user.5
userPassword: {SSHA}RdBCwQ2kIw57LukRthjrFBS/oFylJARnmTnorA==
employeeNumber: 1
initials: AKA
givenName: Aartjan
pager: +1 197 025 3730
mobile: +1 890 430 9077
cn: Aartjan Aalders
sn: Aalders
telephoneNumber: +1 094 100 7524
street: 59748 Willow Street
homePhone: +1 332 432 4295
l: Green Bay
mail: user.3@maildomain.net
st: TN
entryUUID=4e9b7847-edcb-3791-b11b-7505f4a55af4
```

Modifying a Soft-Deleted Entry

You can modify a soft-deleted entry as you would a regular entry using the `ldapmodify` tool and remains hidden in its soft-deleted state after the change. The only restriction is that you cannot change the DN or run a MODDN operation on the soft-deleted entry.

To move a soft-deleted entry from one machine to another, use the `move-subtree` command and specify the DN of the soft-deleted entry. For more information, see *To Move an Entry from One Machine to Another*.

Note: To modify a soft-deleted entry, the user needs the `soft-delete-read` privilege to access the soft-deleted entry.

To Modify a Soft-Deleted Entry

- Soft-deleted entries can be modified like any regular entry. Use `ldapmodify` and specify the soft-deleted DN.

```
$ bin/ldapmodify
dn: entryUUID=4e9b7847-edcb-3791-
b11b-7505f4a55af4+uid=user.1,ou=People,dc=example,dc=com
changetype:modify
replace:telephoneNumber
telephoneNumber: +1 390 103 6918
# Processing MODIFY request for entryUUID=4e9b7847-edcb-3791-
b11b-7505f4a55af4+uid=user.1,ou=People,dc=example,dc=com
# MODIFY operation successful for DN entryUUID=4e9b7847-edcb-3791-
b11b-7505f4a55af4+uid=user.1,ou=People,dc=example,dc=com
```

Hard Deleting a Soft-Deleted Entry

To permanently remove a soft-deleted entry from the server, you can run `ldapdelete` on the soft-deleted entry for soft-deleted entries. To hard delete a soft-deleted entry, use `ldapdelete` with the `--useHardDelete` option. The Hard Delete Request Control works with soft deletes. It mostly applies when soft delete policies are in place as a means to override soft deletes requests. If soft deletes are configured, running `ldapdelete` with the Hard Delete Request Control (i.e., using the option, `--useHardDelete`) guarantees any entry will be permanently deleted.

To Hard Delete a Soft-Deleted Entry (Global Configuration)

- Run `ldapdelete` on a soft-deleted entry to permanently remove it from the Data Store. This example assumes that you configured soft deletes as a global configuration for requests.

```
$ bin/ldapdelete \
  entryUUID=4e9b7847-edcb-3791-
b11b-7505f4a55af4+uid=user.1,ou=People,dc=example,dc=com

Processing DELETE request for entryUUID=4e9b7847-edcb-3791-b11b-
7505f4a55af4+uid=user.1,ou=People,dc=example,dc=com
DELETE operation successful for DN entryUUID=4e9b7847-edcb-3791-b11b-
7505f4a55af4+uid=user.1,ou=People,dc=example,dc=com
```

Note:

You cannot soft-delete an already soft-deleted entry. If you use the `--useSoftDelete` with the `ldapdelete` operation on a soft-deleted entry, an error message will be generated.

```
DELETE operation failed.
Result Code: 53 (Unwilling to Perform)
Diagnostic Message: DELETE operation failed.
```

To Hard Delete a Soft-Deleted Entry (Connection or Request Criteria)

- Run `ldapdelete` with the `--useHardDelete` option on a soft-deleted entry to permanently remove it from the server. This example assumes that you configured soft deletes using a connection or request criteria.

```
$ bin/ldapdelete --useHardDelete \
  entryUUID=4e9b7847-edcb-3791-
b11b-7505f4a55af4+uid=user.1,ou=People,dc=example,dc=com
```

Disabling Soft Deletes as a Global Configuration

To disable soft deletes on your Data Store, simply reset the global configuration property and the remove the soft-delete policy. From that point, all deletes will be processed as hard deletes by default. Any use of the soft-deleted options with the LDAP tools results in an error. Any existing soft-deleted entries that are present after the global configuration is disabled will remain in the server as latent entries.

To Disable Soft Deletes as a Global Configuration

1. Run `dsconfig` to reset the global configuration property. Remember to include the LDAP bind parameters for your system.

```
$ bin/dsconfig set-global-configuration-prop --reset soft-delete-policy
```

2. Run `dsconfig` to delete the soft delete policy that you created. Remember to include the LDAP bind parameters for your system.

```
$ bin/dsconfig delete-soft-delete-policy --policy-name default-soft-delete-policy
```

Configuring Soft Deletes by Connection Criteria

The Data Store supports soft deletes where any delete operation is treated as a soft-delete request as long as the LDAP client meets the connection criteria. You can configure soft deletes by defining the connection criteria used in a client connection policy, and then configuring the soft delete connection criteria in the soft-delete policy.

To Enable Soft Deletes by Connection Criteria

1. Configure a soft-delete policy and global configuration as shown in “Configuring Soft Deletes as a Global Configuration”.

2. Create a simple connection criteria using `dsconfig` and name it "Internal Applications". The soft delete connection criteria is configured for a member of a Line of Business (LOB) Applications group connecting from the 10.8.1.0 network.

```
$ bin/dsconfig create-connection-criteria \
  --criteria-name "Internal Applications" \
  --type simple \
  --set included-client-address:10.8.1.0/8 \
  --set "all-included-user-group-dn:cn=LOB Applications,ou=Groups,dc=example,dc=com"
```

3. In the soft delete policy created in step 1, set the `auto-soft-delete-connection-criteria` property to the simple criteria created in the previous step.

```
$ bin/dsconfig set-soft-delete-policy-prop \
  --policy-name default-soft-delete-policy \
  --set "auto-soft-delete-connection-criteria:Internal Applications"
```

To Disable Soft Deletes by Connection Criteria

- To disable soft deletes by connection criteria, simply reset the `auto-soft-delete-connection-criteria` property on the soft-delete policy.

```
$ bin/dsconfig set-soft-delete-policy-prop \
  --policy-name default-soft-delete-policy \
  --reset auto-soft-delete-connection-criteria
```

Configuring Soft Deletes by Request Criteria

Soft deletes can be configured using request criteria within a client connection policy. All delete requests that meet the request criteria is treated as a soft delete. The presence of a soft delete by connection criteria is exclusive of the soft delete by request criteria. Both can be present in a soft-delete policy.

To Enable Soft Deletes by Request Criteria

1. Configure a soft-delete policy and global configuration as shown in “Configuring Soft Deletes as a Global Configuration”.

2. Configure request criteria for soft deletes. The soft delete request criteria is configured for an external delete request from a member of the Internal Applications group matching an entry with object class "inetorgperson" with the request excluding the Soft Delete Request Control and the Hard Delete Request Control.

```
$ bin/dsconfig create-request-criteria \
  --criteria-name "Soft Deletes" \
  --type simple \
  --set "description:Requests for soft delete" \
  --set operation-type:delete \
  --set operation-origin:external-request \
  --set "connection-criteria:Internal Applications" \
  --set not-all-included-request-control:1.3.6.1.4.1.30221.2.5.20 \
  --set "all-included-target-entry-filter:(objectClass=inetorgperson)"
```

3. In the soft delete policy created in step 1, set the `auto-soft-delete-connection-criteria` property to the simple criteria created in the previous step.

```
$ bin/dsconfig create-soft-delete-policy \
  --policy-name default-soft-delete-policy \
  --set "auto-soft-delete-request-criteria:Soft Deletes"
```

To Disable Soft Deletes by Request Criteria

- To disable soft deletes by request criteria, reset the soft-delete policy.

```
$ bin/dsconfig set-soft-delete-policy-prop \
  --policy-name default-soft-delete-policy \
  --reset auto-soft-delete-request-criteria
```

Configuring Soft Delete Automatic Purging

By default, the Data Store retains soft-deleted entries indefinitely. For companies that want to set up automatic purging of soft-deleted entries, the server provides two properties on the Soft Delete Policy that can be configured for either the maximum retention time for all soft-deleted entries and/or the retained number of soft-deleted entries. These changes take effect without requiring a server restart.

To Configure Soft-Delete Automatic Purging

You can change either the retention time or the retained number of entries to enable automatic purging. By default, both are set to an indefinite retention time and number of entries. The time unit of milliseconds (ms), seconds (s), minutes (m), hours (h), days (d), or weeks (w), may be preceded by an integer to specify a quantity for that unit, such as "1 d", "52 w", etc. Once you configure the properties, the changes take effect immediately without the need for a server restart.

Note that the server will delete all of the soft-deleted entries according to the policy in effect. If the policy is changed while entries are in the process of being deleted, the new policy takes effect after the in-process batch of entries is deleted and applies to any remaining soft-deleted entries going forward according to the new policy.

1. Retrieve the name of the Soft Delete Policy in effect using the `dsconfig` command. For this example, the Soft Delete Policy is called `default-soft-delete-policy`.

```
$ bin/dsconfig get-global-configuration-prop \
  --property soft-delete-policy
```

2. Do one or both of the following:

- Run `dsconfig` to set the retention time for soft-deleted entries.

```
$ bin/dsconfig set-soft-delete-policy-prop \
  --policy-name default-soft-delete-policy \
  --set "soft-delete-retention-time:52 w"
```

- Run `dsconfig` to set the retained number of soft-deleted entries.

```
$ bin/dsconfig set-soft-delete-policy-prop \
  --policy-name default-soft-delete-policy \
  --set soft-delete-retain-number-of-entries:1000000
```

3. The Soft Delete Policy must be assigned to the global configuration if it has not been assigned yet.

```
$ bin/dsconfig set-global-configuration-prop \
  --set soft-delete-policy:default-soft-delete-policy
```

To Disable Soft-Delete Automatic Purging

You can disable Soft-Delete automatic purging using the `dsconfig` command. The change takes effect immediately without the need of a server restart. However, if the server is in the middle of an automatic soft-delete purging, it may continue to purge entries until the next time it evaluates the Soft Delete Policy.

- Run `dsconfig` to reset the Soft-Delete Policy properties that control automatic purging: `soft-delete-retention-time` and `soft-delete-retain-number-of-entries`.

```
$ bin/dsconfig set-soft-delete-policy-prop \
  --policy-name default-soft-delete-policy \
  --reset soft-delete-retention-time \
  --reset soft-delete-retain-number-of-entries
```

Summary of Soft and Hard Delete Processed

The following table summarizes the resulting actions of a DELETE operation for soft deletes.

Table 8: If No Automatic Soft Delete Criteria is Configured

Action	Result
Delete	Performs a hard delete on the entry.
Delete with the Soft Delete Request Control	Performs a soft delete on the entry.
Delete of a soft-deleted entry	Performs a hard delete on the entry.
Delete of a soft-deleted entry with the Soft Delete Request Control	Not allowed. Generates an `UNWILLING_TO_PERFORM` error.
Delete with a Hard Delete Request Control	Performs a hard delete on the entry.
Delete of a soft-deleted entry with the Hard Delete Request Control.	Performs a hard delete on the entry.

The following table summarizes the resulting actions of a DELETE operation for soft deletes configured by connection criteria or request criteria.

Table 9: If Soft Delete Connection or Request Criteria is Configured

Action	Result
Delete not matching criteria	Performs a hard delete on the entry.
Delete matching criteria	Performs a soft delete on the entry.
Delete of a soft-deleted entry not matching criteria	Performs a hard delete on the entry.

Action	Result
Delete of a soft-deleted entry matching criteria	Performs a hard delete on the entry.
Delete not matching criteria with the Hard Delete Request Control	Performs a hard delete on the entry.
Delete matching criteria with the Hard Delete Request Control	Performs a hard delete on the entry.
Delete with Soft and Hard Delete Request Controls	Not allowed. Generates an `UNWILLING_TO_PERFORM` error.

Summary of Soft Delete Controls and Tool Options

The following table shows the OIDs for each soft delete control. The Soft Delete OIDs are defined in the LDAP SDK generated API documentation.

Table 10: SOft Delete OIDs

OID Type	OID
Soft Delete Request Control	1.3.6.1.4.1.30221.2.5.20
Soft Delete Response Control	1.3.6.1.4.1.30221.2.5.21
Hard Delete Request Control	1.3.6.1.4.1.30221.2.5.22
Soft Undelete Request Control	1.3.6.1.4.1.30221.2.5.23
Soft Delete Entry Access Control	1.3.6.1.4.1.30221.2.5.24

The following table shows the new tool options available for the Soft Delete operations.

Table 11: Soft Delete Tool Options

Action	Result
ldapdelete / ldapmodify	**--useSoftDelete/-s**. Process DELETE operations with the Soft Delete Request Control, whereby entries are renamed, and hidden instead of being permanently deleted. The Data Store must be configured to allow soft deletes. Note that any entries in the LDIF file with the changetype of `delete` will be processed as a soft-delete request.
ldapdelete	**--useHardDelete**. Process DELETE operations with the Hard Delete Request Control, which bypasses any soft delete policies and processes the delete request immediately without retaining the entry as a soft-deleted entry. The Data Store must be configured to allow soft deletes.
ldapsearch	**--includeSoftDeletedEntries {with-non-deleted-entries | without-non-deleted-entries | deleted-entries-in-undeleted-form}**. Process search operations with the Soft Delete Entry Access Control. Soft delete search options are as follows:

Action	Result
	• **with-non-deleted-entries**. Returns all entries matching the search criteria with the results including non-deleted and soft-deleted entries. • **without-non-deleted-entries**. Returns only soft-deleted entries matching the search criteria. • **deleted-entries-in-undeleted-form**. Returns only soft-deleted entries matching the search criteria with the results returned in their undeleted entry form. Users must have access to the Soft Delete Entry Access Control to be able to search for soft-deleted entries.
ldapmodify	**--allowUndelete**. Process ADD operations which include the `ds-undelete-from-dn` attribute as undelete requests. Undelete requests re-add previously soft-deleted entries back to the server as non-deleted entries by providing the Undelete Request Control with the ADD operation. The Data Store must be configured to allow soft deletes to process any undelete requests and the client user must have the `soft-delete-read` privilege.

The following table shows the symbolic names that can be used with the server's LDAP commands using the `--control/-J` option.

Table 12: Soft Delete OID Symbolic Names using with the --control/-J Option

Control	Symbolic Name
Soft Delete Request Control	softdelete
Hard Delete Request Control	harddelete
Soft Undelete Request Control	undelete
Soft Delete Entry Access Control	softdeleteentryaccess

Monitoring Soft Deletes

The Data Store provides monitoring entries and logs to track all soft delete operations. The access and debug logs do not have any options specific for soft deletes.

New Monitor Entries

Two new monitor entries are present for a backend monitor entry. Administrators will see the following additional monitor entries on `cn=userRoot Backend,cn=monitor`:

- **ds-soft-delete-entry-operations-count**. Displays the number of soft-deletes performed on the backend since server startup.
- **ds-undelete-operations-count**. Displays the number of undeletes performed on the backend since server startup.

- **ds-backend-soft-deleted-entry-count**. Displays the current number of soft-deleted entries in the database.
- **ds-auto-purged-soft-deleted-entry-count**. Displays the current number of soft-deleted entries purged since the backend or server was restarted.

To Monitor Soft Deletes

- Run `ldapsearch` on the `cn=userRoot Backend,cn=monitor` branch. Use a search criteria targeting the `ds-backend-monitor-entry` object class.

```
$ bin/ldapsearch --baseDN "cn=userRoot Backend,cn=monitor" \
  --searchScope sub "(objectclass=ds-backend-monitor-entry)"
```

```
dn: cn=userRoot Backend,cn=monitor
objectClass: top
objectClass: ds-monitor-entry
objectClass: ds-backend-monitor-entry
objectClass: extensibleObject
cn: userRoot Backend
ds-backend-id: userRoot
ds-backend-base-dn: dc=example,dc=com
ds-backend-is-private: FALSE
ds-backend-entry-count: 200001
ds-backend-soft-deleted-entry-count: 1000
ds-soft-delete-operations-count: 40
ds-undelete-operations-count: 20
ds-auto-purged-soft-deleted-entry-count: 0
ds-base-dn-entry-count: 200001 dc=example,dc=com
ds-backend-writability-mode: enabled
```

Access Logs

The access log records the LDAP operations corresponding to soft delete and undelete for DELETE, SEARCH, MODIFY, and ADD operations with the related soft-deleted values. The access log does not require any configuration for soft delete.

For DELETE (soft-delete) operations, the access log displays:

```
[14/May/2012:09:40:16.942 -0500] DELETE RESULT conn=18 op=1 msgID=2
dn="uid=user.1,ou=People,dc=example,dc=com" resultCode=0 etime=30.367
softDeleteEntryDN="entryUUID=4e9b7847-edcb-3791-b11b-7505f4a55af4+uid=user.1,
ou=People,dc=example,dc=com"
```

For SEARCH operations for soft-deleted entries, the log displays:

```
[14/May/2012:09:40:52.320 -0500] SEARCH RESULT conn=19 op=1 msgID=2
base="dc=example,dc=com" scope=2 filter="(objectclass=ds-soft-delete-entry)"
attrs="ALL" resultCode=0 etime=1.631 entriesReturned=1
```

For MODIFY operations of soft-deleted entries, the log displays:

```
[14/May/2012:09:42:43.679 -0500] MODIFY RESULT conn=20 op=1 msgID=1
dn="entryUUID=4e9b7847-edcb-3791-b11b-7505f4a55af4+uid=user.1,ou=People,dc=exam-
ple,dc=com" resultCode=0 etime=2.639 changeToSoftDeletedEntry=true
```

For ADD (soft undelete) operations, the log displays:

```
[14/May/2012:09:58:16.728 -0500] ADD RESULT conn=25 op=1 msgID=1
dn="uid=user.0,ou=People,dc=example,dc=com" resultCode=0 etime=22.700
undeleteFromDN="entryUUID=ad55a34a-763f-358f-93f9-da86f9ecd9e4+uid=user.0,
ou=People,dc=example,dc=com"
```

Audit Logs

The audit log captures any MODIFY and DELETE operations of soft-deleted entries. These changes are recorded as fully commented-out audit log entries. The audit log does not require any configuration for soft deletes.

For any soft-deleted entry, the audit log entry displays the `ds-soft-delete-entry-dn` property and its soft-deleted entry DN.

```
# 14/May/2012:10:57:09.054 -0500; conn=30; op=1
# ds-soft-delete-entry-dn: entryUUID=68147342-1f61-3465-8489-
3de58c532130+uid=user.2,ou=People,dc=example,dc=com
dn: uid=user.2,ou=People,dc=example,dc=com
changetype: delete
```

For any MODIFY changes made, the log displays the LDIF, the modifier's name and update time.

```
# 14/May/2012:10:58:33.566 -0500; conn=33; op=1
# dn: entryUUID=68147342-1f61-3465-8489-3de58c532130+uid=user.2,ou=People,dc=exam-
ple,dc=com
# changetype: modify
# replace: homePhone
# homePhone: +1 003 428 0966
#-
# replace: modifiersName
# modifiersName: uid=admin,dc=example,dc=com
#-
# replace: modifyTimestamp
# modifyTimestamp: 20131010020345.546Z
```

For any undelete of a soft-deleted entry, the log displays the `ds-undelete-from-dn` attribute plus the entry unique ID, create time and creator's name.

```
# 14/May/2012:10:59:21.754 -0500; conn=34; op=1
dn: uid=user.2,ou=People,dc=example,dc=com
changetype: add
uid: user.2
ds-undelete-from-dn: entryUUID=68147342-1f61-3465-8489-3de58c532130+uid=user.2,ou=Peo-
ple,dc=example,dc=com
ds-entry-unique-id:: vw1jg801S7GWrTiS3UE5DA==
createTimestamp:: 20131010181148.630Z
creatorsName: uid=admin,dc=example,dc=com
```

For hard (permanent) deletes of a soft-deleted entry, the log displays the soft-deleted entry DN that was removed.

```
# 14/May/2012:11:00:14.055 -0500; conn=36; op=1
# dn: entryUUID=68147342-1f61-3465-8489-3de58c532130+uid=user.2,ou=People,dc=exam-
ple,dc=com
# changetype: delete
```

To Configure the File-Based Audit Log for Soft Deletes

1. Enable the audit log if it is disabled.

```
$ bin/dsconfig set-log-publisher-prop --publisher-name "File-Based Audit Logger" \
--set enabled:true
```

2. View the audit log. The `soft-delete-entry-audit-behavior` property is set to "`commented`" by default and provides additional information in comments about the soft-deleted entry that was either created or undeleted.

```
# 11/May/2012:15:33:17.552 -0500; conn=13; op=1
# ds-soft-delete-entry-dn:entryUUID=54716bfd-fbc4-3108-ac37-
bf6b1b166e37+uid=user.15,ou=People,dc=example,dc=com
dn: uid=user.15,ou=People,dc=example,dc=com
changetype: delete
```

Change Log

The change log can be configured to capture soft-delete changes to entries, so that external clients, such as a Data Sync Server, can access these changes. The `ds-soft-delete-entry` attribute represents an entry that has been soft-deleted and is part of the source entry passed into the changelog to indicate the entry has been soft-deleted.

Two important points about soft deletes and the changelog are as follows:

- All soft-delete operations appear in the changelog and appear as a regular DELETE operation. When a soft delete occurs, the resulting changelog entry will include a `ds-soft-delete-entry-dn` operational attribute with the value of the soft-deleted entry DN. If you are using the UnboundID Data Sync Server, it does recognize the `ds-soft-delete-entry-dn` attribute and does not do anything with it.
- The changelog backend’s `soft-delete-entry-included-operation` property determines whether or not MODIFY or DELETE operations of soft-deleted entries appear in the changelog. By default, the property is not enabled by default.

To Configure Soft Deletes on the Changelog Backend

1. Configure soft deletes on the changelog backend.

```
$ bin/dsconfig set-backend-prop \
--backend-name changelog \
--set soft-delete-entry-included-operation:delete \
--set soft-delete-entry-included-operation:modify
```

2. Run a soft-delete operation on an entry.

3. View the changelog for the soft-deleted entry.

```
$ bin/ldapsearch --baseDN cn=changelog \
  "(objectclass=*)" "+"
```

```
dn: cn=changelog
subschemaSubentry: cn=schema
entryUUID: 9920f7e9-5a04-392a-82a8-32662d7d3863
ds-entry-checksum: 304022441
dn: changeNumber=1,cn=changelog
targetUniqueId: 94f634df-c90e-39aa-bd4a-9183c29746d0
changeTime: 20120511154141Z
ds-soft-delete-entry-dn: entryUUID=94f634df-c90e-39aa-bd4a-
9183c29746d0+uid=user.9,ou=People,dc=example,dc=com
modifyTimestamp: 20131010020345.546Z
createTimestamp:: 20131010181148.630Z
localCSN: 000001373C900852000000000003
modifiersName: uid=admin,dc=example,dc=com
entry-size-bytes: 298
```

```
subschemaSubentry: cn=schema
entryUUID: 459b06c6-89f3-307e-a515-22433eb420b6
createTimestamp: 20120511154141.431Z
modifyTimestamp: 20120511154141.431Z
ds-entry-checksum: 1157320579
```

Chapter 8 Importing and Exporting Data

The UnboundID Data Store supports import or export of the database backends in LDAP Data Interchange Format (LDIF). The `bin/import-ldif` and `bin/export-ldif` tools can be used to create or export database backends for online of offline servers. The tools support options that can restrict the input or output to a subset of the entries or a subset of the attributes within entries. The tools also provide features to compress, encrypt or digitally sign the data.

This chapter presents the following topics:

Topics:

Importing Data

The UnboundID Data Store provides initialization mechanisms to import database files. The `import-ldif` command-line tool imports data from an LDAP Data Interchange Format (LDIF) file. The data imported by the `import-ldif` command can include all or a portion of the entries (a subset of the entries or a subset of the attributes within entries or both) contained in the LDIF file. The command also supports importing data that has been compressed, encrypted or digitally signed or both.

The `import-ldif` utility can be run with the server offline or online. If the server is online, administrators can initiate the import from a local or remote client. The LDIF file that contains the import data must exist on the server system. During an online import, the target database repository, or backend, will be removed from service and data held in that backend will not be available to clients.

The `import-ldif` tool has been modified to help guard against accidental overwriting of existing backend data with the addition of the `--overwriteExistingEntries` option. This option must be present when performing an import into a backend with a branch that already contains entries (although the option is not needed if a branch contains just a single base entry).

Validating an LDIF File

Prior to importing data, you can validate an import file using the Data Store's `validate-ldif` tool. When run, the tool binds to the Data Store, locally or remotely, and validates the LDIF file to determine whether it violates the server's schema. Those elements that do not conform to the schema will be rejected and written to standard output. You can specify the path to the output file to which the rejected entries are written and the reasons for their rejection. The `validate-ldif` tool works with regular non-compressed LDIF files or gzip-compressed LDIF files.

To process large files faster, you can also set the number of threads for validation. The tool also provides options to skip specified schema elements if you are only validating certain items, such as attributes only. Use the `--help` option to view the arguments.

To Validate an LDIF File

- Use the `validate-ldif` tool to validate an LDIF file. Make sure the server is online before running this command.

```
$ bin/validate-ldif --ldifFile /path/to/data.ldif \
  --rejectFile rejectedEntries
```

```
1 of 200 entries (0 percent) were found to be invalid.
1 undefined attributes were encountered.
Undefined attribute departmentname was encountered 1 times.
```

Computing Database Cache Estimate

After successful completion of an import, the `import-ldif` command lists detailed information about the database cache characteristics of the imported data set. The current server configuration is considered along with the capabilities of the underlying hardware to guide decisions for changing JVM size and database-cache-percent for the backend.

The `import-ldif` command will complete with a summary of database cache usage characteristics for the imported data set. Additional files are available in the `/logs/tools` directory that describe the database cache characteristics in more detail.

Tracking Skipped and Rejected Entries

During import, entries can be skipped if they do not belong in the specified backend, or if they are part of an excluded base DN or filter. The `--skipFile {path}` argument can be used on the command line to indicate that any entries that are skipped should be written to a specified file. You can add a comment indicating why the entries were skipped.

Similarly, the `--rejectFile {path}` argument can be added to obtain information about which entries were rejected and why. An entry can be rejected if it violates the server's schema constraints, if its parent entry does not exist, if another entry already exists with the same DN, or if it was rejected by a plug-in.

Running an Offline Import

You can run the `import-ldif` tool offline to import LDIF data encoded with the UTF-8 character set. This data can come from LDIF files, compressed LDIF files (GZIP format), or from data generated using a MakeLDIF template. You do not need to authenticate as an administrator when performing offline LDIF imports.

To Perform an Offline Import

- Use the `import-ldif` command to import data from an LDIF file. Make sure the Data Store is offline before running this command. Do not specify any connection arguments when running the command.

  ```
  $ bin/import-ldif --backendID userRoot --ldifFile /path/to/data.ldif \
    --rejectFile /path/to/reject.ldif --skipFile /path/to/skip.ldif
  ```

To Perform an Offline LDIF Import Using a Compressed File

- Use the `import-ldif` command to import data from a compressed gzip formatted file. You must also use the `--isCompressed` option to indicate that the input file is compressed. Make sure the Data Store is offline before running this command. Do not specify any connection arguments when running the command.

```
$ bin/import-ldif --backendID userRoot --isCompressed \
  --ldifFile /path/to/data.gz --rejectFile /path/to/reject.ldif \
  --skipFile /path/to/skip.ldif
```

To Perform an Offline LDIF Import Using a MakeLDIF Template

- Use the `import-ldif` command to import data from a MakeLDIF template, which is located in the `<server-root>/config/MakeLDIF`. Make sure the Data Store is offline before running this command. Do not specify any connection arguments when running the command.

  The following command uses the standard data template and generates 10,000 sample entries, and then imports the file to the server.

  ```
  $ bin/import-ldif --backendID userRoot \
    --templateFile config/MakeLDIF/example.template
  ```

Running an Online LDIF Import

Administrators can run LDIF imports while the server is online from another remote server. The online import resembles the offline import, except that you must provide information about how to connect and authenticate to the target server. You can schedule the import of an LDIF file to occur at a particular time using the `--task` and `--start YYYYMMDDhhmmss` options of the `import-ldif` tool.

You can also specify email addresses for users that should be notified whenever the import process completes (regardless of success or failure, or only if the import fails). To set up SMTP notifications, see *Working with the SMTP Account Status Notification Handler*.

To Perform an Online LDIF Import

- Use the `import-ldif` tool to import data from an LDIF. Make sure the Data Store is online before running this command.

  ```
  $ bin/import-ldif --task --hostname server1 --port 389 \
    --bindDN uid=admin,dc=example,dc=com --bindPassword password \
    --backendID userRoot --ldifFile userRoot.ldif
  ```

To Schedule an Online Import

1. Use the `import-ldif` tool to import data from an LDIF file at a scheduled time. To specify a time in the UTC time zone, include a trailing “Z”. Otherwise, the time will be treated as a local time in the time zone configured on the server. Make sure the Data Store is online before running this command.

   ```
   $ bin/import-ldif --task \
     --hostname server1 \
     --port 389 \
   ```

```
  --bindDN uid=admin,dc=example,dc=com \
  --bindPassword password \
  --backendID userRoot \
  --ldifFile /path/to/data.ldif \
  --start 20111026010000 \
  --completionNotify import-complete@example.com \
  --errorNotify import-failed@example.com
```

```
Import task 2011102617321510 scheduled to start Oct 26, 2011 1:00:00 AM CDT
```

2. Confirm that you successfully scheduled your import task using the `manage-tasks` tool to view a summary of all tasks on the system.

```
$ bin/manage-tasks --summary
```

```
ID             Type   Status
-----------------------------------------------
2011102617321510 Import Waiting on start time
```

3. Use the `manage-tasks` tool to monitor the progress of this task. Use the task ID of the import task. If you cannot find the task ID, use the `--summary` option to view a list of all tasks scheduled on the Data Store.

```
$ bin/manage-tasks --info 2011102617321510
```

```
Task                     Details
-----------------------------------------------------
ID                       2011102617321510
Type                     Import
Status                   Waiting on start time
Scheduled Start Time     Oct 26, 2011 1:00:00 AM CDT
Actual Start Time
Completion Time
Dependencies Failed      None
Dependency Action        None
Email Upon Completion    admin@example.com
Email Upon Error         admin@example.com

Import        Options
----------------------------
LDIF File  /path/to/data.ldif
Backend ID userRoot
```

To Cancel a Scheduled Import

- Use the `manage-tasks` tool to cancel the scheduled task.

```
$ bin/manage-tasks --cancel 2011102417321510
```

Adding Entries to an Existing Data Store

To add entries to an existing Data Store while preserving operational attributes, such as `createTimestamp` or `modifiersName`, the Ignore No User Modification control must be attached to the request. The Ignore No User Modification control allows modification of certain attributes that have the No User Modification constraint. Special care should be used with this control.

The Ignore No User Modification is only applied to ADD requests. Using the control to modify an existing entry, resulting in an operational attribute change, will fail.

To Append Entries to an Existing Data Store

- Use `ldapmodify` with the Ignore No User Modification control (i.e., the OID is 1.3.6.1.4.1.30221.2.5.5).

```
$ bin/ldapmodify --control 1.3.6.1.4.1.30221.2.5.5 \
  --filename change-record.ldif
```

Filtering Data Import

The `import-ldif` command provides a way to either include or exclude specific attributes or entries during an import. The arguments are summarized as follows:

Table 13: Inclusion and Exclusion Arguments for import-ldif

Argument	Description
--includeBranch	Base DN of a branch to include in the LDIF import (can be specified multiple times)
--excludeBranch	Base DN of a branch to exclude from the LDIF import (can be specified multiple times)
--includeAttribute	Attribute to include in the LDIF import (can be specified multiple times)
--excludeAttribute	Attribute to exclude from the LDIF import (can be specified multiple times)
--includeFilter	Search filter to identify entries to include in the LDIF import (can be specified multiple times)
--excludeFilter	Search filter to identify entries to exclude from the LDIF import (can be specified multiple times)
--excludeOperational	Exclude operational attributes from the LDIF import.
--excludeReplication	Exclude replication attributes from the LDIF import.
--excludeSoftDelete	Exclude soft delete entries from the LDIF import.

Exporting Data

The UnboundID Data Store `export-ldif` command-line tool exports data from Data Store backend to an LDAP Data Interchange Format (LDIF) file. The tool must be run in the non-task based mode, which implies that it works outside of the server JVM process. The `export-ldif` must be run without connection or task arguments while the server is either online or offline. This tool exports a point-in-time snapshot of the backend which is guaranteed to provide a consistent state of the database, in LDIF, which can be reimported with `import-ldif` if necessary.

The data exported by `export-ldif` can include all or a portion of the entries (a subset of the entries or a subset of the attributes within entries or both) contained in the backend. This is accomplished by specifying branches, filters, and attributes to include or exclude. The exported LDIF can be compressed, encrypted or digitally signed.

To Perform an Export

- Use the `export-ldif` command to export data to an LDIF file.

```
$ bin/export-ldif --backendID userRoot --ldifFile userRoot.ldif
```

To Perform an Export from Specific Branches

- Use the `export-ldif` command to export data to an LDIF file under a specific branch from the userRoot backend of the local Data Store into a compressed file. The command also excludes operational attributes from the exported data and wraps long lines at column 80.

```
$ bin/export-ldif --backendID userRoot --ldifFile userRoot.ldif.gz --compress \
  --includeBranch ou=people,dc=example,dc=com --excludeOperational \
  --wrapColumn 80
```

Encrypting LDIF Exports and Signing LDIF Files

The Data Store provides features to encrypt data during an LDIF export using the `export-ldif --encryptLDIF` option and to allow the encrypted LDIF file to be imported onto the same instance or another server in the same replication topology using the `import-ldif --isEncrypted` option.

The Data Store also provides an additional argument that digitally signs the contents of the LDIF file, which ensures that the content has not been altered since the export. To digitally sign the contents of the exported LDIF file, use the `export-ldif --sign` option. To allow a signed LDIF file to be imported onto the same instance or another server in the same topology, use the `import-ldif --isSigned` option.

Note that there is not much added benefit to both signing and encrypting the same data, since encrypted data cannot be altered without destroying the ability to decrypt it.

To Encrypt an LDIF Export

- Run `export-ldif` tool with the `--encryptLDIF` option to encrypt the data during an export to an output LDIF file. The following command runs an offline export of the userRoot backend, and encrypts the file when written to an output file called `data.ldif`.

```
$ bin/export-ldif --backendID userRoot --ldifFile /path/to/data.ldif \
  --encryptLDIF
```

To Import an Encrypted LDIF File

An encrypted LDIF file can be imported into the same instance from which it was exported, or into any other server in the same replication topology with that instance. You cannot import an encrypted LDIF file into a server that is not in some way connected to the instance from which it was exported.

- Run the `import-ldif` tool to import the encrypted LDIF file from the previous example. The command imports the `data.ldif` file, decrypts the contents while overwriting the existing contents to the `userRoot` backend. The command requires the `--isEncrypted` option, which instructs the tool that the LDIF file is encrypted.

```
$ bin/import-ldif --backendID userRoot --ldifFile /path/to/data.ldif \
  --overwriteExistingEntries --isEncrypted
```

To Sign an Export

- Run `export-ldif` tool with the `--sign` option to digitally sign the data during an export to an output LDIF file. The following command runs an offline export of the `userRoot` backend, and signs the content when written to an output file called `data.ldif`.

```
$ bin/export-ldif --backendID userRoot \
  --ldifFile /path/to/data.ldif --sign
```

To Import a Signed LDIF File

- Run the `import-ldif` tool to import the signed LDIF file from the previous example. The command imports the `data.ldif` file, checks the signature of the contents while overwriting the existing contents to the `userRoot` backend. The command requires the `--isSigned` option, which instructs the tool that the contents of the LDIF file is signed.

```
$ bin/import-ldif --backendID userRoot \
  --ldifFile /path/to/data.ldif \
  --overwriteExistingEntries --isSigned
```

Filtering Data Exports

The `export-ldif` command analogous arguments to the `import-ldif` tool to provide a way to either include or exclude specific attributes or entries during an export. The arguments are summarized as follows:

Table 14: Inclusion and Exclusion Arguments for export-ldif

Argument	Description
--includeBranch	Base DN of a branch to include in the LDIF export (can be specified multiple times)
--excludeBranch	Base DN of a branch to exclude from the LDIF export (can be specified multiple times)
--includeAttribute	Attribute to include in the LDIF export (can be specified multiple times)
--excludeAttribute	Attribute to exclude from the LDIF export (can be specified multiple times)
--includeFilter	Filter to identify entries to include in the LDIF export (can be specified multiple times)
--excludeFilter	Filter to identify entries to exclude from the LDIF export (can be specified multiple times)
--excludeOperational	Exclude operational attributes from the LDIF export.
--excludeReplication	Exclude replication attributes from the LDIF export.

Argument	Description
--excludeSoftDelete	Exclude soft delete entries from the LDIF export.

Scrambling Data Files

The Data Store provides an LDIF scrambling tool (`scramble-ldif`) that obscures the contents of a specified set of attributes. Scrambling data can be useful if you want to use real production data to test the UnboundID Data Store, but do not want to expose the data internally to employees. The tool is also useful to scramble data when providing Data Store data to a third party to investigate a problem.

The `scramble-ldif` tool was designed to ensure that the information is completely obscured in a non-reversible manner. The tool maintains the entry's indexing characteristics that are consistent with the real data while adhering to the associated attribute syntax. Alphabetic characters are replaced with random alphabetic characters (preserving the case of those letters), and numeric digits are replaced with random numeric digits. The algorithm used to select the letters and digits ensures that the same clear-text value will always result in the same scrambled value in the LDIF file (although the values can be scrambled differently each time the tool is run). Non-alphanumeric characters will be left unaltered.

The `scramble-ldif` tool has options to sequentially generate numbers for specified attribute values. This feature is useful when running tests on your scrambled data. The tool also has an option to gzip compress the scrambled LDIF output file.

To Scramble an LDIF File

This procedure scrambles the data in the following example LDIF entry:

```
dn: uid=smith,ou=People,dc=example,dc=com
objectClass: person
objectClass: inetOrgPerson
objectClass: organizationalPerson
objectClass: top
postalAddress: Aaron Smith$01251 Chestnut Street$Panama City, DE 50369
postalCode: 50369
description: This is the description for Aaron Smith.
uid: asmith
userPassword: password
employeeNumber: 0
initials: AGS
givenName: Aaron
pager: +1 779 041 6341
mobile: +1 010 154 3228
cn: Aaron Smith
sn: Smith
telephoneNumber: +1 685 622 6202
street: 01251 Chestnut Street
homePhone: +1 225 216 5900
l: Panama City
mail: asmith@example.com
st: DE
```

1. Use the `scramble-ldif` tool to scramble an import LDIF file.

```
$ bin/scramble-ldif --sourceLDIF real-data.ldif --targetLDIF scramble.ldif \
  --attributeName postalAddress \
  --attributeName description \
  --attributeName uid \
  --attributeName userPassword \
  --attributeName employeenumber \
  --attributeName initials \
  --attributeName givenName \
  --attributeName pager \
  --attributeName mobile \
  --attributeName cn \
  --attributeName sn \
  --attributeName telephoneNumber \
  --attributeName street \
  --attributeName homephone \
  --attributeName mail \
  --attributeName uid \
  --processDNs
```

```
Processing complete. 100004 entries written
```

2. Check the LDIF file using the `ldifsearch` command with a general search filter, such as `(objectclass=*)`. The Data Store provides utilities to search (`ldifsearch`), modify (`ldifmodify`), or compare (`ldif-diff`) LDIF files without binding to the server.

```
$ bin/ldifsearch --ldifFile scramble.ldif "(objectclass=*)"
```

```
dn: uid=xjgtld,ou=People,dc=example,dc=com
objectClass: person
objectClass: organizationalPerson
objectClass: inetOrgPerson
objectClass: top
postalAddress: Mucvm Sdzyv$44727 Yjsyybhr Bbxmun$Rzgafz Byul, BW 46369
postalCode: 50369
description: Isho pk uyp mexwfvfpuig srn Vkpta Dutrx.
uid: xjgtld
userPassword: wtxooikk
employeenumber: 3
initials: JHU
... (more output) ...
```

To Sequentially Scramble Specific Attributes

- Use the `scramble-ldif` command to obfuscate specific attributes from an import LDIF file.

  The following command scrambles the `givenName`, `cn`, `sn`, and `uid` attributes. The `uid` attribute is replaced with the value 10000. Each subsequent `uid` attribute will be sequentially ordered; thus, the next entry will have a `uid` attribute with the value of 10001. The `--processDNs` option scrambles the DNs with the same scrambled value for the `uid` attribute.

```
$ bin/scramble-ldif --sourceLDIF real-data.ldif --targetLDIF scramble.ldif \
  --attributeName uid \
  --attributeName givenName \
  --attributeName cn \
  --attributeName sn \
  --attributeName uid \
  --sequentialAttributeName uid \
  --initialSequentialValue 10000 \
  --processDNs
```

Chapter 9 Backing Up and Restoring Data

The UnboundID Data Store provides efficient `backup` and `restore` command-line tools that support full and incremental backups. The backups can also be scheduled using the UNIX-based cron scheduler or using the Data Store's Task-based scheduler.

This chapter presents the following topics:

Topics:

Backing Up and Restoring Data

Administrators should have a comprehensive backup strategy and schedule that comprise of daily, weekly, and monthly backups including incremental and full backups of the data store data, configuration, and backends. Administrators should also have a backup plan for the underlying filesystem; for example, taking regular snapshots on ZFS systems on Solaris-based machines. This dual purpose approach provides excellent coverage in the event that a server database must be restored for any reason.

The UnboundID Data Store provides efficient `backup` and `restore` command-line tools that support full and incremental backups. The backups can also be scheduled using the UNIX-based cron scheduler or using the Data Store's Task-based scheduler. The Data Store can run backups with the server online while processing other requests, so that there is no need to shut down the server or place it in read-only mode prior to starting a backup.

If you back up more than one backend, the `backup` tool creates a subdirectory below a specified backup directory for each backend. If you back up only a single backend, then the backup files will be placed in the specified directory. A single directory can only contain files from one backend, so that you cannot have backup files from multiple different backends in the same backup directory.

When performing a backup, the server records information about the current state of the server and backend, including the server product name, the server version, the backend ID, the set of base DNs for the backend, and the Java class used to implement the backend logic. For JE backends, the backup descriptor also includes information about the Berkeley DB JE version and information about the attribute and VLV indexes that have been defined.

When restoring a backup, the server compares the descriptor obtained from the backup with the current state of the server and backend. If any problems are identified, the server generates warnings or errors. The administrator can choose to ignore the warnings with the `ignoreCompatibilityWarnings` option to the `restore` tool, whereas errors will always cause the restore to fail. For example, when restoring a *newer* backup into an older version of the server, a warning will be generated. When restoring an *older* backup into a new version of the server, no warning will be generated, but because the `config` and `schema` backends require special handling, the server generates an error if the server versions do not match exactly (major, minor, point, and patch version numbers).

The Data Store's `backup` command and ZFS snapshots provide good coverage in the event a database needs to be restored. For example, the server database would require restoration if the following occurs: 1) the underlying disks have gone bad and the database is inaccessible, 2) the filesystem is operational but the database has become out-of-sync, 3) some application error has occurred data. The Data Store's `backup` command can help with the first case as it provides a way to store backups on a separate disk from the database itself. ZFS snapshots can help with the last two cases.

To List the Available Backups on the System

- Use the `restore` tool to list the backups in a `backup` directory.

```
$ bin/restore --listBackups --backupDirectory /mybackups
```

```
[13:26:21] The console logging output is also available in '/ds/UnboundID-DS/logs/
 tools/restore.log'

Backup ID:          20120212191715Z
Backup Date:        12/Feb/2012:13:17:19 -0600
Is Incremental:     false
Is Compressed:      false
Is Encrypted:       false
Has Unsigned Hash: false
Has Signed Hash:    false
Dependent Upon:     none
Backup ID:          20120212192411Z
Backup Date:        12/Feb/2012:13:24:16 -0600
Is Incremental:     true
Is Compressed:      false
Is Encrypted:       false
Has Unsigned Hash: false
Has Signed Hash:    false
Dependent Upon:     20120212191715Z
```

To Back Up All Backends

- Use `backup` to save the all of the server’s backends. The optional `--compress` option can reduce the amount of space that the backup consumes, but can also significantly increase the time required to perform the backup.

```
$ bin/backup --backUpAll --compress --backupDirectory /path/to/backup
```

To Back Up a Single Backend

- Go to the server root directory, and use the `backup` tool to save the single backend, userRoot.

```
$ bin/backup --backendID userRoot --compress --backupDirectory /path/to/backup
```

To Perform an Offline Restore

- Use the `restore` command to restore the userRoot backend. Only a single backend can be restored at a time. The Data Store must be shut down before performing an offline restore.

```
$ bin/restore --backupDirectory /path/to/backup/userRoot
```

Note: The server root directory should never be restored from a file system backup or snapshot.

To Assign an ID to a Backup

- Go to the server root directory, and use the backup tool to save the single backend, userRoot. The following command assigns the backup ID "weekly" to the userRoot backup. The backup file appears under `backups/userRoot` directory as `userRoot-backup-weekly`.

```
$ bin/backup --backupDirectory /path/to/backups/userRoot \
  --backendID userRoot --backupID weekly
```

To Run an Incremental Backup on All Backends

The Data Store provides support for incremental backups, which backs up only those items that have changed since the last backup (whether full or incremental) on the system, or since a specified earlier backup. Incremental backups must be placed in the same backup directory as the full backup on which they are based.

- The following command runs an incremental backup on all backends based on the most recent backup:

```
$ bin/backup --backUpAll --incremental --backupDirectory /path/to/backup
```

To Run an Incremental Backup on a Single Backend

- Go to the server root directory, and use `backup` to save the single backend, userRoot.

```
$ bin/backup --backendID userRoot --incremental --backupDirectory /path/to/backup
```

To Run an Incremental Backup based on a Specific Prior Backup

- You can run an incremental backup based on a specific prior backup that is not the most current version on the system. To get the backup ID, use the `restore --listBackups` command (see below).

```
$ bin/backup --backUpAll --incremental --backupDirectory /path/to/backup \
  --incrementalBaseID backup-ID
```

To Restore an Incremental Backup

The process for restoring an incremental backup is exactly the same as the process for restoring a full backup for both the online and offline restore types. The `restore tool` will automatically ensure that the full backup and any intermediate incremental backups are restored first before restoring the final incremental backup. The tool will not restore any files in older backups that are no longer present in the final data set.

To Schedule an Online Backup

You can schedule a backup to run as a Task by specifying the timestamp with the `--task` and `--start` options. The option is expressed in "YYYYMMDDhhmmss’" format. If the option has a value of "0" then the task is scheduled for immediate execution. You cannot run recurring tasks, so daily operations must be run using cron or through some system that can submit the task.

For online (remote) backups, the backup operation can be conducted while the UnboundID Data Store is online if you provide information about how to connect and to authenticate to the target Data Store.

- You can schedule the backup to occur at a specific time using the Task-based `--start YYYYMMDDhhmmss` option. To specify a time in the UTC time zone format, add a trailing “Z” to the time. Otherwise, the time will be treated as a local time in the time zone configured on the server.

```
$ bin/backup --backUpAll --task --start 20111025010000 \
  --backupDirectory /path/to/backup --completionNotify admin@example.com \
  --errorNotify admin@example.com
```

```
Backup task 2011102500084110 scheduled to start Oct 28, 2011 1:00:00 AM CDT
```

To Schedule an Online Restore

By providing connection and authentication information (and an optional start time), the restore can be performed via the Tasks subsystem while the server is online. The Tasks subsystem allows you to schedule certain operations, such as `import-ldif`, `backup`, `restore`, `start-ds`, and `stop-ds`. You can schedule a restore to run as a Task by specifying the timestamp with the `--task` and `--start` options. The option is expressed in "YYYYMMDDhhmmss’" format. If the option has a value of "0" then the task is scheduled for immediate execution. You cannot run recurring tasks, so daily operations must be run using cron or through some system that can submit the task.

- The backend that is being restored will be unavailable while the restore is in progress. To specify a time in the UTC time zone, add a trailing “Z” to the time. Otherwise, the time will be treated as a local time in the configured time zone on the server.

```
$ bin/restore --task --start 20111025010000 \
  --backupDirectory /path/to/backup/userRoot \
  --completionNotify admin@example.com --errorNotify admin@example.com
```

To Encrypt a Backup

- Go to the server root directory, and use the `backup` tool to backup up the single backend, userRoot and encrypt it with the `--encrypt` option.

```
$ bin/backup --encrypt --backendID userRoot --compress --backupDirectory /path/to/
backup
```

To Sign a Hash of the Backup

- Go to the server root directory, and use the `backup` tool to backup up the single backend, userRoot. Use the `-signHash` option to generate a hash of the backup contents and digitally sign the hash of the backup contents. If you want to generate only a hash of the backup contents, run backup with the `--hash` option.

```
$ bin/backup --signHash --backupDirectory backups/userRoot --backendID userRoot \
  --backupDirectory /path/to/backup
```

To Restore a Backup

- Go to the server root directory, and use the `restore` tool to restore a backup. The `backup` tool uses a descriptor file to access property information used for the backup, indicating if the backup was compressed, signed and/or encrypted.

  ```
  $ bin/restore --backupDirectory /path/to/backup
  ```

Moving or Restoring a User Database

Part of any disaster recovery involves the restoration of the user database from one server to another. You should have a well-defined backup plan that takes into account whether or not your data is replicated among a set of servers. The plan is the best insurance against significant downtime or data loss in the event of unrecoverable database issue.

Keep in mind the following general points about database recovery:

- **Regular Backup from Local Replicated Data Store**. Take a backup from a local replicated data store and restore to the failed server. This will be more recent than any other backup you have.
- **Restore the Most Recent Backup**. Restore the most recent backup from a local server. In some cases, this may be preferred over taking a new backup if that would adversely impact performance of the server being backed up although it will take longer for replication to play back changes.
- **Contact Support**. If all else fails, contact your authorized support provider and they can work with you (and possibly in cooperation with the Oracle Berkeley DB JE engineers) to try a low-level recovery, including tools that attempt to salvage whatever data they can obtain from the database.

Comparing the Data in Two Data Stores

The UnboundID Data Store provides an `ldap-diff` tool to compare the data on two LDAP servers to determine any differences that they may contain. The differences are identified by first issuing a subtree search on both servers under the base DN using the default search filter `(objectclass=*)` to retrieve the DNs of all entries in each server. When the tool finds an entry that is on both servers, it retrieves the entry from each server and compares all of its attributes. The tool writes any differences it finds to an LDIF file in a format that could be used to modify the content of the source server, so that it matches the content of the target server. Any non-synchronized entries can be compared again for a configurable number of times with an optional pause between each attempt to account for replication delays.

You can control the specific entries to be compared with the `--searchFilter` option. In addition, only a subset of attributes can be compared by listing those attributes as trailing arguments of the command. You can also exclude specific attributes by prepending a ^ character to the attribute. (On Windows operating systems, excluded attributes must be quoted, for example, "`^attrToExclude`".) The `@objectClassName` notation can be used to compare only attributes that are defined for a given objectclass.

The `ldap-diff` tool can be used on servers actively being modified by checking differing entries multiple times without reporting false positives due to replication delays. By default, it will re-check each entry twice, pausing two seconds between checks. These settings can be configured with the `--numPasses` and `--secondsBetweenPass` options. If the utility cannot make a clean comparison on an entry, it will list any exceptions in comments in the output file.

The Data Store user specified for performing the searches must be privileged enough to see all of the entries being compared and to issue a long-running, unindexed search. For the Data Store, the out-of-the-box `cn=Directory Manager` user has these privileges, but you can assign the necessary privileges by setting the following attributes in the user entry:

```
ds-cfg-default-root-privilege-name: unindexed-search
ds-cfg-default-root-privilege-name: bypass-acl
ds-rlim-size-limit: 0
ds-rlim-time-limit: 0
ds-rlim-idle-time-limit: 0
ds-rlim-lookthrough-limit: 0
```

The `ldap-diff` tool tries to make efficient use of memory, but it must store the DNs of all entries in memory. For Data Stores that contain hundreds of millions of entries, the tool might require a few gigabytes of memory. If the progress of the tool slows dramatically, it might be running low on memory. The memory used by the `ldap-diff` tool can be customized by editing the `ldap-diff.java-args` setting in the `config/java.properties` file and running the `dsjavaproperties` command.

If you do not want to use a subtree search filter, you can use an input file of DNs for the source, target, or both. The format of the file can accept various syntaxes for each DN:

```
dn: cn=this is the first dn
dn: cn=this is the second dn and it is wrapped cn=this is the third dn
# The following DN is base-64 encoded dn::
Y249ZG9uJ3QgeW91IGhhdmUgYmV0dGVyIHRoaW5ncyB0byBkbyB0aGFuIHNlZSB3aGF0IHRoaXMgc2F5cw==
# There was a blank line above dn: cn=this is the final entry.
```

Caution: Do not manually update the servers when the tool identifies differences between two servers involved in replication. First contact your authorized support provider for explicit confirmation, because manual updates to the servers risk introducing additional replication conflicts.

To Compare Two Data Stores Using ldap-diff

1. Use `ldap-diff` to compare the entries in two Data Store instances. Ignore the `userpassword` attribute due to the one-way password hash used for the password storage scheme.

```
$ bin/ldap-diff --outputLDIF difference.ldif \
  --sourceHost server1.example.com --sourcePort 1389 \
  --sourceBindDN "cn=Directory Manager" --sourceBindPassword secret1 \
  --targetHost server2.example.com --targetPort 2389 \
  --targetBindDN "cn=Directory Manager" --targetBindPassword secret2 \
  --baseDN dc=example,dc=com --searchFilter "(objectclass=*)" "^userpassword"
```

2. Open the output file in a text editor to view any differences. The file is set up so that you can re-apply the changes without any modification to the file contents. The file shows any deletes, modifies, and then adds from the perspective of the source server as the authoritative source.

```
# This file contains the differences between two LDAP servers.
#
# The format of this file is the LDIF changes needed to bring server
# ldap://server1.example.com:1389 in sync with server
# ldap://server2.example.com:2389.
#
# These differences were computed by first issuing an LDAP search at both
# servers under base DN dc=example,dc=com using search filter (objectclass=*)
# and search scope SUB to first retrieve the DNs of all entries. And then each
# entry was retrieved from each server and attributes: [^userpassword] were
# compared. # # Any entries that were out-of-sync were compared a total of 3 times
# waiting a minimum of 2 seconds between each attempt to account for replication
# delays.
#
# Comparison started at [24/Feb/2010:10:34:20 -0600]
# The following entries were present only on ldap://server2.example.com:2389 and
# need to be deleted. This entry existed only on ldap://server1.example.com:1389
# Note: this entry might be incomplete. It only includes attributes:
# [^userpassword]dn: uid=user.200,ou=People,dc=example,dc=com
# objectClass: person
# objectClass: inetOrgPerson
... (more attributes not shown) ...
# st: DC
dn: uid=user.200,ou=people,dc=example,dc=com
changetype: delete

# The following entries were present on both servers but were out of sync.

dn: uid=user.199,ou=people,dc=example,dc=com
changetype: modify
add: mobile
mobile: +1 300 848 9999
-
delete: mobile
mobile: +1 009 471 1808

# The following entries were missing on ldap://server2.example.com:2389 and need
# to be added. This entry existed only on ldap://server2.example.com:2389
# Note: this entry might be incomplete. It only includes attributes:

# [^userpassword]
dn: uid=user.13,ou=People,dc=example,dc=com
changetype: add
objectClass: person
objectClass: inetOrgPerson
... (more attributes not shown) ...
# Comparison completed at [24/Feb/2010:10:34:25 -0600]
```

To Compare Configuration Entries Using ldap-diff

- Use `ldap-diff` to compare the configuration entries in two Data Store instances. The filter searches all configuration entries. Ignore the `userpassword` attribute due to the password storage scheme that uses a one-way hashing algorithm.

```
$ bin/ldap-diff --outputLDIF difference.ldif \
  --sourceHost server1.example.com --sourcePort 1389 \
  --sourceBindDN "cn=Directory Manager" --sourceBindPassword secret1 \
  --targetHost server2.example.com --targetPort 2389 \
  --targetBindDN "cn=Directory Manager" --targetBindPassword secret2 \
  --baseDN cn=config --searchFilter "(objectclass=*)" "^userpassword"
```

To Compare Entries Using Source and Target DN Files

- Use `ldap-diff` to compare the entries in two Data Store instances. In the following example, the utility uses a single DN input file for the source and target servers, so that no search filter is used. Ignore the `userpassword` attribute due to the password storage scheme that uses a one-way hashing algorithm.

```
$ bin/ldap-diff --outputLDIF difference.ldif \
  --sourceHost server1.example.com --sourcePort 1389 \
  --sourceBindDN "cn=Directory Manager" --sourceBindPassword secret1 \
  --targetHost server2.example.com --targetPort 2389 \
  --targetBindDN "cn=Directory Manager" --targetBindPassword secret2 \
  --baseDN "dc=example,dc=com" --sourceDNsFile input-file.ldif \
  --targetDNsFile input-file.ldif "^userpassword"
```

To Compare Data Stores for Missing Entries Only Using ldap-diff

- Use `ldap-diff` to compare two Data Stores and return only those entries that are missing on one of the servers using the `--missingOnly` option, which can significantly reduce the runtime for this utility.

```
$ bin/ldap-diff --outputLDIF difference.ldif \
  --sourceHost server1.example.com --sourcePort 1389 \
  --sourceBindDN "cn=Directory Manager" --sourceBindPassword secret1 \
  --targetHost server2.example.com --targetPort 2389 \
  --targetBindDN "cn=Directory Manager" --targetBindPassword secret2 \
  --baseDN dc=example,dc=com --searchFilter "(objectclass=*)" "^userpassword" \
  --missingOnly
```

Chapter 10 Working with Indexes

The UnboundID Data Store uses indexes to improve database search performance and provide consistent search rates regardless of the number of database objects stored in the Directory Information Tree (DIT). Indexes are associated with attributes and stored in database index files, which are managed separately for each base DN in the Data Store.

This chapter presents topics related to indexes:

Topics:

Overview of Indexes

The UnboundID Data Store uses indexes to improve database search performance and provide consistent search rates regardless of the number of database objects stored in the Directory Information Tree (DIT). Indexes are associated with attributes and stored in database index files, which are managed separately for each base DN in the Data Store. The Data Store automatically creates index files when you first initialize a base DN or when you use the `dsconfig` tool to create a local DB backend. During modify operations, the Data Store updates the database index files.

The UnboundID Data Store comes with the following types of indexes:

- **Default system indexes** to ensure that the server operates efficiently. These indexes consists of database files that contain index keys mapping to the list of entry IDs.
- **Default Local DB indexes** that are created for each database suffix. You can modify the index to meet your system’s requirements using the `dsconfig` tool.
- **Local DB VLV indexes** that allow a client to request the server to send search results using the Virtual List View control.
- **Filtered Indexes** that provide the ability to index an attribute but only for entries that match a specified filter based on an equality index. The filtered index can only be used for searches containing that filter. The filtered index can be maintained independently of the equality index for that attribute and even if a normal equality index is not maintained for that attribute.

General Tips on Indexes

Administrators should keep the following tips in mind when working with indexes:

- **Important Critical Indexes**. The Data Store has several built-in indexes on the Local DB Backend that are critical to internal server processing and should never be removed.

  ```
  aci, ds-entry-unique-id, objectClass
  ```

- **Built-in Indexes for Efficient Queries**. The Data Store has built-in indexes on the Local DB Backend that support efficient queries over standard LDAP. These indexes are not required for all deployments.

  ```
  cn, givenName, mail, member, sn, telephoneNumber, uid, uniqueMember
  ```

  If the data in the directory does not include these attributes, then the indexes can be removed. Note however that there is also no cost to having them present either. If the data includes these attributes, but they are not used in queries, then they can be removed, which will reduce the size of the database both on disk and in memory.

- **Online Rebuilds**. Whenever an online index rebuild is in progress, the data in that backend will be available and writable although the index being rebuilt will not be used; therefore, searches which attempt to use that attribute might be unindexed.
- **Index Rebuild Administrative Alert**. The Data Store generates an administrative alert when the rebuild process begins and ends. It will have a degraded-alert-type of "index-rebuild-in-progress" so that a proxy server, such as the Data Store can avoid using that server while the rebuild is in progress.
- **System Indexes Cannot be Rebuilt**. The contents of the backend must be exported and re-imported in order to rebuild system indexes. See the table below for the list of system indexes.
- **Indexing Certain Attributes**. You should ensure that the following recommendations are used when setting up the indexes.
  - Equality and substring indexes should not be used for attributes that contain binary data.
  - Approximate indexes should be avoided for attributes containing numbers, such as telephone numbers.
- **Unindexed Searches**. Attributes that are not indexed are unindexed and result in longer search times as the database itself has to be searched instead of the database index file. Only users with the `unindexed-search` privilege are allowed to carry out unindexed searches. In general, applications should be prevented from performing unindexed searches, so that searches that are not indexed would be rejected rather than tying up a worker thread. The ways to achieve this include:
  - Make sure that only the absolute minimum set of users have the `unindexed-search` privilege.
  - Make sure that `allow-unindexed-searches` property is set to false in all client connection policies in which unindexed searches should never be necessary.
  - Set a nonzero value for the `maximum-concurrent-unindexed-searches` global configuration property to ensure that if unindexed searches are allowed, only a limited number of them will be active at any given time. Administrators can configure the maximum number of concurrent unindexed searches by setting a property under Global Configuration.

    To change the maximum number of concurrent unindexed searches, use the `dsconfig` tool to set a value for the number. A value of "0" (default) represents no limit on the number of concurrent unindexed searches.

    ```
    $ bin/dsconfig set-global-configuration-prop \
      --set maximum-concurrent-unindexed-searches:2
    ```
- **Index Entry Limit**. The Data Store specifies an index entry limit property. This property defines the maximum number of entries that are allowed to match a given index key before it is no longer maintained by the server. If the index keys have reached this limit (default value is 4000), then you must rebuild the indexes using the `rebuild-index` tool. If an index entry limit value is set for the local DB backend, it overrides the value set for the overall JE backend index entry limit configuration (i.e., 4000).

To change the default index entry limit, use the `dsconfig` tool as seen in the following example:

```
$ bin/dsconfig set-local-db-index-prop --backend-name userRoot \
  --index-name cn --set index-entry-limit:5000
```

- **Rebuild Index vs Full Import**. You can expect a limited amount of database growth due to the existence of old data when running `rebuild-index` versus doing a full import of your database.

Index Types

The UnboundID Data Store supports several types of indexes to quickly find entries that match search criteria in LDAP operations. The Data Store uses an attribute's matching rules to normalize its values and uses those values as index keys to a list of matching entry IDs. Entry IDs are integer values that are used to uniquely identify an entry in the backend by means of a set of database index files (`id2entry`, `dn2id`, `dn2uri`, `id2children`, `id2subtree`).

Matching rules are elements defined in the schema that tell the server how to interact with the particular attribute. For example, the uid attribute has an equality matching rule defined in the schema, and thus, has an equality index maintained by the Data Store. The following table describes the index types:

Table 15: Data Store Index Types

Index Type	Description
Approximate	Used to efficiently locate entries that match the approximate search filter. It is used to identify which entries are approximately equal to a given assertion. Approximate indexes can only be applied to attributes that have a corresponding approximate matching rule.
Equality	Used to efficiently locate entries that match the equality search filter. It is used to identify which entries are exactly equal to a given assertion. Equality indexes can only be applied to attributes that have a corresponding equality matching rule. An offshoot of the equality index is the filtered index, which uses a defined search filter for a specific attribute. The filtered index can be maintained independently of the equality index for a specific attribute.
Ordering	Used to efficiently locate entries that match the ordering search filter. It is used to identify which entries have a relative order of values for an attribute. Ordering indexes can only be applied to attributes that have a corresponding ordering matching rule.
Presence	Used to efficiently locate entries that match the presence search filter. It is used to identify which entries have at least one value for a specified attribute. There is only one presence index key per attribute.
Substring	Used to efficiently locate entries that match the substring search filter. It is used to identify which entries contain specific substrings to a given assertion. Substring indexes can only be applied to attributes that have a corresponding substring matching rule.

System Indexes

The UnboundID Data Store contains a set of system database index files that ensure that the server operates efficiently. These indexes cannot be modified or deleted.

Table 16: System Indexes

Index	Description
dn2id	Allows quick retrieval of DNs. The DN database, or `dn2id`, has one record for each entry. The key is the normalized entry DN and the value is the entry ID.
id2entry	Allows quick retrieval of entries. The `id2entry` database contains the LDAP entries. The database key is the entry ID and the value is the entry contents.
referral	Allows quick retrieval of referrals. The referral database called `dn2uri` contains URIs from referral entries. The key is the DN of the referral entry and the value is that of a labeled URI in the ref attribute for that entry.
id2children	Allows quick retrieval of an entry and its children. The `id2children` database provides a mapping between an entry's unique identifier and the entry unique identifiers of the corresponding entry's children.
id2subtree	Allows quick retrieval of an entry's subtree. The `id2subtree` database provides a mapping between an entry's unique identifier and its unique identifiers in its subtree.

To View the System Indexes

Use the `dbtest` command to view the system and user indexes. The index status indicates if it is a trusted index or not. An index is either trusted or untrusted. An untrusted index requires rebuilding.

```
$ bin/dbtest list-index-status --baseDN dc=example,dc=com --backendID userRoot
```

Managing Local DB Indexes

You can modify the local DB indexes to meet your system's requirements using the `dsconfig` tool. If you are using the `dsconfig` tool in interactive command-line mode, you can access the **Local DB Index** menu from the Basic object menu.

To View the List of Local DB Indexes

- Use `dsconfig` with the `list-local-db-indexes` option to view the default list of indexes.

```
$ bin/dsconfig list-local-db-indexes --backend-name userRoot
```

```
Local DB Index     : Type    : index-type
-------------------:---------:--------------------
aci                : generic : presence
cn                 : generic : equality, substring
ds-entry-unique-id : generic : equality
givenName          : generic : equality, substring
mail               : generic : equality
member             : generic : equality
objectClass        : generic : equality
sn                 : generic : equality, substring
telephoneNumber    : generic : equality
uid                : generic : equality
uniqueMember       : generic : equality
```

To View a Property for All Local DB Indexes

- Use `dsconfig` with the `--property` option to view a property assigned set for all local DB indexes. Repeat the option for each property that you want to list. In this example, the `prime-index` property specifies if the backend is configured to prime the index at startup.

  ```
  $ bin/dsconfig list-local-db-indexes --property index-entry-limit \
    --property prime-index --backend-name userRoot
  ```

To View the Configuration Parameters for Local DB Index

- To view the configuration setting of a local DB index, use `dsconfig` with the `get-local-db-index-prop` option and the `--index-name` and `--backend-name` properties. If you want to view the advanced properties, add the `--advanced` option to your command.

  ```
  $ bin/dsconfig get-local-db-index-prop --index-name aci \
    --backend-name userRoot
  ```

To Modify the Configuration of a Local DB Index

You can easily modify an index using the `dsconfig` tool. Any modification or addition of an index requires the indexes to be rebuilt. In general, an index only needs to be built once after it has been added to the configuration.

If you add an index, then import the data using the `import-ldif` tool, then the index will be automatically rebuilt. If you add an index, then add the data using some other method than `import-ldif`, you must rebuild the index using the `rebuild-index` tool.

1. Use `dsconfig` with the `set-local-db-index-prop` option and the `--index-name` and `--backend-name` properties. In this example, update the `prime-index` property, which loads the index at startup. This command requires the `--advanced` option to access this property.

   ```
   $ bin/dsconfig set-local-db-index-prop --index-name uid \
     --backend-name userRoot --set prime-index:true
   ```

2. View the index to verify the change.

   ```
   $ bin/dsconfig get-local-db-index-prop --index-name uid \
     --backend-name userRoot
   ```

3. Stop the Data Store. You can do an index rebuild with the server online; however, keep in mind the tips presented in *General Tips on Indexes*.

   ```
   $ bin/stop-ds
   ```

4. Run the `rebuild-index` tool.

   ```
   $ bin/rebuild-index --baseDN dc=example,dc=com --index uid
   ```

5. Restart the Data Store if shutdown.

```
$ bin/start-ds
```

To Create a New Local DB Index

1. To create a new local DB index, use `dsconfig` with the `--create-local-db-index` option and the `--index-name`, `--backend-name`, and `--set index-type: <value>` options.

```
$ bin/dsconfig create-local-db-index \
  --index-name roomNumber --backend-name userRoot \
  --set index-type:equality
```

2. View the index.

```
$ bin/dsconfig get-local-db-index-prop \
  --index-name roomNumber --backend-name userRoot
```

3. Stop the Data Store. You can do an index rebuild with the server online; however, keep in mind the tips presented in *General Tips on Indexes* on page 148.

```
$ bin/stop-ds
```

4. Rebuild the index using the `rebuild-index` tool.

```
$ bin/rebuild-index --baseDN dc=example,dc=com --index roomNumber
```

5. Restart the Data Store.

```
$ bin/start-ds
```

To Delete a Local DB Index

You can delete an index using the `dsconfig` tool. Check that no plug-in applications are using the index before deleting it. When the index is deleted, the corresponding index database will also be deleted. The disk space is reclaimed once the cleaner threads begin.

- Use `dsconfig` with the `delete-local-db-index` option to remove it from the database.

```
$ bin/dsconfig delete-local-db-index \
  --index-name roomNumber --backend-name userRoot
```

Working with JSON Indexes

JSON indexing is similar to general attribute indexing. Where an attribute can be indexed several ways and requires a separate database for each index type, there is only a single database for each JSON field that can be used for different JSON filter types. This database primarily behaves like the database for an equality attribute index. Each database entry key is the normalized form for a value for the target JSON field, and the corresponding database entry value is an list of the entry IDs for all entries in which the associated attribute type has a JSON object with that value for the target field. The database is configured with a comparator (based on the data type for the target field) that enables iterating through values in a logical order to facilitate inequality and subInitial searches. See *Configure JSON Attribute Constraints* for information about setting indexing parameters for JSON Attributes.

The JSON object filter types that can be enhanced through the use of JSON indexes include:

- `equals`. Identifies entries that have a specific value for the target field. This filter type only requires retrieving a single index key. However, depending on the nature of the search filter, the ID list may contain references to entries that don't actually match the filter (such as if the field is a string, and the filter is configured to use case-sensitive matching).
- `equalsAny`. Identifies entries that have any of a specified set of values for the target field. This filter type only requires retrieving the index keys that correspond to the target values in the filter and merging their ID lists.
- `greaterThan/lessThan`. Identifies entries that have at least one value for the target field that is greater or less than (or possibly equal to) a specified value. This index is similar in use to the `containsField` index, except that it only needs to iterate through a subset of the keys. A filter can contain both `greaterThan` and `lessThan` filters to represent a bounded range.
- `substring`. Identifies entries that have a string value for the target field that matches a given `substring`. The index can only be used for substring filters that include a `subInitial` component. In this case, the server iterates through all of the index keys that match the `startsWith` component, and manually compares values against the remainder of the substring assertion.

JSON indexing is available in local database backends backed by Berkeley DB Java Edition. This includes the following:

- Add, delete, modify, and modify DN operations that make changes to JSON objects stored in the server.
- LDIF imports that include JSON objects, including updates to the cache size estimates for the JSON indexes.
- The `rebuild-index` tool and corresponding backend code to make it possible to generate and rebuild indexes for JSON data. It must be possible to build all JSON indexes for all or a specified subset of fields associated with a given attribute type. The `verify-index` tool should also work with JSON indexes to make it possible to check their validity.
- Matching entry count control and debugsearchindex return attribute provide information about relevant JSON index usage.
- Support for monitoring index content and usage.

Note: Exploded indexes and the entry balancing global index do not support JSON objects.

Working with Local DB VLV Indexes

Local DB VLV indexes allow a client to request a subset of results from a sorted list that match a specific search base, scope, and filter. The client can navigate through the list by passing a context back to the server with the virtual list view control. The Local DB VLV index can be used only when the client request contains the virtual list view (VLV) control and the client has been authorized with an ACI with a `targetcontrol` of **2.16.840.1.113730.3.4.9**.

Note: A client request, which includes a virtual list view control, can be successfully processed without a matching Local DB VLV index if the search is completely indexed. This is not an efficient means of using VLV, since the server has to retrieve each entry twice.

To View the List of Local DB VLV Indexes

- Use `dsconfig` with the `list-local-db-indexes` option to view the default list of indexes. In the example, no VLV indexes are defined.

```
$ bin/dsconfig list-local-db-vlv-indexes --backend-name userRoot
```

To Create a New Local DB VLV Index

1. Use `dsconfig` with the `create-local-db-vlv-index` option and the `--index-name`, `--backend-name`, and `--set index-type:(propertyValue)` options. If you do not set any property values, the default values are assigned.

```
$ bin/dsconfig create-local-db-vlv-index \
  --index-name givenName --backend-name userRoot --set base-dn:dc=example,dc=com \
  --set scope:whole-subtree --set filter:"(objectclass=*)" \
  --set sort-order:givenName
```

2. Rebuild the index using the `rebuild-index` tool. You must add the “vlv.” prefix to the index name to rebuild the VLV index. The following command can be run with the server on or offline with the addition of the `--task` and connection options.

```
$ bin/rebuild-index --baseDN dc=example,dc=com --index vlv.givenName
```

To Modify a VLV Index’s Configuration

1. Use `dsconfig` with the `set-local-db-vlv-index-prop` option and the `--index-name` and `--backend-name` properties. In this example, update the `base-dn` property.

```
$ bin/dsconfig set-local-db-vlv-index-prop --index-name givenName \
  --backend-name userRoot --set base-dn:ou=People,dc=example,dc=com
```

2. Rebuild the index using the `rebuild-index` tool. You must add the prefix "vlv." to the index name. The following command can be run with the server on or offline with the addition of the `--task` and connection options.

```
$ bin/rebuild-index --baseDN dc=example,dc=com --index vlv.givenName
```

To Delete a VLV Index

You can delete a VLV index using the `dsconfig` tool. Check that the index is not being used in any plug-in applications before deleting it.

1. Use `dsconfig` with the `delete-local-db-vlv-index` option to remove it from the database.

```
$ bin/dsconfig delete-local-db-vlv-index --index-name givenName \
  --backend-name userRoot
```

2. Verify the deletion by trying to view the vlv index.

```
$ bin/dsconfig get-local-db-vlv-index-prop --index-name givenName \
  --backend-name userRoot
```

Working with Filtered Indexes

The UnboundID Data Store filtered index is useful when client search requests consisting of a compound &-filter with individual components matching a large number of entries, potentially greater than the index entry limit, have an intersection of a relatively small number of entries.

For example, assume a database contains several thousand company profiles and each company profile is represented by many entries. The "`(objectClass=company)`" filter matches a small set of entries per company, and therefore may exceed the index entry limit since there are many companies. Also assume that the "`(companyDomain=example.com)`" filter matches many of the entries for the company with domain `example.com` and can also result in an unindexed search. The more narrow filter "`(&(objectClass=company)(companyDomain=example.com))`" also results in an unindexed search but only matches a small number of entries. The filtered index makes it possible to index this compound filter by defining an equality index on the `companyDomain` attribute with a static filter of "`(objectClass=company)`" in the `equality-index-filter` property of the index.

Filtered indexing is primarily useful for cases in which clients frequently issue searches with AND filters that meet the following criteria:

- The AND filter itself matches a relatively small number of entries, but each of the individual components may match a very large number of entries.
- The filter has a dynamic component that does change, and that dynamic component always uses the same attribute.
- The filter has a static component that doesn't change.

The filtered index can be maintained independently from the equality filter for that attribute. Further, the filtered index will be used only for searches containing the equality component with the associated attribute type ANDed with this filter. When configuring a filtered index, be aware of the `equality-index-filter` and `maintain-equality-index-without-filter` properties of the index.

Once configured and built with the `rebuild-index` tool or `import-ldif`, searches with filters based on the above example will be processed with the index:

```
(&(objectClass=company)(companyDomain=example.com))
(&(objectClass=company)(|(companyDomain=example.com)(companyDomain=example.org)))
(&(companyDomain=example.com)(objectClass=company))
(&(companyDomain=example.com)(&(objectClass=company)))
(&(companyDomain=example.com)(objectClass=company)(something=else))
(&(companyDomain=example.com)(&(objectClass=company)(something=else)))
(|(&(objectClass=company)(companyDomain=example.com))(&(objectClass=company)
(companyDomain=example.org)))
```

When configuring a filtered index, define the following properties:

Table 17: Filtered Index Properties

Filtered Index Properties	Description
equality-index-filter	Specifies a search filter that may be used in conjunction with an equality component for the associated attribute type. If an equality index filter is defined, then an additional equality index will be maintained for the associated attribute, but only for entries that match the provided filter. Further, the index will be used only for searches containing an equality component with the associated attribute type ANDed with this filter.
maintain-equality-index-without-filter	Specifies whether to maintain a separate equality index for the associated attribute without any filter, in addition to maintaining an index for each equality index filter that is defined. If this is false, then the attribute will not be indexed for equality by itself but only in conjunction with the defined equality index filters.

To Create a Filtered Index

1. Use the `dsconfig` tool to create a filtered index. The following command creates an equality index on the `companyDomain` attribute and maintains an index for the equality filter defined `"(objectclass=company)"`. After you have created the index, you must rebuild the indexes.

```
$ bin/dsconfig create-local-db-index --backend-name "userRoot" \
  --index-name companyDomain --set maintain-equality-index-without-filter:true \
  --set index-type:equality --set equality-index-filter:"(objectclass=company)"
```

2. Stop the Data Store using `bin/stop-ds`.

3. Run the `rebuild-index` tool.

```
$ bin/rebuild-index --baseDN dc=example,dc=com --index companyDomain
```

4. Start the Data Store using `bin/start-ds`.

Tuning Indexes

The UnboundID Data Store provides several tools to help you optimize your indexes and improve the overall read and write performance for your system. The server now supports an optional expanded index database using an *exploded* format to process high write load operations. To view the current state of the server's indexes and make adjustments to the index databases, the Data Store automatically generates an Index Summary Statistics Table after each LDIF import or index rebuild. The `dbtest` tool also includes an Index Histogram to determine the key datasize for the indexes. This section provides descriptions of each of these tools.

About the Exploded Index Format

The Data Store has two index properties on the Backend configuration object that can be used to optimize the server's performance: `index-entry-limit` and `exploded-index-entry-threshold`. The `index-entry-limit` specifies the maximum size of entries kept in an index record, before the server stops maintaining that record, begins scanning the whole database, and runs an expensive unindexed search. Typically, if any index keys have already reached this limit, indexes must be rebuilt before they can be allowed to use a new limit.

The `exploded-index-entry-threshold` property specifies the maximum number of entries that are allowed to match a given index key before that particular index key is stored in a separate database in an expanded (i.e., "exploded") format. An `exploded-index-entry-threshold` value of 0, or any value greater or equal to the `index-entry-limit`, means that the expanded index database will not be used. All keys whose entry count is less than `exploded-index-entry-threshold` continue to be stored in one database in a consolidated format, such that changes to the key require *rewriting* all the entry IDs matching the key. All keys whose entry count is greater than `exploded-index-entry-threshold` and less than the `index-entry-limit` are stored in a *separate* database in an exploded format, such that changes to the key require writing only to the updated entry ID.

For example, as shown in the figure below, the equality index for the `sn` attribute is stored in consolidated format, listing each entry ID for all entries that contain the `sn=smith` attribute. If we enable the `exploded-index-entry-threshold` property by setting its value to 1000 and keep the `index-entry-limit` property to its default limit of 4000, then the expanded index database will be implemented by the server. Any key with an entry count less than 1000 continues to be stored in consolidated format. If a key has an entry count greater than 1000, it will be stored in a separate database where each key is stored with its entry ID individually. The consolidated format is very efficient for read operations because the server can retrieve a row of entry IDs at once, while the exploded format is far more efficient for write operations.

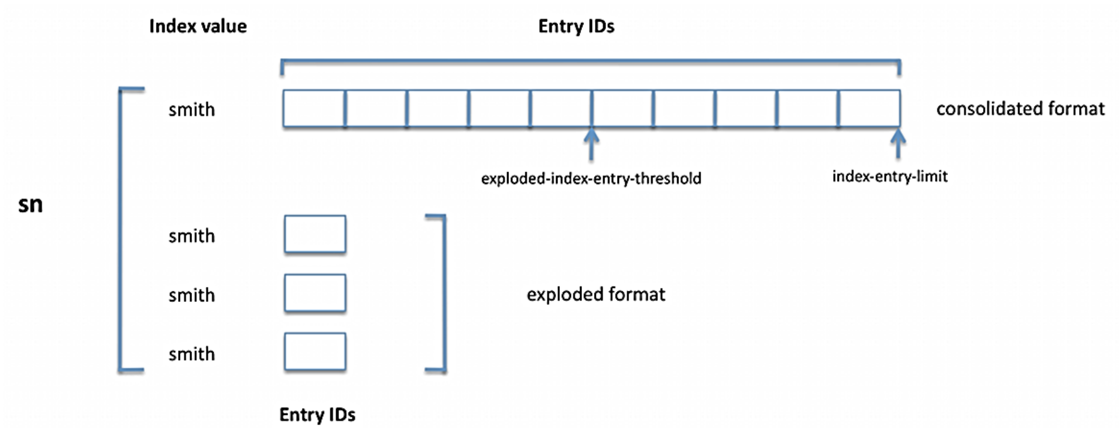


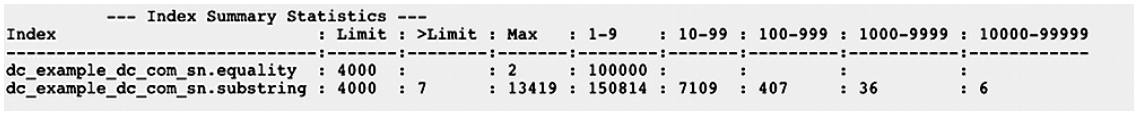
Figure 3: Consolidated and Exploded Index Formats

Note that a large value for the `exploded-index-entry-threshold` can have a big impact on write performance and database growth on disk, since each change to an index key stored in the consolidated format requires that IDs for all entries matching the key be rewritten to the database. For example if the `exploded-index-entry-threshold` is set to 100,000, and the number of entries matching a given key is 50,000, then changes to that key will require writing 200KB to the database since each entry ID is 4 bytes. Add and delete operations are especially impacted since they must update all indexes for an entry. If many indexes have a large `exploded-index-entry-threshold`, this can lead to very low throughput and can cause the database to temporarily grow very large on disk. It is recommended to set this value at or below 10,000, and never set it above 50,000. If any index keys have already reached this threshold, indexes need to be rebuilt before they are allowed to use the new threshold. This is also true for the `index-entry-limit` property: setting a large limit (greater than 10,000) could have a big impact on write performance and database growth on disk.

About the Index Summary Statistics Table

The Data Store now automatically generates an Index Summary Statistics Table, which can be used to determine the optimal configuration for your system's indexes. The table is generated after any LDIF import or an index rebuild, and is written to system out and to `logs/tools/rebuild-index-summary.txt`. The table lists the current index entry limit (set by the `index-entry-limit` property on the local DB configuration), the number of keys whose entry count exceeds this limit if any, and the maximum entry count for any key in the index. The table then displays a histogram of the number of keys whose entry falls within a range of values. An example of the Index Summary Statistics table is show below for the `sn.equality` and the `sn.substring` indexes.

The following figure shows that there are seven substrings whose entry counts exceed the `index-entry-limit` of 4000. Six of the substrings are in the 10000-99999 range with the maximum entry count being 13419. By deduction, one more substring must be present in the 1000-9999 range that exceeds the `index-entry-limit` of 4000. These substrings could be expensive for search operations.

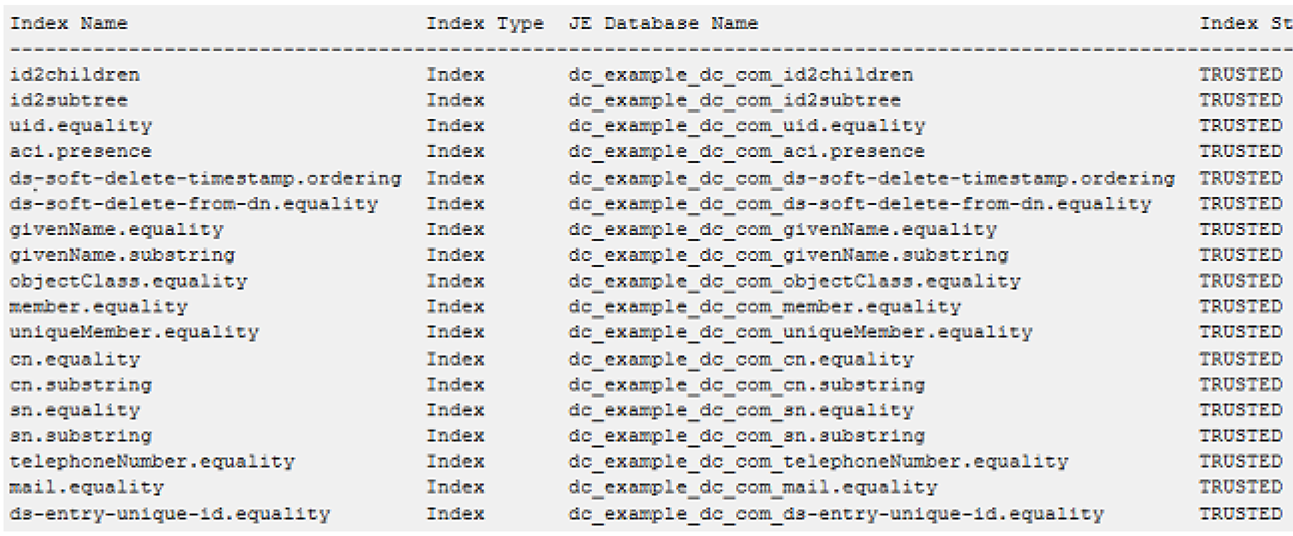


```
          --- Index Summary Statistics ---
Index                          : Limit : >Limit : Max   : 1-9    : 10-99 : 100-999 : 1000-9999 : 10000-99999
-------------------------------:-------:--------:-------:--------:-------:---------:-----------:------------
dc_example_dc_com_sn.equality  : 4000  :        : 2     : 100000 :       :         :           :
dc_example_dc_com_sn.substring : 4000  : 7      : 13419 : 150814 : 7109  : 407     : 36        : 6
```

Figure 4: Example of an Index Summary Statistics Table

About the dbtest Index Status Table

The `dbtest` tool has a `list-all --analyze` option that generates the current status of all of the databases on your system, including all index databases. The table shows the type, entry count (i.e., the number of records in the dtabase), index status (TRUSTED to indicate that the indexes are up-to-date, or UNTRUSTED if the index needs rebuilding), the total data size for each key, the average data size for each key and the maximum data size for each key. Note also that any indexes that are in exploded format are listed on this table.



```
Index Name                          Index Type  JE Database Name                                       Index St
---------------------------------------------------------------------------------------------------------------
id2children                         Index       dc_example_dc_com_id2children                          TRUSTED
id2subtree                          Index       dc_example_dc_com_id2subtree                           TRUSTED
uid.equality                        Index       dc_example_dc_com_uid.equality                         TRUSTED
aci.presence                        Index       dc_example_dc_com_aci.presence                         TRUSTED
ds-soft-delete-timestamp.ordering   Index       dc_example_dc_com_ds-soft-delete-timestamp.ordering    TRUSTED
ds-soft-delete-from-dn.equality     Index       dc_example_dc_com_ds-soft-delete-from-dn.equality      TRUSTED
givenName.equality                  Index       dc_example_dc_com_givenName.equality                   TRUSTED
givenName.substring                 Index       dc_example_dc_com_givenName.substring                  TRUSTED
objectClass.equality                Index       dc_example_dc_com_objectClass.equality                 TRUSTED
member.equality                     Index       dc_example_dc_com_member.equality                      TRUSTED
uniqueMember.equality               Index       dc_example_dc_com_uniqueMember.equality                TRUSTED
cn.equality                         Index       dc_example_dc_com_cn.equality                          TRUSTED
cn.substring                        Index       dc_example_dc_com_cn.substring                         TRUSTED
sn.equality                         Index       dc_example_dc_com_sn.equality                          TRUSTED
sn.substring                        Index       dc_example_dc_com_sn.substring                         TRUSTED
telephoneNumber.equality            Index       dc_example_dc_com_telephoneNumber.equality             TRUSTED
mail.equality                       Index       dc_example_dc_com_mail.equality                        TRUSTED
ds-entry-unique-id.equality         Index       dc_example_dc_com_ds-entry-unique-id.equality          TRUSTED
```

Figure 5: dbtest Output Including Index Databases

Configuring the Index Properties

By default, the `index-entry-limit` and the `exploded-index-entry-threshold` are set to 4000, which means that the latter property is not enabled due to its having an equal value to that of the `index-entry-limit` property. You can enable the exploded index database by changing the `exploded-index-entry-threshold` property to a value less than the `index-entry-limit` and to a non-zero value using the `dsconfig` tool.

To Configure the Index Properties

Before running the following commands, be aware that you will need to do an index rebuild on the system, which requires a system shutdown, unless the command is run as a task.

1. Run `dsconfig` and set the `index-entry-limit` and the `exploded-index-entry-threshold` to 5000 and 1000, respectively. By default, both values are set to 4000. Changing the `exploded-index-entry-threshold` property to a value less than the `index-entry-limit` and to a non-zero value enables the exploded index database. Remember to include the bind parameters for your system. Once you enter the command, you must confirm that you want to apply the changes to your system.

```
$ bin/dsconfig set-backend-prop --backend-name userRoot \
  --set index-entry-limit:5000 \
  --set exploded-index-entry-threshold:1000
```

```
One or more configuration property changes require administrative action
or confirmation/notification.  Those properties include:

 * index-entry-limit:  If any index keys have already reached this limit, indexes
   must be rebuilt before they will be allowed to use the new limit.
   Setting a large limit (greater than 10,000) could have a big impact on
   write performance and database growth on disk.
 * exploded-index-entry-threshold:  If any index keys have already reached
   this threshold, indexes need to be rebuilt before they are allowed to use the
   new threshold. Setting a large limit (greater than 10,000) could have a big
   impact on write performance and database growth on disk.

Continue?  Choose 'no' to return to the previous step (yes / no) [yes]: yes
```

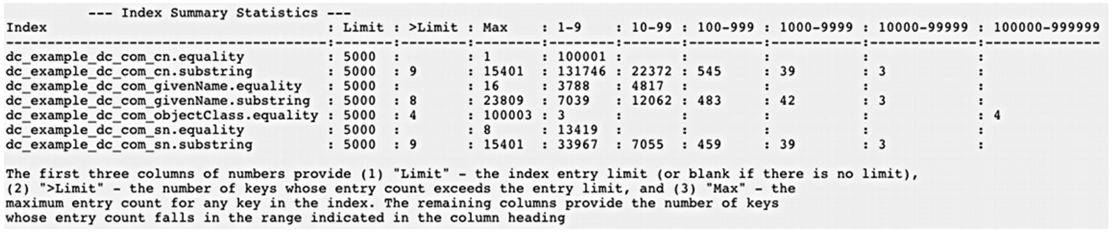
2. Stop the server.

```
$ bin/stop-ds
```

3. Rebuild the index.

```
$ bin/rebuild-index --baseDN dc=example,dc=com \
  --index cn --index givenName --index objectClass \
  --index sn --maxThreads 10
```

4. View the Index Summary Statistics table, which is automatically displayed to system out after running the `rebuild-index` command. You can also access the table at `logs/tools/rebuild-index-summary.txt`. Repeat the last three steps to make more adjustments to your indexes.



```
         --- Index Summary Statistics ---
Index                                  : Limit : >Limit : Max    : 1-9    : 10-99 : 100-999 : 1000-9999 : 10000-99999 : 100000-999999
---------------------------------------:-------:--------:--------:--------:-------:---------:-----------:-------------:--------------
dc_example_dc_com_cn.equality          : 5000  :        : 1      : 100001 :       :         :           :             :
dc_example_dc_com_cn.substring         : 5000  : 9      : 15401  : 131746 : 22372 : 545     : 39        : 3           :
dc_example_dc_com_givenName.equality   : 5000  :        : 16     : 3788   : 4817  :         :           :             :
dc_example_dc_com_givenName.substring  : 5000  : 8      : 23809  : 7039   : 12062 : 483     : 42        : 3           :
dc_example_dc_com_objectClass.equality : 5000  : 4      : 100003 : 3      :       :         :           :             : 4
dc_example_dc_com_sn.equality          : 5000  :        : 8      : 13419  :       :         :           :             :
dc_example_dc_com_sn.substring         : 5000  : 9      : 15401  : 33967  : 7055  : 459     : 39        : 3           :

The first three columns of numbers provide (1) "Limit" - the index entry limit (or blank if there is no limit),
(2) ">Limit" - the number of keys whose entry count exceeds the entry limit, and (3) "Max" - the
maximum entry count for any key in the index. The remaining columns provide the number of keys
whose entry count falls in the range indicated in the column heading
```

5. Restart the server.

```
$ bin/start-ds
```

Chapter 11 Managing Entries

The Data Store is a fully LDAPv3-compliant server that comes with a comprehensive set of LDAP command-line tools to search, add, modify, and delete entries.

This chapter presents the following topics:

Topics:

Searching Entries

The Data Store provides an `ldapsearch` tool to search for entries or attributes within your server. The tool requires the LDAP connection parameters needed to bind to the server, including the `baseDN` option to specify the starting point of the search within the server, and the search scope. The `searchScope` option determines the depth of the search:

- `base` (search only the entry specified)
- `one` (search only the children of the entry and not the entry itself)
- `sub` (search the entry and its descendents)

The `ldapsearch` tool provides basic functionality as specified by the RFC 2254 but provides additional features that takes advantage of the Data Store's control mechanisms. For more information, run the `ldapsearch --help` function.

To Search the Root DSE

The Root DSE is a special entry that resides at the root of the directory information tree (DIT). The entry holds operational information about the server and its supported controls. Specifically, the root DSE entry provides information about the supported LDAPv3 controls, SASL mechanisms, password authentication schemes, supported LDAP protocols, additional features, naming contexts, extended operations, and server information.

Note: The Data Store provides an option to retrieve the Root DSE's operational attributes and add them to the user attribute map of the generated entry. This feature allows client applications that have difficulty handling operational attributes to access the root DSE using the `show-all-attributes` configuration property. Once this property is set, the associated attribute types are re-created and re-registered as user attributes in the schema (in memory, not on disk). Once you set the property, you can use `ldapsearch` without "+" to view the root DSE.

Use the `dsconfig` tool to set the `show-all-attributes` property to TRUE, as follows:

```
$ bin/dsconfig set-root-dse-backend-prop --set show-all-attributes:true
```

- Use `ldapsearch` to view the root DSE entry on the Data Store. Be sure you include the "+" to display the operational attributes in the entry.

```
$ bin/ldapsearch --baseDN "" --searchScope base "(objectclass=*)" "+"
```

To Search All Entries in the Data Store

- Use `ldapsearch` to search all entries in the Data Store. The filter `"(objectclass=*)"` matches all entries. If the `--searchScope` option is not specified, the command defaults to a search scope of sub:

```
$ bin/ldapsearch --baseDN dc=example,dc=com \
  --searchScope sub "(objectclass=*)"
```

To Search for an Access Control Instruction

- Use `ldapsearch` to search the `dc=example,dc=com` base DN entry. The filter `"(aci=*)"` matches all `aci` attributes under the base DN, and the `aci` attribute is specified so that only it is returned. The `cn=Directory Manager` bind DN has the privileges to view an ACI.

```
$ bin/ldapsearch --baseDN dc=example,dc=com "(aci=*)" aci
```

```
dn: dc=example,dc=com
aci: (targetattr!="userPassword")
  (version 3.0; acl "Allow anonymous read access for anyone";
    allow (read,search,compare) userdn="ldap:///anyone";)
aci: (targetattr="*")
  (version 3.0; acl "Allow users to update their own entries";
    allow (write) userdn="ldap:///self";)
aci: (targetattr="*")
  (version 3.0; acl "Grant full access for the admin user";
    allow (all) userdn="ldap:///uid=admin,dc=example,dc=com";)
```

To Search for the Schema

- Use `ldapsearch` to search the `cn=schema` entry. The base DN is specified as `cn=schema`, and the filter `"(objectclass=*)"` matches all entries. The command uses a special attribute "+" to return all operational attributes:

```
$ bin/ldapsearch --baseDN cn=schema \
  --searchScope base "(objectclass=*)" "+"
```

To Search for a Single Entry using Base Scope and Base DN

- Use `ldapsearch` to search for a single entry by specifying the base scope and DN:

```
$ bin/ldapsearch --baseDN uid=user.14,ou=People,dc=example,dc=com \
  --searchScope base "(objectclass=*)"
```

To Search for a Single Entry Using the Search Filter

- Search for a single entry by specifying the `sub` scope and a search filter that describes a single entry:

```
$ bin/ldapsearch --baseDN ou=People,dc=example,dc=com \
  --searchScope sub "(uid=user.14)"
```

To Search for All Immediate Children for Restricted Return Values

- Search for all immediate children of `ou=People,dc=example,dc=com`. The attributes returned are restricted to `sn` and `givenName`. The special attribute "+" returns all operational attributes:

```
$ bin/ldapsearch --baseDN ou=People,dc=example,dc=com \
  --searchScope one '(objectclass=*)' sn givenName "+"
```

To Search for All Children of an Entry in Sorted Order

- Search for all children of the `ou=People,dc=example,dc=com` subtree. The resulting entries are sorted by the server in ascending order by `sn` and then in descending order by `givenName`:

```
$ bin/ldapsearch --baseDN ou=People,dc=example,dc=com \
  --searchScope sub --sortOrder sn,-givenName '(objectclass=*)'
```

To Limit the Number of Returned Search Entries and Search Time

- Search for a subset of the entries in the `ou=People,dc=example,dc=com` subtree by specifying a compound filter. No more than 200 entries will be returned and the server will spend no more than 5 seconds processing the request. Returned attributes are restricted to a few operational attributes:

```
$ bin/ldapsearch --baseDN ou=People,dc=example,dc=com \
  --searchScope sub --sizeLimit 200 --timeLimit 5 \
  "(&(sn<=Doe)(employeeNumber<=1000))" ds-entry-unique-id entryUUID
```

Working with the Matching Entry Count Search Filter

The `ldapsearch` command can be used with the `--matchingEntryCountControl` option to determine the count of entries that match a search filter. An `examineCount` control can be used for searches that are at least partially indexed, in order to determine whether to return an examined count, an unexamined count, or an upper bound count. The factors that determine what is returned are:

- A search is fully indexed if indexes can be used to identify the entry IDs for all entries that match the filter without ambiguity. Indexes can also be used to make sure that all of those candidates are within the scope of the search.
- A search is partially indexed if indexes can be used to identify the entry IDs for all entries that match the search criteria, but the candidate list may potentially also include entries that either don't match the filter or are outside the scope of the search.
- A search is unindexed if it is not possible to retrieve a candidate list based on either the filter or the search scope.

- An unexamined count is a count of the exact number of entries that match the search criteria, only through the use of index processing.
- An examined count is the same as an unexamined count, except that all of the candidate entries are examined to determine whether they would have been returned to the client. An examined count may be less than an unexamined count if the set of matching entries includes those that would be removed by access control evaluation, or special entries like LDAP sub-entries, replication conflict entries, or soft-deleted entries.
- An upper bound count is the maximum number of entries that match the criteria, but indicates that the server could not determine exactly how many matching entries there were without examining each candidate, which it did not do.
- If a search is fully indexed, the result is an examined count or an unexamined count. If `alwaysExamine` is true and `examineCount` is greater than or equal to the number of candidates, the result is an examined count. If `alwaysExamine` is false, or if the number of candidates exceeds `examineCount`, the result is an unexamined count.
- If a search is partially indexed, the result is either an examined count or an upper bound count. The `alwaysExamine` flag isn't relevant in this case. If `examineCount` is greater than or equal to the number of candidates, the result is an examined count. If not, the result is an upper bound count.
- If a search is unindexed, the result is either an examined count or an unknown count. If `allowUnindexed` is true, the unindexed search is processed, which can be very expensive. Instead of getting the matching entries back, the examined count is returned. If `allowUnindexed` is false, an unknown count is returned. If `allowUnindexed` is true, the requester needs to have the `unindexed-search` privilege to get the exact count.

The following is a sample `ldapsearch` with the `--matchingEntryCountControl` option:

```
$./ldapsearch \
  --bindDN "cn=directory manager" \
  --bindPassword password \
  --baseDN dc=example,dc=com \
  --matchingEntryCountControl examineCount=100:alwaysExamine:allowUnindexed:debug \
  "(objectclass=*)"
```

Adding Entries

Depending on the number of entries that you want to add to your Data Store, you can use the `ldapmodify` tool for small additions. The `ldapmodify` tool provides two methods for adding a single entry: using a LDIF file or from the command line. The attributes must conform to your schema and contain the required object classes.

Adding requests with the `ignore-no-user-modification` control enable a client to include attributes that are not normally allowed from external sources. For example, the `userPassword` attribute is a user-modifiable attribute. An add request with the `ignore-no-user-modification` control allows a one-time exception to the password policy, even if the requesting client does not have the `bypass-pw-policy` privilege. This exception enables specifying pre-encoded passwords.

To Add an Entry Using an LDIF File

1. Open a text editor and create an entry that conforms with your schema. For example, add the following entry in the file and save the file as `add-user.ldif`. For the `userPassword` attribute, enter the cleartext password. The Data Store encrypts the password and stores its encrypted value in the server. Make sure that the LDIF file has limited read permissions for only authorized administrators.

```
dn: uid=user.2000,ou=People,dc=example,dc=com
objectClass: top
objectClass: person
objectClass: organizationalPerson
objectClass: inetOrgPerson
postalAddress: Toby Hall$73600 Mash Street$Cincinnati, OH 50563 postalCode: 50563
description: This is the description for Toby Hall.
uid: user.2000
userPassword: wordsmith employeeNumber: 2000
initials: TBH
givenName: Toby
pager: +1 596 232 3321
mobile: +1 039 311 9878
cn: Toby Hall
sn: Hall
telephoneNumber: +1 097 678 9688
street: 73600 Mash Street
homePhone: +1 214 233 8484
l: Cincinnati
mail: user.2000@maildomain.net
st: OH
```

2. Use the `ldapmodify` tool to add the entry specified in the LDIF file. You will see a confirmation message of the addition. If the command is successful, you will see generated success messages with the "#" symbol.

```
$ bin/ldapmodify --defaultAdd --filename add-user.ldif
```

```
# Processing ADD request for uid=user.2000,ou=People,dc=example,dc=com
# ADD operation successful for DN uid=user.2000,ou=People,dc=example,dc=com
```

To Add an Entry Using the Changetype LDIF Directive

RFC 2849 specifies LDIF directives that can be used within your LDIF files. The most commonly used directive is `changetype`, which follows the `dn:` directive and defines the operation on the entry. The main advantage of using this method in an LDIF file is that you can combine adds and modifies in one file.

1. Open a text editor and create an entry that conforms with your schema. For example, add the following entry in the file and save the file as `add-user2.ldif`. Note the use of the `changetype` directive in the second line.

```
dn: uid=user.2001,ou=People,dc=example,dc=com
changetype: add
objectClass: top
objectClass: person
objectClass: organizationalPerson
objectClass: inetOrgPerson
postalAddress: Seely Dorm$100 Apple Street$Cincinnati, OH 50563
postalCode: 50563
description: This is the description for Seely Dorm.
uid: user.2001
userPassword: pleasantry
```

```
employeeNumber: 2001
initials: SPD
givenName: Seely pager: +1 596 665 3344
mobile: +1 039 686 4949
cn: Seely Dorm
sn: Dorm
telephoneNumber: +1 097 257 7542
street: 100 Apple Street
homePhone: +1 214 521 4883
l: Cincinnati
mail: user.2001@maildomain.net
st: OH
```

2. Use the `ldapmodify` tool to add the entry specified in the LDIF file. You will see a confirmation message of the addition. In this example, you do not need to use the `--defaultAdd` or its shortform `-a` option with the command.

```
$ bin/ldapmodify --filename add-user2.ldif
```

To Add Multiple Entries in a Single File

You can have multiple entries in your LDIF file by simply separating each DN and its entry with a blank line from the next entry.

1. Open a text editor and create a couple of entries that conform to your schema. For example, add the following entries in the file and save the file as `add-user3.ldif`. Separate each entry with a blank line.

```
dn: uid=user.2003,ou=People,dc=example,dc=com
objectClass: top
objectClass: person
objectClass:
organizationalPerson
objectClass: inetOrgPerson
...(similar attributes to previous examples)...

dn: uid=user.2004,ou=People,dc=example,dc=com
objectClass: top
objectClass: person
objectClass: organizationalPerson
objectClass: inetOrgPerson
...(similar attributes to previous examples)...
```

2. Use the `ldapmodify` tool to add the entries specified in the LDIF file. In this example, we use the short form arguments for the `ldapmodify` tool.

   The `-h` option specifies the host name, the `-p` option specifies the LDAP listener port, `-D` specifies the bind DN, `-w` specifies the bind DN password, `-a` specifies that entries that omit a changetype will be treated as add operations, and `-f` specifies the path to the input file. If the operation is successful, you will see commented messages (those begining with "#") for each addition.

```
$ bin/ldapmodify -h server.example.com -p 389 \
  -D "cn=admin,dc=example,dc=com" -w password -a -f add-user3.ldif
```

```
# Processing ADD request for uid=user.2003,ou=People,dc=example,dc=com
# ADD operation successful for DN uid=user.2003,ou=People,dc=example,dc=com
# Processing ADD request for uid=user.2004,ou=People,dc=example,dc=com
# ADD operation successful for DN uid=user.2004,ou=People,dc=example,dc=com
```

Deleting Entries Using ldapdelete

You can delete an entry using the `ldapdelete` tool. You should ensure that there are no child entries below the entry as that could create an orphaned entry. Also, make sure that you have properly backed up your system prior to removing any entries.

To Delete an Entry Using ldapdelete

Use `ldapdelete` to delete an entry. The following example deletes the `uid=user.14` entry.

```
$ bin/ldapdelete uid=user.14,ou=People,dc=example,dc=com
```

To Delete Multiple Entries Using an LDIF File

1. You can generate a file of DNs that you would like to delete from the Data Store.

   The following command searches for all entries in the `ou=Accounting` branch and returns the DNs of the subentries.

```
$ bin/dump-dns -D "cn=admin,dc=example,dc=com" -w password --baseDN \
                        "ou=Accounting,ou=People,dc=example,dc=com" --outputFile /
usr/local/entry_dns.txt
```

2. Run the `ldapdelete` command with the file to delete the entries. The command uses the `--continueError` option, which will continue deleting through the whole list even if an error is encountered for a DN entry.

```
$ bin/ldapdelete --filename /usr/local/entry_dns.txt --continueError
```

Deleting Entries Using ldapmodify

You can use the LDIF changetype directive to delete an entry from the Data Store using the `ldapmodify` tool. You can only delete leaf entries.

To Delete an Entry Using ldapmodify

- From the command line, use the `ldapmodify` tool with the `changetype:delete` directive. Enter the DN, press **Enter** to go to the next line, then enter the changetype directive. Press **Control-D** twice to enter the EOF sequence (UNIX) or **Control-Z** (Windows).

```
$ bin/ldapmodify --hostname server1.example.com -port 389 --bindDN
 "uid=admin,dc=example,dc=com" --bindPassword password
dn:uid=user.14,ou=People,dc=example,dc=com
changetype: delete
```

Modifying Entries Using ldapmodify

You can use the `ldapmodify` tool to modify entries from the command line or by using an LDIF file that has the `changetype:modify` directive and value. If you have more than one change, you can separate them using the - (dash) symbol.

To Modify an Attribute from the Command Line

1. Use the `ldapsearch` tool to locate a specific entry.

```
$ bin/ldapsearch -h server.example.com -p 389 -D "cn=admin,dc=example,dc=com" \
  -w password -b dc=example,dc=com "(uid=user.2004)"
```

2. Use the `ldapmodify` command to change attributes from the command line. Specify the modification using the `changetype:modify` directive, and then specify which attributes are to be changed using the `replace` directive. In this example, we change the telephone number of a specific user entry. When you are done typing, you can press **CTRL-D** (Unix EOF escape sequence) twice or **CTRL-Z** (Windows) to process the request.

```
$ bin/ldapmodify -h server.example.com -p 389 -D "cn=admin,dc=example,dc=com" \
  -w password
dn: uid=user.2004,ou=People,dc=example,dc=com
changetype: modify
replace: telephoneNumber
telephoneNumber: +1 097 453 8232
```

To Modify Multiple Attributes in an Entry from the Command Line

1. Use the `ldapsearch` tool to locate a specific entry.

```
$ bin/ldapsearch -h server.example.com -p 389 -D "cn=admin,dc=example,dc=com" \
  -w password -b dc=example,dc=com "(uid=user.2004)"
```

2. Use the `ldapmodify` command to change attributes from the command line. Specify the modification using the `changetype:modify` directive, and then specify which attributes are to be changes using the add and replace directive.

   In this example, we add the `postOfficeBox` attribute, change the mobile and telephone numbers of a specific user entry. The `postOfficeBox` attribute must be present in your schema to allow the addition. The three changes are separated by a dash ("-"). When you are done typing, you can press **CTRL-D** (Unix EOF escape sequence) twice or **CTRL-Z** (Windows) to process the request.

```
$ bin/ldapmodify -h server.example.com -p 389 -D "cn=admin,dc=example,dc=com" -w
 password
dn: uid=user.2004,ou=People,dc=example,dc=com
changetype: modify
add: postOfficeBox
postOfficeBox: 111
-
replace: mobile
mobile: +1 039 831 3737
-
```

```
replace: telephoneNumber
telephoneNumber: +1 097 453 8232
```

To Add an Attribute from the Command Line

- Use the `ldapmodify` command from the command line. Specify the modification using the `changetype:modify` directive, and then specify which attributes are to be added using the `add` directive. In this example, we add another value for the `cn` attribute, which is multi-valued. When you are done typing, you can press **CTRL-D** (UNIX EOF escape sequence) twice to process the request.

  ```
  $ bin/ldapmodify -h server.example.com -p 389 -D "cn=admin,dc=example,dc=com" \
    -w password
  dn: uid=user.2004,ou=People,dc=example,dc=com
  changetype: modify
  add: cn
  cn: Sally Tea Tree
  ```

  An error could occur if the attribute is single-valued, if the value already exists, if the value does not meet the proper syntax, or if the value does not meet the entry's objectclass requirements. Also, make sure there are no trailing spaces after the attribute value.

To Add an Attribute Using the Language Subtype

The Data Store provides support for attributes using language subtypes. The operation must specifically match the subtype for successful operation. Any non-ASCII characters must be in UTF-8 format.

The Data Store provides support for attributes using language subtypes. The operation must specifically match the subtype for successful operation. Any non-ASCII characters must be in UTF-8 format.

```
$ bin/ldapmodify -h server.example.com -p 389 -w password
dn: uid=user.2004,ou=People,dc=example,dc=com
changetype: modify
add: postalAddress; lang-ko
postalAddress; lang-ko:Byung-soon Kim$2020-14 Seoul
```

To Add an Attribute Using the Binary Subtype

The Data Store provides support for attributes using binary subtypes, which are typically used for certificates or JPEG images that could be stored in an entry. The operation must specifically match the subtype for successful operation. The version directive with a value of "1" must be used for binary subtypes. Typical binary attribute types are `userCertificate` and `jpegPhoto`.

- Use the `ldapmodify` command to add an attribute with a binary subtype. The attribute points to the file path of the certificate.

  ```
  $ bin/ldapmodify -h server.example.com -p 389 -D "cn=admin,dc=example,dc=com" \
    -w password
  version: 1
  dn: uid=user.2004,ou=People,dc=example,dc=com
  changetype: modify
  add: userCertificate;binary
  userCertificate;binary:<file:///path/to/cert
  ```

To Delete an Attribute

Use `ldapmodify` with the LDIF `delete` directive to delete an attribute.

```
$ bin/ldapmodify -h server.example.com -p 389 -D "cn=admin,dc=example,dc=com" \
  -w password
dn: uid=user.2004,ou=People,dc=example,dc=com
changetype: modify
delete: employeeNumber
```

To Delete One Value from an Attribute with Multiple Values

You can use the LDIF `delete` directive to delete a specific attribute value from an attribute. For this example, assuming you have multiple values of `cn` in an entry (e.g., `cn: Sally Tree`, `cn: Sally Tea Tree`).

- Use `ldapmodify` to delete a specific attribute of a multi-valued pair, then specify the attribute pair that you want to delete. In this example, we keep `cn:Sally Tree` and delete the `cn: Sally Tea Tree`.

```
$ bin/ldapmodify -h server.example.com -p 389 -D "cn=admin,dc=example,dc=com" \
  -w password
dn: uid=user.2004,ou=People,dc=example,dc=com
changetype: modify
delete: cn
cn: Sally Tea Tree
```

To Rename an Entry

Renaming an entry involves changing the relative distinguished name (RDN) of an entry. You cannot rename a RDN if it has children entries as this violates the LDAP protocol.

- Use the `ldapmodify` tool to rename an entry. The following command changes `uid=user.14` to `uid=user.2014` and uses the changetype, `newrdn`, and `deleteoldrdn` directives.

```
$ bin/ldapmodify
dn: uid=user.14,ou=People,dc=example,dc=com
changetype:moddn
newrdn: uid=user.2014
deleteoldrdn: 1
```

To Move an Entry Within a Data Store

You can use `ldapmodify` to move an entry from one base DN to another base DN. Before running the `ldapmodify` command, you must assign access control instructions (ACIs) on the parent entries. The source parent entry must have an ACI that allows export operations: `allow(export)`. The target parent entry must have an ACI that allows import operations: `allow(import)`. For more information on access control instructions, see *Working with Access Control*.

- Use the `ldapmodify` command to move an entry from the Contractor branch to the `ou=People` branch.

```
$ bin/ldapmodify
dn: uid=user.14,ou=contractors,dc=example,dc=com
changetype:moddn
newrdn: uid=user.2014
deleteoldrdn: 0
newsuperior: ou=People,dc=example,dc=com
```

To Move an Entry from One Machine to Another

The Data Store provides a tool, `move-subtree`, to move a subtree or one entry on one machine to another. The subtree or entry must exist on the source server and must not be present on the target server. The source server must also support the 'real attributes only' request control. The target server must support the Ignore NO-USER-MODIFICATION request control.

Note: The `move-subtree` tool moves a subtree or multiple entries from one machine to another. The tool does not copy the entries. Once the entries are moved, they are no longer present on the source server.

- Use the `move-subtree` tool to move an entry (e.g., `uid=test.user,ou=People,dc=example,dc=com`) from the source host to the target host.

```
$ bin/move-subtree --sourceHost source.example.com --sourcePort 389 \
  --sourceBindDN "uid=admin,dc=example,dc=com" --sourceBindPassword password \
  --targetHost target.example.com --targetPort 389 \
  --targetBindDN "uid=admin,dc=example,dc=com" --targetBindPassword password \
  --entryDN uid=test.user,ou=People,dc=example,dc=com
```

To Move Multiple Entries from One Machine to Another

The `move-subtree` tool provides the ability to move multiple entries listed in a DN file from one machine to another. Empty lines and lines beginning with the octothorpe character (#) will be ignored. Entry DNs may optionally be prefixed with `dn:` , but long DNs cannot be wrapped across multiple lines.

1. Open a text file, enter a list of DNs, one DN per line, and then save the file. You can also use the `ldapsearch` command with the special character "1.1" to create a file containing a list of DNs that you want to move. The following example searches for all entries that match (`department=Engineering`) and returns only the DNs that match the criteria. The results are re-directed to an output file, `test-dns.ldif`:

```
$ bin/ldapsearch --baseDN dc=example,dc=com \
  --searchScope sub "(department=Engineering)" "1.1" > test-dns.ldif
```

2. Run the `move-subtree` tool with the `--entryDNFile` option to specify the file of DNs that will be moved from one machine to another.

```
$ bin/move-subtree --sourceHost source.example.com --sourcePort 389 \
  --sourceBindDN "uid=admin,dc=example,dc=com" --sourceBindPassword password \
  --targetHost target.example.com --targetPort 389 \
  --targetBindDN "uid=admin,dc=example,dc=com" --targetBindPassword password \
  --entryDNFile /path/to/file/test-dns.ldif
```

3. If an error occurs with one of the DNs in the file, the output message shows the error. The `move-subtree` tool will continuing processing the remaining DNs in the file.

```
An error occurred while communicating with the target server: The entry
uid=user.2,ou=People,dc=example,dc=com cannot be added because an entry with that
 name
already exists
Entry uid=user.3,ou=People,dc=example,dc=com was successfully moved from
source.example.com:389 to target.example.com:389
Entry uid=user.4,ou=People,dc=example,dc=com was successfully moved from
source.example.com:389 to target.example.com:389
```

Working with the Parallel-Update Tool

The UnboundID Data Store provides a `parallel-update` tool, which reads change information (add, delete, modify, and modify DN) from an LDIF file and applies the changes in parallel. This tool is a multi-threaded version of the `ldapmodify` tool that is designed to process a large number of changes as quickly as possible.

The `parallel-update` tool provides logic to prevent conflicts resulting from concurrent operations targeting the same entry or concurrent operations involving hierarchically-dependent entries (for example, modifying an entry after it has been added, or adding a child after its parent). The tool also has a retry capability that can help ensure that operations are ultimately successful even when interdependent operations are not present in the correct order in the LDIF file (for example, the change to add a parent entry is provided later in the LDIF file than a change to add a child entry).

After the tool has applied the changes and reaches the end of the LDIF file, it automatically displays the update statistics described in the following table

Table 18: Parallel-Update Tool Result Statistics

Processing Statistic	Description
Attempts	Number of update attempts
Successes	Number of successful update attempts
Rejects	Number of rejected updates
ToRetry	Number of updates that will be retried
AvgOps/S	Average operations per second
RctOps/S	Recent operations per second. Total number of operations from the last interval of change updates.
AvgDurMS	Average duration in milliseconds
RctDurMS	Recent duration in milliseconds. Total duration from the last interval of change updates.

To Run the Parallel-Update Tool

1. Create an LDIF file with your changes. The third change will generate a rejected entry because its `userPassword` attribute contains an encoded value, which is not allowed.

```
dn:uid=user.2,ou=People,dc=example,dc=com
changetype: delete

dn:uid=user.99,ou=People,dc=example,dc=com
changetype: moddn
newrdn: uid=user.100
```

```
deleteoldrdn: 1

dn:uid=user.101,ou=People,dc=example,dc=com
changetype: add
objectClass: person
objectClass: inetOrgPerson
objectClass: organizationalPerson
objectClass: top
postalAddress: Ziggy Zad$15172 Monroe Street$Salt Lake City, MI 49843
postalCode: 49843
description: This is the description for Ziggy Zad.
uid: user.101
userPassword: {SSHA}IK57iPozIQybmIJMMdRQOpIRudIDn2RcF6bDMg==

dn:uid=user.100,ou=People,dc=example,dc=com
changetype: modify
replace: st
st: TX
-
replace: employeeNumber
employeeNumber: 100
```

2. Use `parallel-update` to apply the changes in the LDIF file to a target server. In this example, we use ten concurrent threads. The optimal number of threads depends on your underlying system. The `--ldifFile` and `--rejectFile` options are also required.

```
$ bin/parallel-update --hostname 127.0.0.1 \
  --ldifFile changes.ldif --rejectFile reject.ldif --numThreads 10
```

```
Reached the end of the LDIF file
Attempts Successes Rejects ToRetry AvgOps/S RctOps/S AvgDurMS RctDurMS
-------- --------- ------- ------- -------- -------- -------- ---------
       4         3       1       0        3        3       26       26
All processing complete Attempted 4 operations in 1 seconds
```

3. View the rejects file for any failed updates.

```
# ResultCode=53, Diagnostic Message=Pre-encoded passwords are not allowed for
# the password attribute userPassword
dn: uid=user.101,ou=People,dc=example,dc=com
changetype: add
objectClass: person
objectClass: inetOrgPerson
objectClass: organizationalPerson
objectClass: top
postalAddress: Ziggy Zad$15172 Monroe Street$Salt Lake City, MI 49843
postalCode: 49843
description: This is the description for Ziggy Zad.
uid: user.101
userPassword: {SSHA}IK57iPozIQybmIJMMdRQOpIRudIDn2RcF6bDMg==
```

Working with LDAP Transactions

The UnboundID Data Store provides support for *batched transactions*, which are processed all at once at commit time. Applications developed to perform batched transactions should include as few operations in the transaction as possible. The changes are not actually processed until the commit request is received. Therefore, the client cannot know whether the changes will be successful until commit time. If any of the operations fail, then the entire set of operations fails.

Batched transactions are write operations (add, delete, modify, modify DN, and password modify) that are processed as a single atomic unit when the commit request is received. If an abort request is received or an error occurs during the commit request, the changes are rolled back. The batched transaction mechanism supports the standard LDAP transaction implementation based on RFC 5805. It is not currently possible to process a transaction that requires changes to be processed across multiple servers or multiple Data Store backends.

Directory servers may limit the set of controls that are available for use in requests that are part of a transaction. RFC 5805 section 4 indicates that the following controls may be used in conjunction with the transaction specification request control: assertion request control, manageDsaIT request control, pre-read request control, and post-read request control. The proxied authorization v1 and v2 controls cannot be included in requests that are part of a transaction, but they can be included in the start transaction request to indicate that all operations within the transaction should be processed with the specified authorization identity.

The UnboundID Data Store supports the following additional UnboundID-specific controls in conjunction with operations included in a transaction: account usable request control, hard delete request control, intermediate client request control, password policy request control, replication repair request control, soft delete request control, soft deleted entry access request control, subtree delete request control, and undelete request control.

To Request a Batched Transaction Using ldapmodify

1. Use the `ldapmodify` tool's `--useTransaction` option. It provides a mechanism for processing multiple operations as part of a single batched transaction. Create a batch text file with the changes that you want to apply as a single atomic unit:

```
dn:uid=user.3,ou=People,dc=example,dc=com
changetype: delete
dn:uid=user.1,ou=People,dc=example,dc=com
changetype: modify
replace: pager
pager: +1 383 288 1090
```

2. Use `ldapmodify` with the `--useTransaction` and `--filename` options to run the batched transaction.

```
$ bin/ldapmodify --useTransaction --filename test.ldif
```

```
#Successfully created a transaction with transaction ID 400
#Processing DELETE request for uid=user.3,ou=People,dc=example,dc=com
#DELETE operation successful for DN uid=user.3,ou=People,dc=example,dc=com
#This operation will be processed as part of transaction 400
#Processing MODIFY request for uid=user.1,ou=People,dc=example,dc=com
#MODIFY operation successful for DN uid=user.1,ou=People,dc=example,dc=com
#This operation will be processed as part of transaction 400
#Successfully committed transaction 400
```

Chapter 12 Working with Virtual Attributes

The UnboundID Data Store provides mechanisms to support virtual attributes in an entry. Virtual attributes are abstract, dynamically generated attributes that are invoked through an LDAP operation, such as `ldapsearch`, but are not stored in the Data Store backend. While most virtual attributes are operational attributes, providing processing-related information that the server requires, the virtual attribute subsystem allows you to create user-defined virtual attributes to suit your data store requirements.

This chapter presents the following topics:

Topics:

Overview of Virtual Attributes

The UnboundID Data Store allows its entries to hold virtual attributes. Virtual attributes are dynamically generated attributes that are invoked through an LDAP operation, such as `ldapsearch`, but are not stored in the Data Store backend. Most virtual attributes are operational attributes, providing processing-related information that the server requires. However, the virtual attribute subsystem allows you to create user-defined virtual attributes to suit your requirements.

Viewing the List of Default Virtual Attributes

The Data Store has a default set of virtual attributes that can be viewed using the `dsconfig` tool. Some virtual attributes are enabled by default and are useful for most applications. You can easily enable or disable each virtual attribute using the `dsconfig` tool.

The default set of virtual attributes are described in the table below. You can enable or disable these attributes using the `dsconfig` tool.

Table 19: Virtual Attrbutes

Virtual Attributes	Description
ds-entry-checksum	Generates a simple checksum of an entry's contents, which can be used with an LDAP assertion control to ensure that the entry has not been modified since it was last retrieved.
ds-instance-name	Generates the name of the Data Store instance from which the associated entry was read. This virtual attribute can be useful in load-balancing environments to determine the instance from which an entry was retrieved.
entryDN	Generates an `entryDN` operational attribute in an entry that holds a normalized copy of the entry's current distinguished name (DN). Clients can use this attribute in search filters.
hasSubordinates	Creates an operational attribute that has a value of TRUE if the entry has subordinate entries.
isMemberOf	Generates an `isMemberOf` operational attribute that contains the DNs of the groups in which the user is a member.
numSubordinates	Generates an operational attribute that returns the number of child entries. While there is no cost if this operational attribute is enabled, there could be a performance cost if it is requested. Note that this operational attribute only returns the number of immediate children of the node.
subschemaSubentry	A special entry that provides information in the form of operational attributes about the schema elements defined in the server. It identifies the location of the schema for that part of the tree. ➢ ldapSyntaxes - set of attribute syntaxes ➢ matchingRules - set of matching rules ➢ matchingRuleUse - set of matching rule uses ➢ attributeTypes - set of attribute types ➢ objectClasses - set of object classes

Virtual Attributes	Description
	➢ nameForms - set of name forms ➢ dITContentRules - set of DIT content rules ➢ dITStructureRules - set of DIT structure rules
User Defined Virtual Attribute	Generates virtual attributes with user-defined values in entries that match the criteria defined in the plug-in's configuration. User-defined virtual attributes are intended to specify a hard-coded value for entries matching a given set of criteria.
Virtual Static Member	Generates a member attribute whose values are the DNs of the members of a specified virtual static group. Virtual static groups are best used in client applications with a large number of entries that can only support static groups and obtains all of its membership from a dynamic group. Do not modify the filter in the `Virtual Static Member` attribute as it is an advanced property and modifying it can lead to undesirable side effects.
Virtual Static Uniquemember	Generates a `uniqueMember` attribute whose values are the DNs of the members of a specified virtual static group. Virtual static groups are best used in client applications with a large number of entries that can only support static groups and obtains all of its membership from a dynamic group. Do not modify the filter in the `Virtual Static Uniquemember` attribute as it is an advanced property and modifying it can lead to undesirable side effects.

To View the List of Default Virtual Attributes Using dsconfig Non-Interactive Mode

- Use `dsconfig` to view the virtual attributes.

```
$ bin/dsconfig list-virtual-attributes
```

Viewing Virtual Attribute Properties

Each virtual attribute has basic properties that you can view using the `dsconfig` tool. The complete list of properties is described in the *UnboundID Data Store Configuration Reference*. Some basic properties are as follows:

- **Description**. A description of the virtual attribute.
- **Enabled**. Specifies whether the virtual attribute is enabled for use.
- **Base-DN**. Specifies the base DNs for the branches containing entries that are eligible to use this virtual attribute. If no values are given, the server generates virtual attributes anywhere in the server.
- **Group-DN**. Specifies the DNs of the groups whose members can use this virtual attribute. If no values are given, the group membership is not taken into account when generating the virtual attribute. If one or more group DNs are specified, then only members of those groups are allowed to have the virtual attribute.
- **Filter**. Specifies the filters that the server applies to entries to determine if they require virtual attributes. If no values are given, then any entry is eligible to have a virtual attribute value generated.

To View Virtual Attribute Properties

- Use `dsconfig` to view the properties of a virtual attribute.

```
$ bin/dsconfig get-virtual-attribute-prop --name isMemberOf
```

Enabling a Virtual Attribute

You can enable a virtual attribute using the `dsconfig` tool. If you are using `dsconfig` in interactive command-line mode, you can access the virtual attribute menu on the Standard object menu.

To Enable a Virtual Attribute using dsconfig Interactive Mode

1. Use `dsconfig` to enable a virtual attribute. Specify the connection port, bind DN, password, and host information. Then type the LDAP connection parameter for your Data Store: 1 for LDAP, 2 for SSL, 3 for StartTLS.

   ```
    bin/dsconfig
   ```

2. On the **Data Store configuration console main** menu, type `o` to change the object menu, and then type the number corresponding to **Standard**.

3. On the **Data Store configuration console main** menu, type the number corresponding to virtual attributes.

4. On the **Virtual Attribute management** menu, type the number to view and edit an existing virtual attribute.

5. From the list of existing virtual attributes on the system, select the virtual attribute to work with. For this example, type the number corresponding to the `numSubordinates` virtual attribute.

6. On the **numSubordinates Virtual Attribute Properties** menu, type the number to enable the virtual attribute. On the **Enabled Property** menu for the `numSubordinates` virtual attribute, type the number to change the value to TRUE.

7. On the **numSubordinates Virtual Attribute Properties** menu, type `f` to apply the changes.

8. Verify that the virtual attribute is enabled. Note that this example assumes you have configured the group entries.

   ```
   $ bin/ldapsearch --baseDN dc=example,dc=com "(ou=People)" numSubordinates
   ```

   ```
   dn: ou=People,dc=example,dc=com
   numSubordinates: 1000
   ```

To Enable a Virtual Attribute Using dsconfig Non-Interactive Mode

- Use `dsconfig` to enable the `numSubordinates` virtual attribute.

```
$ bin/dsconfig set-virtual-attribute-prop \
  --name numSubordinates --set enabled:true
```

Creating User-Defined Virtual Attributes

User-defined virtual attributes allow you to specify an explicit value to use for the virtual attribute. There are no restrictions on the length of the value for a user-defined virtual attribute. You must only ensure that the new virtual attribute conforms to your schema, otherwise you will see an error message when you configure it.

You can define your virtual attributes using the `dsconfig` tool on the Standard object menu. Only the value property is specific to the user-defined virtual attribute. All the other properties are common across all kinds of virtual attributes, which include the following:

- **enabled --** Indicates whether the virtual attribute should be used.
- **attribute-type --** The attribute type for the virtual attribute that will be generated.
- **base-dn**, **group-dn**, **filter --** May be used to select which entries are eligible to contain the virtual attribute.
- **client-connection-policy --** May be used to configure who can see the virtual values.
- **conflict-behavior --** Used to indicate how the server should behave if there are one or more real values for the same attribute type in the same entry. The server can either return only the real value(s), only the virtual value(s), or merge both real and virtual values.
- **require-explicit-request-by-name --** Used to indicate whether the server should only generate values for the virtual attribute if it was included in the list of requested attributes.
- **multiple-virtual-attribute-evaluation-order-index**, **multiple-virtual-attribute-merge-behavior --** Used to control the behavior the server should exhibit if multiple virtual attributes may be used to contribute values to the same attribute.

To Create a User-Defined Virtual Attribute in Interactive Mode

The following example shows how to create a user-defined virtual attribute that assigns an Employee Password Policy to any entry that matches the filter `"(employeeType=employee)"`.

1. Run `dsconfig` to configure the user-defined virtual attribute. Specify the connection port, bind DN, password, and host information. Then type the LDAP connection parameter for your Data Store: 1 for LDAP, 2 for SSL, 3 for StartTLS.

2. On the **Data Store configuration console main** menu, type `o` to change the object menu, and then type the number to select Standard.
3. On the**Data Store configuration console main** menu, type the number corresponding to virtual attributes.
4. On the **Virtual Attribute management** menu, type the number to create a new virtual attribute.
5. Next, you can use an existing virtual attribute as a template for your new attribute, or your can create a new attribute from scratch. In this example, type `n` to create a new Virtual Attribute from scratch.
6. On the **Virtual Attribute Type** menu, enter a number corresponding to the type of virtual attribute that you want to create. In this example, type the number corresponding to User Defined Virtual Attribute.
7. Next, enter a name for the new virtual attribute. In this example, enter "`Employee Password Policy Assignment`."
8. On the **Enabled Property** menu, enter the number to set the property to true (enable).
9. On the **Attribute-Type Property** menu, type the `attribute-type` property for the new virtual attribute. You can enter the OID number or attribute name. The `attribute-type` property must conform to your schema. For this example, type "`ds-pwp-password-policy-dn`".
10. Enter the value for the virtual attribute, and then press Enter or Return to continue. In this example, enter `cn=Employee Password Policy,cn=Password Policies,cn=config`, and then type Enter or Return to continue.
11. On the **User Defined Virtual Attributes** menu, enter a description for the virtual attribute. Though optional, this step is useful if you plan to create a lot of virtual attributes. Enter the option to change the value, and then type a description of the virtual attribute. In this example, enter: `Virtual attribute that assigns the Employee Password Policy to all entries that match (employeeType=employee)`.
12. On the **User Defined Virtual Attribute** menu, type the number corresponding to the filter.
13. On the **Filter Property** menu, enter the option to add one or more filter properties, type the filter, and then press **Enter** to continue. In this example, type `(employeeType=employee)`. Press the number to use the filter value entered.
14. On the **User Defined Virtual Attribute** menu, type `f` to finish creating the virtual attribute.
15. Verify that the attribute was created successfully. Add the `employeeType=employee` attribute to an entry (e.g., `uid=user.0`) using `ldapmodify`. Add the `employeeType=contractor` attribute to another entry (e.g., `uid=user.1`).
16. Use `ldapsearch` to search for the user with the `employeeType=employee` attribute (e.g., `uid=user.0`). You will notice the `ds-pwp-password-policy-dn` attribute has the assigned password policy as its value.

```
$ bin/ldapsearch --baseDN dc=example,dc=com "(uid=user.0)" \
  ds-password-policy-dn
```

```
dn: uid=user.0,ou=People,dc=example,dc=com
ds-pwp-password-policy-dn: cn=Employee Password Policy,cn=Password Policies,cn=config
```

17. Run `ldapsearch` again using the filter "`(uid=user.1)`", the `ds-pwp-password-policy-dn` attribute will not be present in the entry, because the entry has the attribute, `employeeType=contractor`.

```
$ bin/ldapsearch --baseDN dc=example,dc=com "(uid=user.1)" \
  ds-password-policy-dn
```

```
dn: uid=user.1,ou=People,dc=example,dc=com
```

To Create a User-Defined Virtual Attribute Using dsconfig in Non-Interactive Mode

- You can also use `dsconfig` in non-interactive command-line mode to create a virtual attribute. The following command sets up the Employee Password Policy Assignment virtual attribute introduced in the previous section:

```
$ bin/dsconfig create-virtual-attribute \
  --name "Employee Password Policy Assignment" \
  --type user-defined \
  --set enabled:true \
  --set attribute-type:ds-pwp-password-policy-dn \
  --set "filter:(employeeType=employee)" \
  --set "value:cn=Employee Password Policy,cn=Password Policies,cn=config"
```

Creating Mirror Virtual Attributes

The UnboundID Data Store provides a feature to mirror the value of another attribute in the same entry or mirror the value of the same or a different attribute in an entry referenced by the original entry. For example, given a DIT where users have a manager attributed with a value of the DN of the employee as follows:

```
dn: uid=apeters,ou=people,dc=example,dc=com
objectClass: person
objectClass: inetOrgPerson
objectClass: organizationalPerson
objectClass: top
manager:uid=jdoe,ou=people,dc=example,dc=com
uid: apeters
... (more attributes) ...
```

You can set up a mirror virtual attribute, so that the returned value for the `managerName` virtual attribute can be the `cn` value of the entry referenced by the `manager` attribute as follows:

```
$ bin/ldapsearch --baseDN dc=example,dc=com "(uid=apeters)" \
dn: uid=apeters,ou=people,dc=example,dc=com

objectClass: person
objectClass: inetOrgPerson
objectClass: organizationalPerson
objectClass: top
manager:uid=jdoe,ou=people,dc=example,dc=com
managerName: John Doe
uid: apeters
```

```
... (more attributes not shown) ...
```

To Create a Mirror Virtual Attribute in Non-Interactive Mode

You can also use `dsconfig` in non-interactive command-line mode to create a mirror virtual attribute. The following example sets up the `managerName` virtual attribute introduced in the previous section:

1. Update the schema to define the `managerName` attribute. In a text editor, create a file with the following schema definition for the attribute and save it as `98-myschema.ldif`, for example, in the `<server-root>/config/schema` folder. You can optionally add the attribute to an object class. See *Extending the Schema Using a Custom Schema File* for more information.

   ```
   dn: cn=schema
   objectClass: top
   objectClass: ldapSubent
   ry
   objectClass: subschema attributeTypes: ( 1.3.6.1.4.1.32473.3.1.9.4 NAME
    'managerName'
     EQUALITY caseIgnoreMatch SUBSTR caseIgnoreSubstringsMatch SYNTAX
    1.3.6.1.4.1.1466.115.121.1.44{256}
     X-ORIGIN 'Data Store Example' )
   ```

2. Restart the Data Store.

   ```
   $ bin/stop-ds --restart
   ```

3. Use `dsconfig` to create the virtual attribute.

   ```
   $ bin/dsconfig create-virtual-attribute \
     --name "managerName" \
     --type mirror \
     --set "description:managerName from manager cn" \
     --set enabled:true \
     --set attribute-type:managerName \
     --set source-attribute:cn \
     --set source-entry-dn-attribute:manager
   ```

4. Verify the mirror virtual attribute by searching for an entry.

   ```
   $ bin/ldapsearch --baseDN dc=example,dc=com "(uid=apeters)"
   ```

   ```
   dn: uid=apeters,ou=People,dc=example,dc=com
   ... (attributes) ...
   manager: uid=jdoe,ou=People,dc=example,dc=com
   managerName: John Doe
   ```

Editing a Virtual Attribute

You can edit virtual attributes using the `dsconfig` tool. You must ensure that the virtual attribute conforms to your plug-in schema, otherwise you will see an error message when you edit the virtual attribute. If you are using `dsconfig` in interactive command-line mode, you can access the virtual attribute menu on the Standard object menu.

To Edit a Virtual Attribute Using dsconfig in Non-Interactive Mode

- Use `dsconfig` to change a property's value.

```
$ bin/dsconfig set-virtual-attribute-prop --name dept-number \
  --set "value:111"
```

Deleting a Virtual Attribute

You can delete virtual attributes using the `dsconfig` tool. If you are using `dsconfig` in interactive command-line mode, you can access the virtual attribute menu on the Standard object menu.

To Delete a Virtual Attribute

- Use `dsconfig` to delete an existing virtual attribute.

```
$ bin/dsconfig delete-virtual-attribute --name dept-number
```

Chapter 13 Working with Groups

LDAP groups are special types of entries that represent collections of users. Groups are often used by external clients, for example, to control who has access to a particular application or features. They may also be used internally by the server to control its behavior. For example, groups can be used by the access control, criteria, or virtual attribute subsystems.

The specific ways in which clients create and interact with a particular group depends on the type of group being used. In general, there are three primary ways in which clients attempt to use groups:

- To determine whether a specified user is a member of a particular group.
- To determine the set of groups in which a specified user is a member.
- To determine the set of all users that are members of a particular group.

This chapter provides an overview of Data Store groups concepts and provides procedures on setting up and querying groups in the Data Store.

Topics:

Overview of Groups

The Data Store provides the following types of groups:

- **Static Groups**. A static group is an entry that contains an explicit list of member or uniquemember attributes, depending on its particular structural object class. Static groups are ideal for relatively small, infrequently changing elements. Once the membership list grows, static groups become more difficult to manage as any change in a member base DN must also be changed in the group. Static groups use one of three structural object classes: `groupOfNames`, `groupOfUniqueNames`, and `groupOfEntries`.

  The Data Store also supports nested groups, in which a parent group entry contains child attributes whose DNs reference another group. Nested groups are a flexible means to organize entries that provide inherited group membership and privileges. To maintain good performance throughput, a group cache is enabled by default. The cache supports static group nesting that includes other static, virtual static, and dynamic groups.

- **Dynamic Groups**. A dynamic group has its membership list determined by search criteria using a LDAP URL. Dynamic groups solve the scalability issues encountered for static groups as searches are efficient, constant-time operations. However, if searches range over a very large set of data, performance could be affected.

- **Virtual Static Groups**. A virtual static group is a combination of both static and dynamic groups, in which each member in a group is a virtual attribute that is dynamically generated when invoked. Virtual static groups solve the scalability issues for clients that can only support static groups and are best used when the application targets a search operation for a specific member. Virtual static groups are not good for applications that need to retrieve the entire membership list as the process for constructing the entire membership list can be expensive.

About the isMemberOf and isDirectMemberOf Virtual Attribute

The existence of both static, nested, dynamic, and virtual static groups can make it unnecessarily complex to work with groups in the server, particularly because the ways you interact with them are so different. And the fact that static groups can use three different structural object classes (not counting the auxiliary class for virtual static groups) does not make things any easier.

To make group operations simpler, the UnboundID Data Store provides the ability to generate either an `isMemberOf` and `isDirectMemberOf` virtual attributes in user entries. These attributes dramatically simplify the process for making group-related determinations in a manner that is consistent across all types of groups.

The value of the `isMemberOf` virtual attribute is a list of DNs of all groups (including static, nested, dynamic, and virtual static groups) in which the associated user is a member. The value of the `isDirectMemberOf` virtual attribute is a subset of the values of isMemberOf, which represents the groups for which the entry is an explicit or direct member. While the `isMemberOf` virtual attribute is enabled by default, you must enable the `isDirectMemberOf` virtual attribute if you plan to use it. Run the following `dsconfig` command to enable the virtual attribute:

```
dsconfig set-virtual-attribute-prop --name isDirectMemberOf --set enabled:true
```

Because the `isMemberOf` and `isDirectMemberOf` are operational attributes, only users who specifically have been granted the privilege can see it. The default set of access control rules do not allow any level of access to user data. The only access that is granted is what is included in user-defined access control rules, which is generally given to a `uid=admin` administrator account. It is always a best practice to restrict access to operational and non-operational attributes to the minimal set of users that need to see them. The root bind DN, `cn=Directory Manager`, has the privilege to view operational attributes by default.

To determine whether a user is a member of a specified group using the `isMemberOf` virtual attribute, simply perform a base-level search against the user's entry with an equality filter targeting the `isMemberOf` attribute with a value that is the DN of the target group. The `isMemberOf` attribute is best implemented when you want to only find groups that users are an actual member of (i.e., not including nested group membership). The following table illustrates this simple base-level search:

Base DN	uid=john.doe,ou=People,dc=example,dc=com
Scope	base
Filter	(isMemberOf=cn=Test Group,ou=Groups,dc=example,dc=com)
Requested Attributes	1.1

If this search returns an entry, then the user is a member of the specified group. If no entry is returned, then the user is not a member of the given group.

To determine the set of all groups in which a user is a member, simply retrieve the user's entry with a base-level search and include the `isMemberOf` attribute:

Base DN	uid=john.doe,ou=People,dc=example,dc=com
Scope	base
Filter	(objectclass=*)
Requested Attributes	isMemberOf

To determine the set of all members for a specified group, issue a subtree search with an equality filter targeting the `isMemberOf` attribute with a value that is the DN of the target group and requesting the attributes you wish to have for member entries:

Base DN	uid=john.doe,ou=People,dc=example,dc=com
Scope	sub
Filter	(isMemberOf=cn=Test Group,ou=Groups,dc=example,dc=com)
Requested Attributes	cn, mail

The `isDirectMemberOf` virtual attribute can be used in the examples above in place of `isMemberOf` if you only need to find groups that users are an actual member of. You must use `isMemberOf` for nested group membership.

Note that if this filter targets a dynamic group using an unindexed search, then this may be an expensive operation. However, it will not be any more expensive than retrieving the target group and then issuing a search based on information contained in the member URL.

For static groups, this approach has the added benefit of using a single search to retrieve information from all user entries, whereas it would otherwise be required to retrieve the static group and then perform a separate search for each member's entry.

Using Static Groups

A static group contains an explicit membership list where each member is represented as a DN-valued attribute. There are three types of static groups supported for use in the Data Store:

- **groupOfNames**. A static group that is defined with the `groupOfNames` structural object class and uses the `member` attribute to hold the DNs of its members. RFC 4519 requires that the `member` attribute be required in an entry. However, the Data Store has relaxed this restriction by making the `member` attribute optional so that the last member in the group can be removed. The following entry depicts a group defined with the `groupOfNames` object class:

  ```
  dn: cn=Test Group,ou=Groups,dc=example,dc=com
  objectClass: top
  objectClass: groupOfNames
  cn: Test Group
  member: uid=user.1,ou=People,dc=example,dc=com
  member: uid=user.2,ou=People,dc=example,dc=com
  member: uid=user.3,ou=People,dc=example,dc=com
  ```

- **groupOfUniqueNames**. A static group that is defined with the `groupOfUniqueNames` structural object class and uses the `uniquemember` attribute to hold the DNs of its members. RFC 4519 requires that the `uniquemember` attribute be required in an entry. However, the Data Store has relaxed this restriction by making the `uniquemember` attribute optional so that the last member in the group can be removed. The following entry depicts a group defined with the `groupOfUniqueNames` object class:

  ```
  dn: cn=Test Group,ou=Groups,dc=example,dc=com
  objectClass: top
  objectClass: groupOfUniqueNames
  cn: Test Group
  uniquemember: uid=user.1,ou=People,dc=example,dc=com
  uniquemember: uid=user.2,ou=People,dc=example,dc=com
  uniquemember: uid=user.3,ou=People,dc=example,dc=com
  ```

- **groupOfEntries**. A static group that is defined with the `groupOfEntries` object class and uses the `member` attribute to hold the DNs of its members. This group specifies that the `member` attribute is optional to ensure that the last member can be removed from the group. Although the draft proposal (draft-findlay-ldap-groupofentries-00.txt) has expired, the Data Store supports this implementation. The following entry depicts a group defined with the `groupOfEntries` object class:

  ```
  dn: cn=Test Group,ou=Groups,dc=example,dc=com
  objectClass: top
  objectClass: groupOfEntries
  cn: Test Group
  member: uid=user.1,ou=People,dc=example,dc=com
  member: uid=user.2,ou=People,dc=example,dc=com
  member: uid=user.3,ou=People,dc=example,dc=com
  ```

Creating Static Groups

You can configure a static group by adding it using an LDIF file. Static groups contain a membership list of explicit DNs specified by the `uniquemember` attribute.

To Create a Static Group

1. Open a text editor, and then create a group entry in LDIF. Make sure to include the `groupOfUniquenames` object class and `uniquemember` attributes. If you did not have `ou=groups` set up in your server, then you can add it in the same file. When done, save the file as `static-group.ldif`. The following example LDIF file creates two groups, `cn=Development` and `cn=QA`.

```
dn: ou=groups,dc=example,dc=com
objectclass: top
objectclass: organizationalunit
ou: groups

dn: cn=Development,ou=groups,dc=example,dc=com
objectclass: top
objectclass: groupOfUniqueNames
cn: Development
ou: groups
uniquemember: uid=user.14,ou=People,dc=example,dc=com
uniquemember: uid=user.91,ou=People,dc=example,dc=com
uniquemember: uid=user.180,ou=People,dc=example,dc=com

dn: cn=QA,ou=groups,dc=example,dc=com
objectclass: top
objectclass: groupOfUniqueNames
cn: QA
ou: groups
uniquemember: uid=user.0,ou=People,dc=example,dc=com
uniquemember: uid=user.1,ou=People,dc=example,dc=com
uniquemember: uid=user.2,ou=People,dc=example,dc=com
```

2. Use `ldapmodify` to add the group entries to the server.

```
$ bin/ldapmodify --defaultAdd --filename static-group.ldif
```

3. Verify the configuration by using the virtual attribute `isDirectMemberOf` that checks membership for a non-nested group. By default, the virtual attribute is disabled by default, but you can enable it using `dsconfig`.

```
$ bin/dsconfig set-virtual-attribute-prop --name isDirectMemberOf --set enabled:true
```

4. Use `ldapsearch` to specifically search the `isDirectMemberOf` virtual attribute to determine if `uid=user.14` is a member of the `cn=Development` group. In this example, assume that administrator has the privilege to view operational attributes.

```
$ bin/ldapsearch --baseDN dc=example,dc=com "(uid=user.14)" isDirectMemberOf
```

```
dn: uid=user.14,ou=People,dc=example,dc=com
isDirectMemberOf: cn=Development,ou=groups,dc=example,dc=com
```

5. Typically, you would want to use the group as a target in access control instructions. Open a text editor, create an `aci` attribute in an LDIF file, and save the file as `dev-group-aci.ldif`.

Add the file using the `ldapmodify` tool. You can create a similar ACI for the QA group, which is not shown in this example.

```
dn: ou=People,dc=example,dc=com
changetype: modify
add: aci
aci: (target ="ldap:///ou=People,dc=example,dc=com")
  (targetattr != "cn || sn || uid")
  (targetfilter ="(ou=Development)")
  (version 3.0; acl "Dev Group Permissions";
    allow (write) (groupdn = "ldap:///cn=Development,ou=groups,dc=example,dc=com");)
```

6. Add the file using the `ldapmodify` tool.

```
$ bin/ldapmodify --filename dev-group-aci.ldif
```

To Add a New Member to a Static Group

- To add a new member to the group, add a new value for the `uniquemember` attribute that specifies the DN of the user to be added. The following example adds a new `uniquemember`, `user.4`:

```
dn: cn=QA,ou=Groups,dc=example,dc=com
changetype: modify
add: uniquemember
uniquemember: uid=user.4,ou=People,dc=example,dc=com
```

To Remove a Member from a Static Group

- To remove a member from a static group, remove that user's DN from the `uniquemember` attribute. The following example removes the DN of `user.1`:

```
dn: cn=QA,ou=Groups,dc=example,dc=com
changetype: modify
delete: uniquemember
uniquemember: uid=user.1,ou=People,dc=example,dc=com
```

Searching Static Groups

The following sections describe how to compose searches to determine if a user is a member of a static group, to determine all the static groups in which a user is a member, and to determine all the members of a static group.

To Determine if a User is a Static Group Member

To determine whether a user is a member of a specified group, perform a base-level search to retrieve the group entry with an equality filter looking for the membership attribute of a value equal to the DN of the specified user.

For best performance, you will want to include a specific attribute list (just "cn", or "1.1" request that no attributes be returned) so that the entire member list is not returned. For example, to determine whether the user "`uid=john.doe,ou=People,dc=example,dc=com`" is a member of the `groupOfNames` static group "`cn=Test Group,ou=Groups,dc=example,dc=com`", issue a search with the following criteria:

Table 20: Search Criteria for a Single User's Membership in a Static Group

Base DN	cn=Test Group,ou=Groups,dc=example,dc=com
Scope	base
Filter	(member=uid=john.doe,ou=People,dc=example,dc=com)
Requested Attributes	1.1

If the search returns an entry, then the user is a member of the specified group. If the search does not return any entries, then the user is not a member of the group. If you do not know the membership attribute for the specified group (it could be either a `member` or `uniqueMember` attribute), then you may want to revise the filter so that it allows either one as follows:

```
(|(member=uid=john.doe,ou=People,dc=example,dc=com)
(uniqueMember=uid=john.doe,ou=People,dc=example,dc=com))
```

- Run a base-level search to retrieve the group entry with an equality filter looking for the membership attribute.

```
$ bin/ldapsearch --baseDN "cn=Test Group,ou=Groups,dc=example,dc=com"
  --searchScope base "(member=uid=john.doe,ou=People,dc=example,dc=com)" "1.1"
```

To Determine the Static Groups to Which a User Belongs

To determine the set of all static groups in which a user is specified as a member, perform a subtree search based at the top of the DIT. The search filter must be configured to match any type of static group in which the specified user is a member.

For example, the following criteria may be used to determine the set of all static groups in which the user, `uid=john.doc,ou=People,dc=example,dc=com`, is a member:

Table 21: Search Criteria for Determining All the Static Groups for a User

Base DN	dc=example,dc=com
Scope	sub
Filter	(|(&(objectClass=groupOfNames) (member=uid=john.doe,ou=People,dc=example,dc=com)) (&(objectClass=groupOfUniqueNames)(uniqueMem-ber=uid=john.doe,ou=People,dc=example,dc=com)) (&(objectClass=groupOfEntries) (member=uid=john.doe,ou=People,dc=example,dc=com)))
Requested Attributes	1.1

Every entry returned from the search represents a static group in which the specified user is a member.

- Run a sub-level search to retrieve the static groups to which a user belongs.

```
$ bin/ldapsearch --baseDN "dc=example,dc=com" --searchScope sub \
  "(|(&(objectClass=groupOfNames)
  (member=uid=john.doe,ou=People,dc=example,dc=com)) \
  (&(objectClass=groupOfUniqueNames)\
  (uniqueMember=uid=john.doe,ou=People,dc=example,dc=com)) \
  (&(objectClass=groupOfEntries) \
  (member=uid=john.doe,ou=People,dc=example,dc=com)))" "1.1"
```

Note: A base level search of the user's entry for `isMemberOf` or `isDirectMemberOf` virtual attributes will give the same results. You can also use the virtual attributes with virtual static groups.

To Determine the Members of a Static Group

To determine all of the members for a static group, simply retrieve the group entry including the membership attribute. The returned entry will include the DNs of all users that are members of that group. For example, the following criteria may be used to retrieve the list of all members for the group `cn=Test Group,ou=Groups,dc=example,dc=com`:

Table 22: Search Criteria for All of the Static Group's Members

Base DN	cn=Test Group,ou=Groups,dc=example,dc=com
Scope	base
Filter	(objectClass=*)
Requested Attributes	member uniqueMember

If you want to retrieve additional information about the members, such as attributes from member entries, you must issue a separate search for each member to retrieve the user entry and the desired attributes.

- Run a base-level search to retrieve all of the members in a static group.

```
$ bin/ldapsearch --baseDN "cn=Test Group,ou=Groups,dc=example,dc=com" \
  --searchScope base "(objectclass=*)" uniqueMember
```

Note: If you want to retrieve attributes from member entries, it is more efficient to search all users whose `isMemberOf` attribute contains the group DN, returning the attributes desired.

Using Dynamic Groups

Dynamic groups contain a set of criteria used to identify members rather than maintaining an explicit list of group members. If a new user entry is created or if an existing entry is modified so that it matches the membership criteria, then the user will be considered a member of the dynamic group. Similarly, if a member’s entry is deleted or if it is modified so that it no longer matches the group criteria, then the user will no longer be considered a member of the dynamic group.

In the Data Store, dynamic groups include the `groupOfURLs` structural object class and use the `memberurl` attribute to provide an LDAP URL that defines the membership criteria. The base, scope, and filter of the LDAP URL will be used in the process of making the determination, and any other elements present in the URL will be ignored. For example, the following entry defines a dynamic group in which all users below `dc=example,dc=com` with an `employeeType` value of contractor will be considered members of the group:

```
dn: cn=Sales Group,ou=groups,dc=example,dc=com
objectClass: top
objectClass: groupOfURLs
cn: Sales Group
memberURL: ldap:///dc=example,dc=com??sub?(employeeType=contractor)
```

Assuming that less than 80,000 entries have the `employeeType` of contractor, you need to create the following index definition to evaluate the dynamic group:

```
$ bin/dsconfig create-local-db-index --backend-name userRoot \
  --index-name employeeType --set index-entry-limit:80000 \
  --set index-type:equality
```

Creating Dynamic Groups

You can configure a dynamic group in the same manner as static groups using an LDIF file. Dynamic groups contain a membership list of attributes determined by search filter using an LDAP URL. You must use the `groupOfURLs` object class and the `memberURL` attribute.

To Create a Dynamic Group

1. Assume that `uid=user.15` is not part of any group. Use `ldapsearch` to verify that `uid=user.15` is not part of any group. In a later step, we will add the user to the dynamic group.

   ```
   $ bin/ldapsearch --baseDN dc=example,dc=com --searchScope sub "(uid=user.15)" ou
   ```

   ```
   dn: uid=user.15,ou=People,dc=example,dc=com
   ```

2. Assume for this example that `uid=user.0` has an `ou=Engineering` attribute indicating that he or she is a member of the Engineering department.

   ```
   $ bin/ldapsearch --baseDN dc=example,dc=com --searchScope sub "(uid=user.0)" ou
    isMemberOf
   ```

   ```
   dn: uid=user.0,ou=People,dc=example,dc=com
   ou: Engineering
   ```

3. Open a text editor, and then create a dynamic group entry in LDIF. The LDIF defines the dynamic group to include all users who have the `ou=Engineering` attribute. When done, save the file as `add-dynamic-group.ldif`.

   ```
   dn: cn=eng-staff,ou=groups,dc=example,dc=com
   objectclass: top
   objectclass: groupOfURLs
   ou: groups
   cn: eng-staff
   memberURL: ldap:///ou=People,dc=example,dc=com??sub?(ou=Engineering)
   ```

4. Use `ldapmodify` to add the group entry to the server.

   ```
   $ bin/ldapmodify --defaultAdd --filename add-dynamic-group.ldif
   ```

5. Use `ldapsearch` to specifically search the `isMemberOf` virtual attribute to determine if `uid=user.0` is a member of the `cn=Engineering` group or any other group.

```
$ bin/ldapsearch --baseDN dc=example,dc=com "(uid=user.0)" isMemberOf
```

```
dn: uid=user.0,ou=People,dc=example,dc=com
isMemberOf: cn=eng-staff,ou=groups,dc=example,dc=com
```

6. If your data is relatively small (under 1 million entries), you can search for all users in the group that meet the search criteria (`ou=Engineering`). For very large databases, it is not practical to run a database-wide search for all users as there can be a performance hit on the Data Store. The following command returns the DNs of entries that are part of the `cn=eng-staff` dynamic group and sorts them in ascending order by the `sn` attribute.

```
$ bin/ldapsearch --baseDN dc=example,dc=com --sortOrder sn \
  "(isMemberOf=cn=eng-staff,ou=groups,dc=example,dc=com)" dn
```

7. Add `uid=user.15` to the `eng-staff` group by adding an `ou=Engineering` attribute to the entry. This step highlights an advantage of dynamic groups: you can make a change in an entry without explicitly adding the DN to the group as you would with static groups. The entry will be automatically added to the `eng-staff` dynamic group.

```
$ bin/ldapmodify
dn: uid=user.15,ou=People,dc=example,dc=com
changetype: modify
add: ou
ou: Engineering
```

8. Use `ldapsearch` to check if the user is part of the `cn=eng-staff` dynamic group.

```
$ bin/ldapsearch --baseDN dc=example,dc=com --searchScope sub "(uid=user.15)"
 isMemberOf
```

```
dn: uid=user.15,ou=People,dc=example,dc=com
isMemberOf: cn=eng-staff,ou=groups,dc=example,dc=com
```

Searching Dynamic Groups

The following sections describe how to compose searches to determine if a user is a member of a dynamic group, to determine all the dynamic groups in which a user is a member, and to determine all the members of a dynamic group.

To Determine if a User is a Dynamic Group Member

To determine whether a user is a member of a specific dynamic group, you must verify that the user's entry is both within the scope of the member URL and that it matches the filter contained in that URL. You can verify that a user's entry is within the scope of the URL using simple client-side only processing. Evaluating the filter against the entry on the client side can be more complicated. While possible, particularly in clients that are able to perform schema-aware evaluation, a simple alternative is to perform a base-level search to retrieve the user's entry with the filter contained in the member URL.

For example, to determine whether the user `uid=john.doe,ou=People,dc=example,dc=com` is a member of the dynamic group with the above member URL, issue a search with the following criteria:

Table 23: Search Criteria for a Single User's Membership in a Dynamic Group

Base DN	uid=john.doe,ou=People,dc=example,dc=com
Scope	base
Filter	(ou=Engineering)
Requested Attributes	1.1

Note that the search requires the user DN to be under the search base defined in the `memberurl` attribute for the user to be a member. If the search returns an entry, then the user is a member of the specified group. If the search does not return any entries, then the user is not a member of the group.

To Determine the Dynamic Groups to Which a User Belongs

To determine the set of all dynamic groups in which a user is a member, first perform a search to find all dynamic group entries defined in the server. You can do this using a subtree search with a filter of `"(objectClass=groupOfURLs)"`.

You should retrieve the `memberURL` attribute so that you can use the logic described in the previous section to determine whether the specified user is a member of each of those groups. For example, to find the set of all dynamic groups defined in the `dc=example,dc=com` tree, issue a search with the following criteria:

Table 24: Search Criteria for Determining All of the Dynamic Groups for a User

Base DN	dc=example,dc=com
Scope	sub
Filter	(objectClass=groupOfURLs)
Requested Attributes	memberURL

Each entry returned will be a dynamic group definition. You can use the base, scope, and filter of its `memberURL` attribute to determine whether the user is a member of that dynamic group.

To Determine the Members of a Dynamic Group

To determine all members of a dynamic group, issue a search using the base, scope, and filter of the member URL. The set of requested attributes should reflect the attributes desired from the member user entries, or "1.1" if no attributes are needed.

For example, to retrieve the `cn` and `mail` attributes from the group described above, use the following search:

Table 25: Search Criteria for Determining the Members of a Dynamic Group

Base DN	dc=example,dc=com
Scope	sub
Filter	(employeeType=contractor)
Requested Attributes	cn, mail

Caution: Note that this search may be expensive if the associated filter is not indexed or if the group contains a large number of members.

Using Dynamic Groups for Internal Operations

You can use dynamic groups for internal operations, such as ACI or component evaluation. The Data Store performs the `memberurl` parsing and internal LDAP search; however, the internal search operation may not be performed with access control rules applied to it.

For example, the following dynamic group represents an organization’s employees within the same department:

```
dn: cn=department 202,ou=groups,dc=example,dc=com
objectClass: top
objectClass: groupOfURLs
cn: department 202
owner: uid=user.1,ou=people,dc=example,dc=com
owner: uid=user.2,ou=people,dc=example,dc=com
memberURL: ldap:///ou=People,dc=example,dc=com??sub?
  (&(employeeType=employee)(departmentNumber=202))
description: Group of employees in department 202
```

The above group could be referenced from within the ACI at the `dc=example,dc=com` entry. For example:

```
dn:dc=example,dc=com
aci: (targetattr="employeeType")
  (version 3.0; acl "Grant write access to employeeType" ;
    allow (all) groupdn="ldap:///cn=department 202,ou=groups,dc=example,dc=com";)
```

Any user matching the filter can bind to the server with their entry and modify the `employeeType` attribute within any entry under `dc=example,dc=com`.

Using Virtual Static Groups

Static groups can be easier to interact with than dynamic groups, but large static groups can be expensive to manage and require a large amount of memory to hold in the internal group cache. The Data Store provides a third type of group that makes it possible to get the efficiency and ease of management of a dynamic group while allowing clients to interact with it as a static group. A *virtual static group* is a type of group that references another group and provides access to the members of that group as if it was a static group.

To create a virtual static group, create an entry that has a structural object class of either `groupOfNames` or `groupOfUniqueNames` and an auxiliary class of `ds-virtual-static-group`. It should also include a `ds-target-group-dn` attribute, whose value is the group from which the virtual static group should obtain its members. For example, the following will create a virtual static group that exposes the members of the `cn=Sales Group,ou=Groups,dc=example,dc=com` dynamic group as if it were a static group:

```
dn: cn=Virtual Static Sales Group,ou=Groups,dc=example,dc=com
objectClass: top
objectClass: groupOfNames
objectClass: ds-virtual-static-group
cn: Virtual Static Sales Group
```

```
ds-target-group-dn: cn=Sales Group,ou=Groups,dc=example,dc=com
```

Note that you must also enable a virtual attribute that allows the `member` attribute to be generated based on membership for the target group. A configuration object for this virtual attribute does exist in the server configuration, but is disabled by default. To enable it, issue the following change:

```
$ bin/dsconfig set-virtual-attribute-prop --name "Virtual Static member" \
  --set enabled:true
```

If you want to use virtual static groups with the `groupOfUniqueNames` object class, then you will also need to enable the `Virtual Static uniqueMember` virtual attribute in the same way.

Creating Virtual Static Groups

If your application only supports static groups but has scalability issues, then using a virtual static group could be a possible solution. A virtual static group uses a virtual attribute that is dynamically generated when called after which the operations that determine group membership are passed to another group, such as a dynamic group. You must use the `ds-virtual-static-group` object class and the `ds-target-group-dn` virtual attribute.

Virtual static groups are best used when determining if a single user is a member of a group. It is not a good solution if an application accesses the full list of group members due to the performance expense at constructing the list. If you have a small database and an application that requires that the full membership list be returned, you must also enable the `allow-retrieving-membership` property for the Virtual Static `uniqueMember` virtual attribute using the `dsconfig` tool.

To Create a Virtual Static Group

1. Open a text editor, and then create a group entry in LDIF. The entry contains the `groupOfUniqueNames` object class, but in place of the `uniquemember` attribute is the `ds-target-group-dn` virtual attribute, which is part of the `ds-virtual-static-group` auxiliary object class. When done, save the file as `add-virtual-static-group.ldif`.

```
dn: cn=virtualstatic,ou=groups,dc=example,dc=com
objectclass: top
objectclass: groupOfUniqueNames
objectclass: ds-virtual-static-group
ou: groups
cn: virtual static
ds-target-group-dn: cn=eng-staff,ou=groups,dc=example,dc=com
```

2. Use `ldapmodify` to add the virtual static group entry to the server.

```
$ bin/ldapmodify -h server1.example.com -p 389 -D "uid=admin,dc=example,dc=com" \
  -w password -a -f add-virtual-static-group.ldif
```

3. Use `dsconfig` to enable the Virtual Static `uniqueMember` attribute, which is disabled by default.

```
$ bin/dsconfig set-virtual-attribute-prop --name "Virtual Static uniqueMember" \
  --set enabled:true
```

4. In the previous section, we set up `uid=user.0` to be part of the `cn=eng-staff` dynamic group. Use `ldapsearch` with the `isMemberOf` virtual attribute to determine if `uid=user.0` is part of the virtual static group.

```
$ bin/ldapsearch -h server1.example.com -p 389 -D "cn=Directory Manager" \
  -w secret -b dc=example,dc=com" "(uid=user.0)" isMemberOf
```

```
dn: uid=user.0,ou=People,dc=example,dc=com
isMemberOf: cn=virtualstatic,ou=groups,dc=example,dc=com
isMemberOf: cn=eng-staff,ou=groups,dc=example,dc=com
```

5. Use `ldapsearch` to determine if `uid=user.0` is a member of the virtual static group. You should see the returned `cn=virtualstatic` entry if successful.

```
$ ldapsearch -h localhost -p 1389 -D "cn=Directory Manager" -w password \
  -b "cn=virtualStatic,ou=Groups,dc=example,dc=com" \
  "(&(objectclass=groupOfUniqueNames) \
  (uniquemember=uid=user.0,ou=People,dc=example,dc=com))"
```

6. Next, try searching for a user that is not part of the `cn=eng-staff` dynamic group (e.g., `uid=user.20`), nothing will be returned.

```
$ ldapsearch -h localhost -p 1389 -D "cn=Directory Manager" -w password \
  -b "cn=virtualStatic,ou=Groups,dc=example,dc=com" \
  "(&(objectclass=groupOfUniqueNames) \
  (uniquemember=uid=user.20,ou=People,dc=example,dc=com))"
```

Searching Virtual Static Groups

Because virtual static groups behave like static groups, the process for determining whether a user is a member of a virtual static group is identical to that of a member in a static group. Similarly, the process for determining all virtual static groups in which a user is a member is basically the same as the process as that of real static groups in which a user is a member. In fact, the query provided in the static groups discussion returns virtual static groups in addition to real static groups, because the structural object class of a virtual static group is the same as the structural object class for a static group.

You can also retrieve a list of all members of a virtual static group in the same way as a real static group: simply retrieve the `member` or `uniqueMember` attribute of the desired group. However, because virtual static groups are backed by dynamic groups and the process for retrieving member information for dynamic groups can be expensive, virtual static groups do not allow retrieving the full set of members by default. The virtual attribute used to expose membership can be updated to allow this with a configuration change such as the following:

```
$ bin/dsconfig set-virtual-attribute-prop --name "Virtual Static member" \
  --set allow-retrieving-membership:true
```

Because this can be an expensive operation, we recommend that the option to allow retrieving virtual static group membership be left disabled unless it is required.

Creating Nested Groups

The UnboundID Data Store supports nested groups, where the DN of an entry that defines a group is included as a member in the parent entry. For example, the following example shows a nested static group (e.g., `cn=Engineering Group`) that has `uniquemember` attributes consisting of other groups, such as `cn=Developers Group` and the `cn=QA Group` respectively.

```
dn: cn=Engineering Group,ou=Groups,dc=example,dc=com
objectclass: top
objectclass: groupOfUniqueNames
cn: Engineering Group
uniquemember: cn=Developers,ou=Groups,dc=example,dc=com
uniquemember: cn=QA,ou=Groups,dc=example,dc=com
```

Nested group support is enabled by default on the Data Store. To support nested groups without the performance hit, the Data Store uses a group cache, which is also enabled by default. The cache supports static group nesting that includes other static, virtual static, and dynamic groups. The Data Store provides a new monitoring entry for the group cache, `cn=Group Cache,cn=Monitor`.

In practice, nested groups are not commonly used for several reasons. LDAP specifications do not directly address the concept of nested groups, and some servers do not provide any level of support for them. Supporting nested groups in LDAP clients is not trivial, and many data store-enabled applications that can interact with groups do not provide any support for nesting. If nesting support is not needed in your environment, or if nesting support is only required for clients but is not needed for server-side evaluation (such as for groups used in access control rules, criteria, virtual attributes, or other ways that the server may need to make a membership determination), then this support should be disabled.

To Create Nested Static Groups

1. The following example shows how to set up a nested static group, which is a static group that contains `uniquemember` attributes whose values contain other groups (static, virtual static, or dynamic). Open a text editor, and then create a group entry in LDIF. Make sure to include the `groupOfUniquenames` object class and `uniquemember` attributes. If you did not have `ou=groups` set up in your server, then you can add it in the same file. When done, save the file as `nested-group.ldif`. Assume that the static groups, `cn=Developers Group` and `cn=QA Group`, have been configured.

   ```
   dn: ou=groups,dc=example,dc=com
   objectclass: top
   objectclass: organizationalunit
   ou: groups

   dn: cn=Engineering Group,ou=groups,dc=example,dc=com
   objectclass: top
   objectclass: groupOfUniqueNames
   cn: Engineering Group
   uniquemember: cn=Developers,ou=groups,dc=example,dc=com
   uniquemember: cn=QA,ou=groups,dc=example,dc=com
   ```

2. Use `ldapmodify` to add the group entry.

```
$ bin/ldapmodify --defaultAdd --filename nested-static-group.ldif
```

3. Verify the configuration by using the `isMemberOf` virtual attribute that checks the group membership for an entry. By default, the virtual attribute is enabled. Use `ldapsearch` to specifically search the `isMemberOf` virtual attribute to determine if `uid=user.14` is a member of the `cn=Development` group. In this example, assume that the administrator has the privilege to view operational attributes.

```
$ bin/ldapsearch --baseDN dc=example,dc=com "(uid=user.14)" isMemberOf

dn: uid=user.14,ou=People,dc=example,dc=com
isMemberOf: cn=Development,ou=groups,dc=example,dc=com
```

4. Typically, you would want to use the group as a target in access control instructions. Open a text editor, create an ACI in LDIF, and save the file as `eng-group-aci.ldif`.

```
dn: ou=People,dc=example,dc=com
changetype: modify
add: aci
aci: (target ="ldap:///ou=People,dc=example,dc=com")
  (targetattr != "cn || sn || uid")
  (targetfilter ="(ou=Engineering Group)")
  (version 3.0; acl "Engineering Group Permissions";
    allow (write) (groupdn = "ldap:///cn=Engineering
 Group,ou=groups,dc=example,dc=com");)
```

5. Add the file using the `ldapmodify` tool.

```
$ bin/ldapmodify --filename eng-group-aci.ldif
```

Note: When nesting dynamic groups, you cannot include other groups as members of a dynamic group. You can only support "nesting" by including the members of another group with a filter in the member URL. For example, if you have two groups `cn=dynamic1` and `cn=dynamic2`, you can nest one group in another by specifying it in the member URL as follows:

```
cn=dynamic1,ou=groups,dc=example,dc=com
objectClass: top
objectClass: groupOfURLs
memberURL: ldap:///dc=example,dc=com??sub?
(isMemberOf=cn=dynamic2,ou=groups,dc=example,dc=com)
```

The members included from the other group using this method are not considered "nested" members and will be returned even when using `isDirectMemberOf` when retrieving the members.

Maintaining Referential Integrity with Static Groups

The Data Store can automatically update references to an entry whenever that entry is removed or renamed in a process called *referential integrity*. For example, if a user entry is deleted, then referential integrity plugin will remove that user from any static groups in which the user was a member (this is not necessary for dynamic groups, since no explicit membership is maintained). Similarly, if a modify DN operation is performed to move or rename a user entry, then referential integrity updates static groups in which that user is a member with the new user DN.

Referential integrity support is disabled by default, but may be enabled using the `dsconfig` tool as follows:

```
$ bin/dsconfig set-plugin-prop --plugin-name "Referential Integrity" \
  --set enabled:true
```

Other configuration attributes of note for this plugin include:

- **attribute-type**. This attribute specifies the names or OIDs of the attribute types for which referential integrity will be maintained. By default, referential integrity is maintained for the `member` and `uniqueMember` attributes. Any attribute types specified must have a syntax of either distinguished name (OID "1.3.6.1.4.1.1466.115.121.1.12") or name and optional UID (OID "1.3.6.1.4.1.1466.115.121.1.34"). The specified attribute types must also be indexed for equality in all backends for which referential integrity is to be maintained.

- **base-dn**. This attribute specifies the subtrees for which referential integrity will be maintained. If one or more values are provided, then referential integrity processing will only be performed for entries which exist within those portions of the DIT. If no values are provided (which is the default behavior), then entries within all public naming contexts will be included.

- **log-file**. This attribute specifies the path to a log file that may be used to hold information about the DNs of deleted or renamed entries. If the plugin is configured with a nonzero update interval, this log file helps ensure that appropriate referential integrity processing occurs even if the server is restarted.

- **update-interval**. This attribute specifies the maximum length of time that a background thread may sleep between checks of the referential integrity log file to determine whether any referential integrity processing is required. By default, this attribute has a value of "0 seconds", which indicates that all referential integrity processing is to be performed synchronously before a response is returned to the client. A duration greater than 0 seconds indicates that referential integrity processing will be performed in the background and will not delay the response to the client.

In the default configuration, where referential integrity processing is performed synchronously, the throughput and response time of delete and modify DN operations may be adversely impacted because the necessary cleanup work must be completed before the response to the original operation can be returned. Changing the configuration to use a non-zero update interval alleviates this performance impact because referential integrity processing uses a separate background thread and does not significantly delay the response to delete or modify DN operations.

However, performing referential integrity processing in a background thread may introduce a race condition that may adversely impact clients that delete a user and then immediately attempt to re-add it and establish new group memberships. If referential integrity processing has not yet been completed for the delete, then newly-established group memberships may be removed along with those that already existed for the previous user. Similarly, if the newly-created user is to be a member of one or more of the same groups as the previous user, then attempts by the client to re-establish those memberships may fail if referential integrity processing has not yet removed the previous membership. For this reason, we recommend that the default synchronous behavior be maintained unless the performance impact associated with it is unacceptable and clients are not expected to operate in a manner that may be adversely impacted by delayed referential integrity processing.

Note: The internal operations of the referential integrity plug-in are not replicated. So, in a replicated topology, you must enable the referential integrity plug-in consistently on all servers in the topology to ensure that changes made by the referential integrity plug-in are passed along to a replication server.

For more information about administering the referential integrity plug-in, see Chapter 6, “Configuring the Data Store” in the *UnboundID Data Store Administration Guide*.

Monitoring the Group Membership Cache

The Data Store logs information at startup about the memory consumed by the group membership cache. This hard-coded cache contains information about all of the group memberships for internal processing, such as ACIs. The group membership cache is enabled by default.

The information about this cache is logged to the standard output log (`server.out`) and the standard error log. When using groups, you can use the log information to tune the server for best performance. For example, at startup the server logs a message like the following to the `server.out` log:

```
[16/Aug/2011:17:14:39.462 -0500] category=JEB severity=NOTICE msgID=1887895587
msg="The database cache now holds 3419MB of data and is 32 percent full"
```

The error log will contain something like the following:

```
[16/Aug/2011:18:40:39.555 -0500] category=EXTENSIONS severity=NOTICE msgID=1880555575
msg="'Group cache (174789 static group(s) with 7480151 total memberships and 1000002
unique members, 0 virtual static group(s), 1 dynamic group(s))' currently consumes
149433592 bytes and can grow to a maximum of 149433592 bytes"
```

Using the Entry Cache to Improve the Performance of Large Static Groups

The UnboundID Data Store provides an entry cache implementation, which allows for fine-grained control over the kinds of entries that may be held in the cache. You can define filters to specify the entries included in or excluded from the cache, and you can restrict the cache so that it holds only entries with at least a specified number of values for a given set of attributes.

Under most circumstances, we recommend that the Data Store be used *without* an entry cache. The Data Store is designed to efficiently retrieve and decode entries from the database in most cases. The database cache is much more space-efficient than the entry cache, and heavy churn in the entry cache can adversely impact garbage collection behavior.

However, if the Data Store contains very large static groups, such as those containing thousands or millions of members, and clients need to frequently retrieve or otherwise interact with these groups, then you may want to enable an entry cache that holds only large static groups.

In servers containing large static groups, you can define an entry cache to hold only those large static groups. This entry cache should have an include filter that matches only group entries (for example, "`(|(objectclass=groupOfNames)(objectclass=groupOfUniqueNames)(objectclass=groupOfEntries))`"). The filter contains a minimum value count so that only groups with a large number of members (such as those with at least 100 `member` or `uniqueMember` values) will be included. The Data Store provides an entry cache implementation with these settings although it is disabled by default.

To Enable the Entry Cache

- Run `dsconfig` to enable the entry cache.

```
$ bin/dsconfig set-entry-cache-prop --cache-name "Static Group Entry Cache" \
  --set enabled:true
```

To Create Your Own Entry Cache for Large Groups

- You can create your own entry cache for large groups using the `dsconfig create-entry-cache` subcommand.

```
# bin/dsconfig create-entry-cache --type fifo \
  --set enabled:true \
  --set cache-level:10 \
  --set max-entries:175000 \
  --set "include-filter:(objectClass=groupOfUniqueNames)" \
  --set min-cache-entry-value-count:10000 \
  --set min-cache-entry-attribute:uniquemember
```

Monitoring the Entry Cache

You can monitor the memory consumed by your entry cache using the `entry-cache-info` property in the periodic stats logger. You can retrieve the monitor entry over LDAP by issuing a search on `baseDN="cn=monitor"` using `filter="(objectClass=ds-fifo-entry-cache-monitor-entry)"`. For example, the entry might appear as follows:

```
dn: cn=Static Group Entry Cache Monitor,cn=monitor
objectClass: top
objectClass: ds-monitor-entry
objectClass: ds-fifo-entry-cache-monitor-entry
objectClass: extensibleObject
cn: Static Group Entry Cache Monitor
cacheName: Static Group Entry Cache
entryCacheHits: 6416407
entryCacheTries: 43069073
entryCacheHitRatio: 14
maxEntryCacheSize: 12723879900
currentEntryCacheCount: 1
maxEntryCacheCount: 175000
entriesAddedOrUpdated: 1
evictionsDueToMaxMemory: 0
evictionsDueToMaxEntries: 0
entriesNotAddedAlreadyPresent: 0
entriesNotAddedDueToMaxMemory: 0
```

```
entriesNotAddedDueToFilter: 36652665
entriesNotAddedDueToEntrySmallness: 0
lowMemoryOccurrences: 0
percentFullMaxEntries: 0
jvmMemoryMaxPercentThreshold: 75
jvmMemoryCurrentPercentFull: 24
jvmMemoryBelowMaxMemoryPercent: 51
isFull: false
capacityDetails: NOT FULL: The JVM is using 24% of its available memory. Entries can be
added to the cache until the overall JVM memory usage reaches the configured limit of
75%. Cache has 174999 remaining entries before reaching the configured limit of 175000.
```

By default, the entry cache memory is set to 75%, with a maximum of 90%.

Tuning the Index Entry Limit for Large Groups

The Data Store uses indexes to improve database search performance and provide consistent search rates regardless of the number of database objects stored in the DIT. You can specify an index entry limit property, which defines the maximum number of entries that are allowed to match a given index key before it is no longer maintained by the server. If the index keys have reached this limit (which is 4000 by default), then you must rebuild the indexes using the `rebuild-index` tool as follows:

```
$ bin/rebuild-index --baseDN dc=example,dc=com --index objectclass
```

In the majority of Data Store environments, the default index entry limit value of 4000 entries should be sufficient. However, group-related processing, it may be necessary to increase the index entry limit. For directories containing more than 4000 groups with the same structural object class (i.e., more than 4000 entries, 4000 `groupOfUniqueNames` entries, 4000 `groupOfEntries` entries, or 4000 `groupOfURLs` entries), then you may want to increase the index entry limit for the `objectClass` attribute so that it has a value larger than the maximum number of group entries of each type. Set `index-entry-limit` property using a command line like the following:

```
$ bin/dsconfig set-local-db-index-prop --backend-name userRoot \
  --index-name objectClass --set index-entry-limit:175000
```

As an alternative, a separate backend may be created to hold these group entries, so that an unindexed search in that backend yields primarily group entries. If you make no changes, then the internal search performed at startup to identify all groups and any user searches looking for groups of a given type may be very expensive.

For directories in which any single user may be a member of more than 4000 static groups of the same type, you may need to increase the index entry limit for the `member` and/or `uniqueMember` attribute to a value larger than the maximum number of groups in which any user is a member. If you do not increase the limit, then searches to retrieve the set of all static groups in which the user is a member may be unindexed and therefore very expensive.

Summary of Commands to Search for Group Membership

The following summary of commands show the fastest way to retrieve direct or indirect member DNs for groups.

- To retrieve direct member (non-nested) DNs of group "`cn=group.1,ou=groups,dc=example,dc=com`".

```
$ bin/ldapsearch --baseDN "cn=group.1,ou=Groups,dc=example,dc=com" "(objectClass=*)"
 uniqueMember member
```

- To retrieve direct member entries (non-nested) under "`dc=example,dc=com`" of group "`cn=group.1,ou=groups,dc=example,dc=com`". This is useful when attributes from member entries are used in the filter or being returned.

```
$ bin/ldapsearch --baseDN "ou=people,dc=example,dc=com"
 "(isDirectMemberOf=cn=group.1,ou=Groups,dc=example,dc=com)"
```

- To retrieve group DNs in which user "`uid=user.2,ou=people,dc=example,dc=com`" is a direct member (non-nested, static groups).

```
$ bin/ldapsearch --baseDN "uid=user.2,ou=people,dc=example,dc=com" "(objectClass=*)"
 isDirectMemberOf
```

- To retrieve all member entries under `ou=people,dc=example,dc=com` of group "`cn=group.1,ou=groups,dc=example,dc=com`".

```
$ bin/ldapsearch --baseDN "ou=people,dc=example,dc=com"
 "(isMemberOf=cn=group.1,ou=Groups,dc=example,dc=com)"
```

- To retrieve the group DNs in which user "`uid=user.2,ou=people,dc=example,dc=com`" is a member.

```
$ bin/ldapsearch --baseDN "uid=user.2,ou=people,dc=example,dc=com" "(objectClass=*)"
 isMemberOf
```

Migrating Sun/Oracle Groups

You can migrate Sun/Oracle static and dynamic groups to UnboundID Data Store groups. The following sections outline the procedures for migrating static groups to both UnboundID static groups and virtual static groups as well as how to migrate dynamic groups. For information about the differences in access control evaluation between Sun/Oracle and the UnboundID Data Store, see Migrating ACIs from Sun/Oracle to UnboundID Data Store.

Migrating Static Groups

The UnboundID Data Store supports static LDAP groups with structural object classes of `groupOfNames`, `groupOfUniqueNames`, or `groupOfEntries`. In general, static groups may be imported without modification.

A FIFO entry cache can be enabled to cache group-to-user mappings, which improves performance when accessing very large entries, though at the expense of greater memory consumption. The UnboundID Data Store provides an out-of-the-box FIFO entry cache object for this purpose. This object must be explicitly enabled using `dsconfig` as described in *Using the Entry Cache to Improve the Performace of Large Static Groups*.

To Migrate Static Groups

1. Run the `migrate-ldap-schema` tool to enumerate any schema differences between the DSEE deployment and the UnboundID deployment.

2. Run the `migrate-sun-ds-config` tool to enumerate any configuration differences between the DSEE deployment and the UnboundID deployment.

3. Import or configure any necessary schema and/or configuration changes recorded by the above tools.

4. Import the existing users and groups using the `import-ldif` tool.

5. From the UnboundID Data Store root directory, open the `sun-ds-compatibility.dsconfig` file in the `docs` folder using a text editor.

6. Find the **FIFO Entry Cache** section and, after reading the accompanying comments, enable the corresponding `dsconfig` command by removing the comment character ("#").

   ```
   $ bin/dsconfig set-entry-cache-prop \
     --cache-name "Static Group Entry Cache" --set enabled:true
   ```

7. Enable the Referential Integrity Plug-in. This will ensure that references to an entry are automatically updated when the entry is deleted or renamed.

   ```
   $ bin/dsconfig set-plugin-prop --plug-name "Referential Integrity" --set enabled:true
   ```

   If this Data Store is part of a replication topology, you should enable the Referential Integrity Plug-in for each replica.

Migrating Static Groups to Virtual Static Groups

In many cases, electing to use virtual static groups in place of static groups can produce marked performance gains without any need to update client applications. The specifics of a migration to virtual static groups varies depending on the original DIT, but the general approach involves identifying common membership traits for all members of each group and then expressing those traits in the form of an LDAP URL.

In the following example, the common membership trait for all members of the All Users group is the parent DN ou=People,dc=example,dc=com. In other cases, a common attribute may need to be used. For example, groups based on the location of its members could use the `l` (location) or `st` (state) attribute.

To Migrate DSEE Static Groups to Virtual Static Groups

In the following example, consider the common case of an "All Users" group, which contains all entries under the parent DN "`ou=People,dc=example,dc=com`". When implemented as a virtual static group, this group may have a large membership set without incurring the overhead of a static group.

1. First, create a dynamic group.

```
dn: cn=Dynamic All Users,ou=Groups,dc=example,dc=com
objectClass: top
objectClass: groupOfURLs
cn: Dynamic All Users
memberURL: ldap:///ou=People,dc=example,dc=com??sub?(objectClass=person)
```

2. Next, create a virtual static group that references the dynamic group.

```
dn: cn=All Users,ou=Groups,dc=example,dc=com
objectClass: top
objectClass: groupOfUniqueNames
objectClass: ds-virtual-static-group
cn: All Users
ds-target-group-dn: cn=Dynamic All Users,ou=Groups,dc=example,dc=com
```

3. Finally, the `Virtual Static uniqueMember` virtual attribute must be enabled to populate the All Users group with `uniqueMember` virtual attributes.

```
$ bin/dsconfig set-virtual-attribute-prop --name "Virtual Static uniqueMember" \
  --set enabled:true
```

4. Confirm that the virtual static group is correctly configured by checking a user's membership in the group.

```
$ bin/ldapsearch --baseDN "cn=All Users,ou=Groups,dc=example,dc=com" \
  --searchScope base "(uniqueMember=uid=user.0,ou=People,dc=example,dc=com)" 1.1
```

```
dn: cn=All Users,ou=Groups,dc=example,dc=com
```

5. The ability to list all members of a virtual static group is disabled by default. You may enable this feature, but only if specifically required by a client application.

```
$ bin/dsconfig set-virtual-attribute-prop --name "Virtual Static uniqueMember" \
  --set allow-retrieving-membership: true
```

Note: The virtual static group may also be implemented using the `groupOfNames` object class instead of `groupOfUniqueNames`. In that case, you must update the `Virtual Static member` configuration object instead of the `Virtual Static uniqueMember` configuration object.

Migrating Dynamic Groups

The UnboundID Data Store supports dynamic groups with the `groupofURLs` object class. In general, dynamic groups may be imported without modification.

To Migrate Dynamic Groups

1. Run the `migrate-ldap-schema` tool to enumerate any schema differences between the DSEE deployment and the UnboundID deployment.

2. Run the `migrate-sun-ds-config` tool to enumerate any configuration differences between the DSEE deployment and the UnboundID deployment.

3. Import or configure any necessary schema and/or configuration changes recorded by the above tools.

4. Import the existing users and groups using the `import-ldif` tool.

Chapter 14 Encrypting Sensitive Data

The Data Store provides several ways that you can protect sensitive information in the server. You can enable on-disk encryption for data in backends as well as in the changelog and the replication databases, and you can also protect sensitive attributes by limiting the ways that clients may interact with them.

This chapter presents the following topics:

Topics:

Encrypting and Protecting Sensitive Data

The Data Store provides an encryption-settings database that holds encryption and decryption definitions to protect sensitive data. You can enable on-disk encryption for data in backends as well as in the changelog and the replication databases. You can also protect sensitive attributes by limiting the ways that clients may interact with them.

About the Encryption-Settings Database

The encryption-settings database is a repository that the server uses to hold information for encrypting and decrypting data. The database contains any number of *encryption-settings definitions* that specifies information about the cipher transformation and encapsulates the key used for encryption and decryption.

Before data encryption can be enabled, you first need to create an encryption-settings definition. An encryption-settings definition specifies the cipher transformation that should be used to encrypt the data, and encapsulates the encryption key. The `encryption-settings` command-line tool can be used to manage the encryption settings database, including creating, deleting, exporting, and importing encryption-settings definitions, listing the available definitions, and indicating which definition should be used for subsequent encryption operations.

Although the encryption-settings database can have multiple encryption-settings definitions, only one of them can be designated as the *preferred* definition. The preferred encryption-settings definition is the one that will be used for any subsequent encryption operations. Any existing data that has not yet been encrypted remains unencrypted until it is rewritten (e.g., as a result of a modify or modify DN operation, or if the data is exported to LDIF and re-imported). Similarly, if you introduce a new preferred encryption-settings definition, then any existing encrypted data will continue to use the previous definition until it is rewritten. If you do change the preferred encryption-settings definition for the server, then it is important to retain the previous definitions until you are confident that no remaining data uses those older keys.

Supported Encryption Ciphers and Transformations

The set of encryption ciphers that are supported by the Data Store is limited to those ciphers supported by the JVM in which the server is running. For specific reference information about the algorithms and transformations available in all compliant JVM implementations, see the following:

- Java Cryptography Architecture Reference Guide
- Java Cryptography Architecture Standard Algorithm Name Documentation

When configuring encryption, the cipher to be used must be specified using a key length (in bits) and either a cipher algorithm name (e.g., "AES") or a full cipher transformation which explicitly specifies the mode and padding to use for the encryption (e.g., "AES/CBC/

PKCS5Padding"). If only a cipher algorithm is given, then the default mode and padding for that algorithm will be automatically selected.

The following cipher algorithms and key lengths have been tested using the Sun/Oracle JVM using JVM and the IBM JVM:

Table 26: Cipher Algorithms

Cipher Algorithm	Key Length (bits)
AES	128
Blowfish	128
DES	64
DESede	192
RC4	128

Note: By default, some JVM implementations may come with limited encryption strength, which may restrict the key lengths that can be used. For example, the Sun/Oracle JVM does not allow AES with 192-bit or 256-bit keys unless the unlimited encryption strength policy files are downloaded and installed.

The Data Store supports four Cipher Stream Providers, which are used to obtain cipher input and output streams to read and write encrypted data.

Table 27: Cipher Stream Providers

Cipher Stream Providers	Description
Default	Default cipher stream provider using a hard-coded default key.
File-Based	Used to read a specified file in order to obtain a password used to generate cipher streams for reading and writing encrypted data.
Third-Party	Used to provide cipher stream provider implementations created in third-party code using the UnboundID server SDK.
Wait-for-Passphrase	Causes the server to wait for an administrator to enter a passphrase that will be used to derive the key for cipher streams. You can supply the passphrase to the server by running `encryption-settings supply-passphrase`.

Using the encryptions-settings Tool

The `encryption-settings` tool provides a mechanism for interacting with the server's encryption-settings database. It may be used to list the available definitions, create new definitions, delete existing definitions, and indicate which definition should be the preferred definition. It may also be used to export definitions to a file for backup purposes and to allow them to be imported for use in other Data Store instances.

To List the Available Encryption Definitions

- Use the `encryption-settings` tool with the `list` subcommand to display the set of available encryption settings definitions. This subcommand does not take any arguments. For each definition, it will include the unique identifier for the definition, as well as the cipher transformation and key length that will be used for encryption and whether it is the preferred definition.

```
$ bin/encryption-settings list
```

```
Encryption Settings Definition ID: 4D86C7922F71BB57B8B5695D2993059A26B8FC01
Preferred for New Encryption: false
Cipher Transformation: DESede
Key Length (bits): 192

Encryption Settings Definition ID: F635E109A8549651025D01D9A6A90F7C9017C66D
Preferred for New Encryption: true
Cipher Transformation: AES
Key Length (bits): 128
```

Creating Encryption-Settings Definitions

To create a new encryption-settings definition, use the `create` subcommand. This subcommand takes the following arguments:

- **--cipher-algorithm {algorithm}**. Specifies the base cipher algorithm that should be used. This should just be the name of the algorithm (e.g., "AES", "DES", "DESede", "Blowfish", "RC4", etc.). This argument is required.
- **--cipher-transformation {transformation}**. Specifies the full cipher transformation that should be used, including the cipher mode and padding algorithms (e.g., "AES/CBC/PKCS5Padding"). This argument is optional, and if it is not provided, then the JVM-default transformation will be used for the specified cipher algorithm.
- **--key-length-bits {length}**. Specifies the length of the encryption key in bits (e.g., 128). This argument is required.
- **--set-preferred**. Indicates that the new encryption-settings definition should be made the preferred definition and therefore should be used for subsequent encryption operations in the server. When creating the first definition in the encryption-settings database, it will automatically be made the preferred definition.

To Create an Encryption-Settings Definition

- Use the `encryption-settings` tool with the `create` subcommand to specify the definition.

```
$ bin/encryption-settings create --cipher-algorithm AES \
  --key-length-bits 128 --set-preferred
```

```
Successfully created a new encryption settings definition with ID
F635E109A8549651025D01D9A6A90F7C9017C66D
```

Changing the Preferred Encryption-Settings Definition

To change the preferred encryption-settings definition, use the `encryption-settings` tool with the `set-preferred` subcommand. This subcommand takes the following arguments:

- **--id {id}**. Specifies the ID for the encryption-settings definition to be exported. This argument is required.

To Change the Preferred Encryption-Settings Definition

- Use the `encryption-settings` tool with the `set-preferred` subcommand to change a definition to a preferred definition.

```
$ bin/encryption-settings set-preferred --id 4D86C7922F71BB57B8B5695D2993059A26B8FC01
```

```
Encryption settings definition 4D86C7922F71BB57B8B5695D2993059A26B8FC01 was
successfully set as the preferred definition for subsequent encryption operations
```

Deleting an Encryption-Settings Definition

To delete an encryption-settings definition, use the `encryption-settings` tool with the `delete` subcommand. The subcommand takes the following arguments:

- **--id {id}**. Specifies the ID for the encryption-settings definition to be deleted. This argument is required.

Note that you should never delete an encryption-settings definition unless you are certain that no data in the server is still encrypted using the settings contained in that definition. Any data still encrypted with a definition that has been removed from the database will be inaccessible to the server and will cause errors for any attempt to access it. If you wish to safely delete an encryption-settings definition (e.g., because you believe the encryption key may have been compromised), then see the instructions in the *Dealing with a Compromised Encryption Key* section.

If you merely want the server to stop using that definition for encryption and use a different definition instead, then make sure that the desired definition exists in the encryption-settings database (creating it if necessary) and set it to be the preferred definition. As long as the encryption key has not been compromised, there is no harm in having old encryption-settings definitions available to the server, and it is recommended that they be retained just in case they are referenced by something.

Also note that you cannot delete the preferred encryption-settings definition unless it is the only one left. If you want to delete the currently-preferred definition when one or more other definitions are available, then you must first make one of the other definitions preferred as described in the previous section.

To Delete an Encryption-Settings Definition

- Use the `encryption-settings` command with the `delete` subcommand. Make sure to include the `--id` argument to specify the definition.

```
$ bin/encryption-settings delete --id F635E109A8549651025D01D9A6A90F7C9017C66D
```

```
Successfully deleted encryption settings definition
F635E109A8549651025D01D9A6A90F7C9017C66D
```

Configuring the Encryption-Settings Database

Because the encryption-settings database contains the encryption keys used to protect server data, the contents of the encryption-settings database is itself encrypted. By default, the server will derive a key to use for this purpose, but it is recommended that you customize the logic used to access the encryption-settings database with a cipher stream provider. The UnboundID Server SDK provides an API that can be used to create custom cipher stream provider implementations, but the server also comes with one that will obtain the key from a PIN file that you create (see the example procedure below).

To Configure the Encryption-Settings Database

1. Use `dsconfig` to configure the server so that the encryption-settings database is encrypted with a PIN contained in the file `config/encryption-settings.pin`.

```
$ bin/dsconfig create-cipher-stream-provider \
  --provider-name "Encryption Settings PIN File" \
  --type file-based \
  --set enabled:true \
  --set password-file:config/encryption-settings.pin
```

2. Use `dsconfig` to set the global configuration property for the cipher stream provider, which sets the on-disk encryption.

```
$ bin/dsconfig set-global-configuration-prop \
  --set "encryption-settings-cipher-stream-provider:Encryption Settings PIN File"
```

3. Use the `encryption-settings` tool to create a new encryption-settings definition.
This command automatically generates a new 256-bit encryption key for use with AES encryption, and mark it as the preferred definition for future encryption operations in the server. Note that this command will fail if you do not have the unlimited encryption strength policy installed as described in the previous section (if you do not have that policy installed, then you are restricted to a 128-bit key for AES encryption).

```
$ bin/encryption-settings create \
  --cipher-algorithm AES \
  --key-length-bits 256 \
  --set-preferred
```

4. Obtain a list of the definitions in the encryption-settings database.

```
$ bin/encryption-settings list
```

5. You can export an encryption-settings definition from the database using a command like the following where the encryption-settings ID should be changed as necessary to suit your deployment:

```
$ bin/encryption-settings export \
  --id DA39A3EE5E6B4B0D3255BFEF95601890AFD80709 \
  --output-file /tmp/exported-key \
  --pin-file /tmp/exported-key.pin
```

6. If no PIN file is specified, then you will be interactively prompted to provide it. To import an encryption-settings definition into the database on another server.

```
$ bin/encryption-settings import \
  --input-file /tmp/exported-key \
  --pin-file /tmp/exported-key.pin \
  --set-preferred
```

Backing Up and Restoring the Encryption-Settings Definitions

If you are using data encryption in a Data Store instance, it is absolutely essential that you not lose any of the encryption-settings definitions that may have been used to encrypt data in the server. If an encryption-settings definition is lost, then any data encrypted with that definition will be completely inaccessible. As such, it is important to ensure that you have good backups of the encryption-settings definitions to prevent them from being lost.

The Data Store provides two different mechanisms for backing up and restoring encryption-settings definitions. You can export and import individual encryption-settings definitions using the `encryption-settings` tool. Or, you can back up and restore the entire encryption-settings database using the Data Store's `backup` and `restore` tools.

Exporting Encryption-Settings Definitions

To back up an individual definition (or to export it from one server so that you can import it into another), use the `export` subcommand to the `encryption-settings` command. The subcommand takes the following arguments:

- **--id {id}**. Specifies the ID for the encryption-settings definition to be exported. This argument is required.
- **--output-file {path}**. Specifies the path to the output file to which the encryption-settings definition will be written. This argument is required.
- **--pin-file {path}**. Specifies the path to a PIN file containing the password to use to encrypt the contents of the exported definition. If this argument is not provided, then the PIN will be interactively requested from the server.

To Export an Encryption-Settings Definition

- Use the `encryption-settings` tool with the `export` subcommand to export the definition to a file.

```
$ bin/encryption-settings export --id F635E109A8549651025D01D9A6A90F7C9017C66D \
  --output-file /tmp/exported-key
Enter the PIN to use to encrypt the definition:
Re-enter the encryption PIN:
```

```
Successfully exported encryption settings definition
F635E109A8549651025D01D9A6A90F7C9017C66D to file /tmp/exported-key
```

Importing Encryption-Settings Definitions

To import an encryption-settings definition that has been previously exported, use the `encryption-settings` tool with the `import` subcommand. The subcommand takes the following arguments:

- **--input-file {path}**. Specifies the path to the file containing the exported encryption-settings definition. This argument is required.
- **--pin-file {path}**. Specifies the path to a PIN file containing the password to use to encrypt the contents of the exported definition. If this argument is not provided, then the PIN will be interactively requested from the server.
- **--set-preferred**. Specifies that the newly-imported encryption-settings definition should be made for the preferred definition for subsequent encryption-settings.

To Import an Encryption-Settings Definition

- Use the `encryption-settings` tool with the `import` subcommand to import the definition to a file.

```
$ bin/encryption-settings import --input-file /tmp/exported-key --set-preferred
Enter the PIN used to encrypt the definition:
```

```
Successfully imported encryption settings definition
F635E109A8549651025D01D9A6A90F7C9017C66D from file /tmp/exported-key
```

Backing Up the Encryption-Settings Definitions

The encryption-settings database may be backed up and restored like a Data Store backend using the `backup` and `restore` commands.

To Back Up an Encryption-Settings Definition

Because of the importance of the encryption settings database when using data encryption in the server, it is strongly recommended that whenever you back up a component of the server that uses encrypted data, you also back up the encryption settings database.

- To back up just the encryption settings database, you could use a command like:
  -
    ```
    $ bin/backup --backendID encryption-settings \
      --backupDirectory bak/encryption-settings
    ```

    ```
    [13:57:32] The console logging output is also available in
    '/ds/logs/tools/backup.log'
    [13:57:32] Starting backup for backend encryption-settings
    [13:57:32] The backup process completed successfully
    ```
  - Alternately, you can back up multiple backends at once using this tool, and you can even back up all backends at once with a single command.

    ```
    $ bin/backup --backUpAll -d bak
    ```

Restoring an Encryption-Settings Definition

Because of the importance of not losing any encryption-settings definitions that might be referenced by encrypted data in the server, the restore process for the encryption-settings database is a little different than that used when restoring other backends in the server. Rather than completely replacing any existing encryption-settings database, the version of the database being restored will be merged with the existing database. The encryption-settings definitions in the database (before the restore begins) will still be available after the restore has completed even if they were not in the archived version of the database. The preferred encryption-settings definition will be the definition that was preferred in the archived database.

To Restore an Encryption-Settings Definition

- Use the `encryption-settings` tool with the `restore` subcommand to restore an encryption-settings database.

```
$ bin/restore -d /backups/encryption-settings
```

```
[13:58:11] The console logging output is also available in
'/ds/logs/tools/ restore.log'
[13:58:11] Backup 20101121195732Z has been successfully restored for
backend encryption-settings
[13:58:11] The restore process completed successfully
```

Enabling Data Encryption in the Server

To enable data encryption in the server, you must have at least one encryption-settings definition available for use. Then, it is only necessary to set the value of the `encrypt-data` global configuration property to true.

Setting the global configuration property will automatically enable data encryption for all types of backends that support it (including the changelog backend) as well as for the replication server database. All subsequent write operations will cause the corresponding records written into any of these locations to be encrypted. Any existing data will remain unencrypted until it is rewritten by a write operation. If you wish to have existing data encrypted, then you will need to export that data to LDIF and re-import it. This will work for both the data backends and the changelog, but it is not an option for the replication database, so existing change records will remain unencrypted until they are purged. If this is not considered acceptable in your environment, then follow the steps in the *Dealing with a Compromised Encryption Key* to safely purge the replication database.

To Enable Data Encryption in the Server

- Use `dsconfig` to set the global configuration property for data encryption to true.

```
$ bin/dsconfig set-global-configuration-prop --set encrypt-data:true
```

Using Data Encryption in a Replicated Environment

Data encryption is only used for the on-disk storage for data within the server. Whenever clients access that data, it is presented in unencrypted form (although the communication with those clients may itself be encrypted using SSL or StartTLS). Replication, the communication of updates between replication servers, is always encrypted using SSL. Each server may apply data encryption in a completely independent manner and have different sets of encryption-settings definitions. It is also possible to have a replication topology containing some servers with data encryption enabled and others with it disabled.

However, when initializing the backend of one server from another server with data encryption enabled, then the server being initialized must have access to all encryption-settings definitions that may have been used for data contained in that backend. To do this, perform a backup of the encryption-settings database on the source server using `bin/backup --backendID encryption-settings` and restore it on the target server using `bin/restore`. The `bin/restore` tool behaves differently with `encryption-settings`. It appends the `encryption-settings` backup to the existing `encryption-settings` backend.

Dealing with a Compromised Encryption Key

If an encryption-settings definition becomes compromised such that an unauthorized individual obtains access to the encryption key, then any data encrypted with that definition is also vulnerable because it can be decrypted using that key. It is very important that the encryption-settings database be protected (e.g., using file permissions and/or filesystem ACLs) to ensure that its contents remain secure.

In the event that an encryption-settings definition is compromised, then you should immediately stop using that definition. Any data encrypted with the compromised key should be re-encrypted with a new definition or purged from the server. This can be done on one server at a time to avoid an environment-wide downtime, but it should be completed as quickly as possible on all servers that had used that definition at any point in the past in order to minimize the risk of that data becoming exposed.

To Deal with a Compromised Encryption Key

The recommended process for responding to a compromised encryption settings definition is as follows:

1. Create a new encryption-settings definition and make it the preferred definition for new writes.

2. Ensure that client traffic is routed away from the server instance to be updated. For example, if the Data Store is accessed through a Proxy Server, then you may set the `health-check-state` configuration property for any LDAP external server definitions that reference that server to have a value of unavailable.

3. Ensure that external clients are not allowed to write operations in the data store instance. This may be accomplished by setting the `writability-mode` global configuration property to have a value of `internal-only`.
4. Wait for all outstanding local changes to be replicated out to other servers. This can be accomplished by looking at the monitor entries with the `ds-replication-server-handler-monitor-entry` object class to ensure that the value of the `update-sent` attribute is no longer increasing.
5. Stop the data store instance.
6. Delete the replication server database by removing all files in the `changeLogDb` directory below the server root. As long as all local changes have been replicated out to other servers, this will not result in any data loss in the replication environment.
7. Export the contents of all local DB and changelog backends to LDIF. Then, re-import the data from LDIF, which will cause it to be encrypted using the new preferred encryption settings definition.
8. Export the compromised key from the encryption settings database to back it up in case it may be needed again in the future (e.g., if some remaining data was later found to have been encrypted with the key contained in that definition). Then, delete it from the encryption settings database so that it can no longer be used by that data store instance.
9. Start the data store instance.
10. Allow replication to bring the server back up-to-date with any changes processed while it was offline.
11. Re-allow externally-initiated write operations by changing the value of the global `writability-mode` configuration property back to enabled.
12. Re-configure the environment to allow client traffic to again be routed to that server instance (e.g., by changing the value of the "health-check-state" property in the corresponding LDAP external instance definitions in the Proxy Server instances back to "dynamically-determined").

Configuring Sensitive Attributes

Data encryption is only applied to the on-disk storage for a Data Store instance. It does not automatically protect information accessed or replicated between servers, although the server offers other mechanisms to provide that protection (i.e., SSL, StartTLS, SASL). Ensuring that all client communication uses either SSL or StartTLS encryption and ensuring that all replication traffic uses SSL encryption ensures that the data is protected from unauthorized individuals who may be able to eavesdrop on network communication. This communication security may be enabled independently of data encryption (although if data encryption is enabled, then it is strongly recommended that secure communication be used to protect network access to that data).

However, for client data access, it may not be as simple as merely enabling secure communication. In some cases, it may be desirable to allow insecure access to some data. In other cases, it may be useful to have additional levels of protection in place to ensure that some attributes are even more carefully protected. These kinds of protection may be achieved using sensitive attribute definitions.

Each sensitive attribute definition contains a number of configuration properties, including:

- **`attribute-type`**. Specifies the set of attribute types whose values may be considered sensitive. At least one attribute type must be provided, and all specified attribute types must be defined in the server schema.
- **`include-default-sensitive-operational-attributes`**. Indicates whether the set of sensitive attributes should automatically be updated to include any operational attributes maintained by the Data Store itself that may contain sensitive information. At present, this includes the `ds-sync-hist` operation attribute, which is used for data required for replication conflict resolution and may contain values from other attributes in the entry.
- **`allow-in-filter`**. Indicates whether sensitive attributes may be used in filters. This applies not only to the filter used in search requests, but also filters that may be used in other places, like the assertion and join request controls. The value of this property must be one of:
  - `Allow` (allow sensitive attributes to be used in filters over both secure and insecure connections)
  - `Reject` (reject any request which includes a filter targeting one or more sensitive attributes over both secure and insecure connections)
  - `Secure-only` (allow sensitive attributes to be used in filters over secure connections, but reject any such requests over insecure connections)
- **`allow-in-add`**. Indicates whether sensitive attributes may be included in entries created by LDAP add operations. The value of this property must be one of:
  - `Allow` (allow sensitive attributes to be included in add requests over both secure and insecure connections)
  - `Reject` (reject any add request containing sensitive attributes over both secure and insecure connections)
  - `Secure-only` (allow sensitive attributes to be included in add requests received over a secure connection, but reject any such requests over an insecure connection)
- **`allow-in-compare`**. Indicates whether sensitive attributes may be targeted by the assertion used in a compare operation. The value of this property must be one of:
  - `Allow` (allow sensitive attributes to be targeted by requests over both secure and insecure connections)
  - `Reject` (reject any compare request targeting a sensitive attribute over both secure and insecure connections)
  - `Secure-only` (allow compare requests targeting sensitive attributes over a secure connection, but reject any such requests over an insecure connection)

- **`allow-in-modify`**. Indicates whether sensitive attributes may be updated using modify operations. The value of this property must be one of:
  - `Allow` (allow sensitive attributes to be modified by requests over both secure and insecure connections)
  - `Reject` (reject any modify request updating a sensitive attribute over both secure and insecure connections)
  - `Secure-only` (only modify requests updating sensitive attributes over a secure connection, but reject any such request over an insecure connection)

The `allow-in-returned-entries`, `allow-in-filter`, `allow-in-add`, `allow-in-compare`, and `allow-in-modify` properties all have default values of `secure-only`, which prevents the possibility of exposing sensitive data in the clear to anyone able to observe network communication.

If a client connection policy references a sensitive attribute definition, then any restrictions imposed by that definition will be enforced for any clients associated with that client connection policy. If multiple sensitive attribute definitions are associated with a client connection policy, then the server will use the most restrictive combination of all of those sets.

Note that sensitive attribute definitions work in conjunction with other security mechanisms defined in the server and may only be used to enforce additional restrictions on clients. Sensitive attribute definitions may never be used to grant a client additional access to information that it would not have already had through other means. For example, if the `employeeSSN` attribute is declared to be a sensitive attribute and the `allow-in-returned-entries` property has a value of `Secure-only`, then the `employeeSSN` attribute will only be returned to those clients that have both been granted permission by the access control rules defined in the server and are communicating with the server over a secure connection. The `employeeSSN` attribute will be stripped out of entries returned to clients normally authorized to see it if they are using insecure connections, and it will also be stripped out of entries for clients normally not authorized to see it even if they have established secure connections.

To Create a Sensitive Attribute

1. To create a sensitive attribute, you must first create one or more sensitive attribute definitions.

   For example, to create a sensitive attribute definition that will only allow access to the `employeeSSN` attribute by clients using secure connections, the following configuration changes may be made:

   ```
   $ bin/dsconfig create-sensitive-attribute \
     --attribute-name "Employee Social Security Numbers" \
     --set attribute-type:employeeSSN \
     --set include-default-sensitive-operational-attributes:true \
     --set allow-in-returned-entries:secure-only \
     --set allow-in-filter:secure-only \
     --set allow-in-add:secure-only \
     --set allow-in-compare:secure-only \
     --set allow-in-modify:secure-only
   ```

2. Associate those sensitive attribute definitions with the client connection policies for which you want them to be enforced.

```
$ bin/dsconfig set-client-connection-policy-prop --policy-name default \
  --set "sensitive-attribute:Employee Social Security Numbers"
```

Configuring Global Sensitive Attributes

Administrators can assign one or more sensitive attribute definitions to a client connection policy. However, in an environment with multiple client connection policies, it could be easy to add a sensitive attribute definition to one policy but overlook it in another. The Data Store supports the ability to define sensitive attributes as a global configuration option so that they will automatically be used across all client connection policies.

To Configure a Global Sensitive Attribute

- Run `dsconfig` to add a global sensitive attribute across all client connection policies. The following command adds the `employeeSSN` as a global sensitive attribute, which is applied across all client connection policies.

```
$ bin/dsconfig set-global-configuration-prop --add "sensitive-attribute:employeeSSN"
```

Excluding a Global Sensitive Attribute on a Client Connection Policy

Administrators can set a global sensitive attribute across all client connection policies. However, there may be cases when a specific data store must exclude the sensitive attribute as it may not be needed for client connection requests. For example, in most environments it is good to declare the `userPassword` attribute to be a sensitive attribute in a manner that prevents it from being read by external clients. Further, this solution is more secure than protecting the `password` attribute using the server's default global ACI, which only exists for backwards compatibility purposes. If the Data Sync Server is installed, then it does need to be able to access passwords for synchronization purposes. In this case, the administrator can set `userPassword` to be a sensitive attribute in all client connection policies, but exclude it in a policy specifically created for use by the Data Sync Server. The Data Store provides an `exclude-global-sensitive-attribute` property for this purpose.

To Exclude a Global Sensitive Attribute on a Client Connection Policy

1. Run `dsconfig` to remove the global ACI that limits access to the `userPassword` or `authPassword` attribute. This is present for backwards compatibility.

```
$ bin/dsconfig set-access-control-handler-prop \
  --remove 'global-aci:(targetattr="userPassword || authPassword")
  (version 3.0; acl "Prevent clients from retrieving passwords from the server";
  deny (read,search,compare) userdn="ldap:///anyone";)'
```

2. Run `dsconfig` to add the `userPassword` attribute as a global sensitive attribute, which is applied to all client connection policies. Do this by adding the built-in "Sensitive Password Attributes" Sensitive Attribute definition to the Global Configuration.

```
$ bin/dsconfig set-global-configuration-prop \
  --add "sensitive-attribute:Sensitive Password Attributes"
```

3. If the server is designated to synchronize passwords with a Sync Server, then it is necessary to configure a client connection policy for the Sync User to exclude the global sensitive attribute. The following is an example on how to create a new policy if the sync server binds with the default DN of `cn=Sync User,cn=Root DNs,cn=config`.

```
$ bin/dsconfig create-connection-criteria \
  --criteria-name "Requests by Sync Users" \
  --type simple \
  --set user-auth-type:internal \
  --set user-auth-type:sasl \
  --set user-auth-type:simple \
  --set "included-user-base-dn:cn=Sync User,cn=Root DNs,cn=config"

$ bin/dsconfig create-client-connection-policy \
  --policy-name "Sync Server Connection Policy" \
  --set enabled:true \
  --set evaluation-order-index:9998 \
  --set "connection-criteria:Requests by Sync Users" \
  --set "exclude-global-sensitive-attribute:Sensitive Password Attributes"
```

Chapter 15 Working with the LDAP Changelog

The Data Store provides a client-accessible LDAP changelog (based on the Changelog Internet Draft Specification) for the purpose of allowing other LDAP clients to retrieve changes made to the server in standard LDAP format. The LDAP changelog is typically used by external software to maintain application compatibility between client services.

This chapter will present the following topics related to the LDAP Changelog:

Topics:

Overview of the LDAP Changelog

The Data Store provides a client-accessible LDAP changelog (based on the Changelog Internet Draft Specification) for the purpose of allowing other LDAP clients to retrieve changes made to the server in standard LDAP format. The LDAP changelog is typically used by external software to maintain application compatibility between client services. For example, you can install the Data Sync Server that monitors the LDAP changelog for any updates that occur on a source data store and synchronizes these changes to a target DIT or database server. The Data Store provides an additional feature in that the LDAP changelog supports virtual attributes.

Note: The LDAP Changelog should not be confused with the Replication Changelog. The main distinction is as follows:

- The LDAP Changelog (i.e., the external changelog that clients can access) physically resides at `<server-root>/db/changelog`.
- The Replication Changelog Backend (i.e., the changelog that replication servers use) physically resides at `<server-root>/changelogDB`.

Key Changelog Features

As of version 3.2, the Data Store supports two new Changelog Backend properties that allow access control filtering and sensitive attribute evaluation for targeted entries. External client applications can change the contents of attributes they can see in the targeted entry based on the access control rules applied to the associated base DN.

- **apply-access-controls-to-changelog-entry-contents**. Indicates whether the contents of changelog entry attributes (i.e., `changes`, `deletedEntryAttrs`, `ds-changelog-entry-key-attr-values`, `ds-changelog-before-values`, and `ds-changelog-after-values`) are subject to access control and/or sensitive attribute evaluation to limit data that LDAP clients can see. The client must have the access control permissions to read changelog entries to retrieve them in any form. If this feature is enabled and the client does not have permission to read an entry at all, or if that client does not have permission to see any attributes that were targeted by the change, then the associated changelog entries targeted by those operations will be suppressed. If a client does not have permission to see certain attributes within the target entry, then references to those attributes in the changelog entry will also be suppressed. This property only applies to standard LDAP searches of the `cn=changelog` branch.
- **report-excluded-changelog-attributes**. Indicates whether to include additional information about any attributes that may have been removed due to access control filtering. This property only applies to content removed as a result of processing performed by the `apply-access-controls-to-changelog-entry-contents` property. Possible values are:
  - **none -** Indicates that changelog entries should not include any information about attributes that have been removed.

- **attribute-counts -** Indicates that changelog entries should include a count of user and/or operational attributes that have been removed. If any user attribute information was excluded from a changelog entry, the number of the excluded user attributes will be reported in the `ds-changelog-num-excluded-user-attributes` attribute of the changelog entry. If any operational attribute information was excluded from a changelog entry, then the number of the excluded operational attributes will be reported in the `ds-changelog-num-excluded-operational-attributes` attribute of the changelog entry. Both the `ds-changelog-num-excluded-user-attributes` and `ds-changelog-num-excluded-operational-attributes` are operational and must be explicitly requested by clients (or all operational attributes requested using "+") to be returned.
- **attribute-names -** Indicates that changelog entries should include the names of user and/or operational attributes that have been removed. If any user attribute information was excluded from a changelog entry, then the names of the excluded user attributes will be reported in the `ds-changelog-excluded-user-attributes` attribute of the changelog entry. If any operational attribute information was excluded from a changelog entry, then the names of the excluded operational attributes will be reported in the `ds-change-log-excluded-operational-attribute` attribute of the changelog entry. Both the `ds-changelog-excluded-user-attribute` and `ds-changelog-excluded-operational-attribute` attributes are operational and must be explicitly requested by clients (or all operational attributes requested via "+") to be returned.

To Enable Access Control Filtering in the LDAP Changelog

To set up access control to the LDAP Changelog, use the `dsconfig` tool to enable the properties to the Changelog Backend. Only admin users with the `bypass-acl` privilege can read the changelog.

1. Enable the `apply-access-control-to-changelog-entry-contents` property to allow LDAP clients to undergo access control filtering using standard LDAP searches of the `cn=changelog` backend.

```
$ bin/dsconfig set-backend-prop --backend-name "changelog" \
  --set "apply-access-controls-to-changelog-entry-contents:true"
```

   Access control filtering will be applied regardless of the value of the `apply-access-controls-to-changelog-entry-contents` setting when the Changelog Backend is servicing requests from an UnboundID Data Sync Server that has the `filter-changes-by-user` Sync Pipe property set.

2. Optional. Set the `report-excluded-changelog-attributes` property to include a count of users that have been removed through access control filtering. The count appears in the `ds-changelog-num-excluded-user-attributes` attribute for users and the `ds-changelog-num-excluded-operational-attributes` attribute for operational attributes.

```
 $ bin/dsconfig set-backend-prop --backend-name "changelog" \
  --set "report-excluded-changelog-attributes:attribute-counts"
```

Useful Changelog Features

The Data Store provides two useful changelog configuration properties: `changelog-max-before-after-values` and `changelog-include-key-attribute`.

- **changelog-max-before-after-values**. Setting this property to a non-zero value causes all of the old values and all of the new values (up to the specified maximum) for each changed attribute to be stored in the changelog entry. The values will be stored in the `ds-changelog-before-values` and `ds-changelog-after-values` attributes on the changelog entry. These attributes are not present by default.

  Note: The `changelog-max-before-after-values` property can be expensive for attributes with hundreds or thousands of values, such as a group entry.

  If any attribute has more than the maximum number of values, their names and number of before/after values will be stored in the `ds-changelog-attr-exceeded-max-values-count` attribute on the changelog entry. This is a multi-valued attribute whose format is:

  ```
  attr=attributeName,beforeCount=100,afterCount=101
  ```

  where "attributeName" is the name of the attribute and the "beforeCount" and "afterCount" are the total number of values for that attribute before and after the change, respectively. This attribute indicates that you need to reset the `changelog-max-before-after-values` property to a higher value. When this attribute is set, an alert will be generated.

  Note: If the number of values for an attribute exceeds the maximum value set by the `changelog-max-before-after-values` property, then those values will not be stored.

- **changelog-include-key-attribute**. This property is used for correlation attributes that need to be synchronized across servers, such as `uid`. It causes the current (after-change) value of the specified attributes to be recorded in the `ds-changelog-entry-key-attr-values` attribute on the changelog entry. This applies for all change types. On a DELETE operation, the values are from the entry before they were deleted.

  The key values will be recorded on every change and override the settings configured in `changelog-include-attribute`, `changelog-exclude-attribute`, `changelog-deleted-entry-include-attribute`, or `changelog-deleted-entry-exclude-attribute`.

Example of the Changelog Features

After the `changelog-max-before-after-values` property is set, the before-and-after values of any change attribute will be recorded in the LDAP Changelog. For example, given a simple entry with two multi-valued mail attributes:

```
dn: uid=test,dc=example,dc=com
objectclass: inetorgperson
cn: test user
sn: user
description: oldDescription
mail: test@yahoo.com
mail: test@gmail.com
```

Then, apply the following changes to the entry:

```
dn: uid=test,dc=example,dc=com
changetype: modify
add: mail
mail: test@hotmail.com
-
delete: mail
mail: test@yahoo.com
-
replace: description
description: newDescription
```

The resulting changelog would record the following attribute values:

```
dn: changeNumber=1,cn=changelog
objectClass: top
objectClass: changeLogEntry
targetDN: uid=test,dc=example,dc=com
changeType: modify
changes::
YWRkOiBtYWlsCm1haWw6IHRlc3RAaG90bWFpbC5jb20KLQpkZWxldGU6IG1haWwKbWFpbDogdGVzdEB5YWh
vby5jb20KLQpyZXBsYWNlOiBkZXNjcmlwdGlvbgpkZXNjcmlwdGlvbjogbmV3RGVzY3JpcHRpb24KLQpyZX
BsYWNlOiBtb2RpZmllcnNOYW1lCm1vZGlmaWVyc05hbWU6IGNuPURpcmVjdG9yeSBNYW5hZ2VyLGNuPVJvb
3QgRE5zLGNuPWNvbmZpZwotCnJlcGxhY2U6IGRzLXVwZGF0ZS10aW1lCmRzLXVwZGF0ZS10aW1lOjogQUFB
QkxxQitIaTQ9Ci0KAA==
ds-changelog-before-values:: ZGVzY3JpcHRpb246IG9sZERlc2NyaXB0aW9uCm1haWw6IHRlc3RAeW
Fob28uY29tCm1haWw6IHRlc3RAZ21haWwuY29tCmRzLXVwZGF0ZS10aW1lOjogQUFBQkxxQjdaZ1E9Cm1vZ
GlmaWVyc05hbWU6IGNuPURpcmVjdG 9yeSBNYW5hZ2VyLGNuPVJvb3QgRE5zLGNuPWNvbmZpZwo=
ds-changelog-after-values:: ZGVzY3JpcHRpb246IG5ld0Rlc2NyaXB0aW9uCm1haWw6IHRlc3RAZ21
haWwuY29tCm1haWw6IHRlc3RAaG90bWFpbC5jb20KZHMtdXBkYXRlLXRpbWU6OiBBQUFCTHFCK0hpND0KbW
9kaWZpZXJzTmFtZTogY249RGlyZWN0b3J5IE1hbmFnZXIsY249Um9vdCBETnMsY249Y29uZmlnCg==
ds-changelog-entry-key-attr-values:: dWlkOiB0ZXN0Cg==
changenumber: 1
```

You can run the `bin/base64 decode -d` command-line tool to view the decoded value for the changes, `ds-changelog-before-values`, `ds-changelog-after-values` attributes:

After base64 decoding, the `changes` attribute reads:

```
add: mail
mail: test@hotmail.com
-
delete: mail
mail: test@yahoo.com
-
replace: description
description: newDescription
-
replace: modifiersName
modifiersName: cn=Directory Manager,cn=Root DNs,cn=config
-
replace: modifyTimestamp
modifyTimestamp: 20131010020345.546Z
-
```

After base64 decoding, the `ds-changelog-before-values` attribute reads:

```
description: oldDescription
mail: test@yahoo.com
mail: test@gmail.com
modifyTimestamp: 20131010020345.546Z
modifiersName: cn=Directory Manager,cn=Root DNs,cn=config
```

After base64 decoding, the `ds-changelog-after-values` attribute reads:

```
description: newDescription
mail: test@gmail.com
mail: test@hotmail.com
modifyTimestamp: 20131010020345.546Z
modifiersName: cn=Directory Manager,cn=Root DNs,cn=config
```

Viewing the LDAP Changelog Properties

You can view the LDAP changelog properties by running the `dsconfig get-backend-prop` command and specifying the changelog backend.

To View the LDAP Changelog Properties Using dsconfig Non-Interactive Mode

- Use `dsconfig` to view the changelog properties on the Data Store. To view "advanced" properties that are normally hidden, add the `--advanced` option when running the command. For a specific description of each property, see the *UnboundID Data Store Configuration Reference*.

```
$ bin/dsconfig get-backend-prop --backend-name changelog
```

```
Property                                  : Value(s)
------------------------------------------:-------------
backend-id                                : changelog
description                               : -
enabled                                   : false
writability-mode                          : disabled
base-dn                                   : cn=changelog
set-degraded-alert-when-disabled          : false
return-unavailable-when-disabled          : false
db-directory                              : db
db-directory-permissions                  : 700
changelog-maximum-age                     : 2 d
db-cache-percent                          : 1
changelog-include-attribute               : -
changelog-exclude-attribute               : -
changelog-deleted-entry-include-attribute : -
changelog-deleted-entry-exclude-attribute : -
changelog-include-key-attribute           : -
changelog-max-before-after-values         : 0
changelog-write-batch-size                : 100
changelog-purge-batch-size                : 1000
changelog-write-queue-capacity            : 100
write-lastmod-attributes                  : true
use-reversible-form                       : false
je-property                               : -
```

Enabling the LDAP Changelog

By default, the LDAP changelog is disabled on the Data Store. If you are using the `dsconfig` tool in interactive mode, the changelog appears in the Backend configuration as a Standard object menu item.

Note: You can enable the feature using the `dsconfig` tool only if required as it can significantly affect LDAP update performance.

To Enable the LDAP Changelog Using dsconfig Non-Interactive Mode

- Use `dsconfig` to enable the changelog property on the Data Store.

```
$ bin/dsconfig set-backend-prop \
  --backend-name changelog --set enabled:true
```

To Enable the LDAP Changelog Using Interactive Mode

1. Use `dsconfig` to enable the changelog on each server in the network. Then, authenticate to the server by entering the host name, LDAP connection, port, bindDN and bind password.

```
$ bin/dsconfig
```

2. On the **Data Store Configuration Console main** menu, type `o` to change from the Basic object level to the Standard object level.
3. Enter the option to select the Standard Object level.
4. On the **Data Store Configuration console main** menu, type the number corresponding to Backend.
5. On the **Backend Management** menu, enter the option to view and edit an existing backend.
6. Next, you should see a list of the accessible backends on your system. For example, you may see options for the `changelog` and `userRoot` backends. Enter the option to work with the changelog backend.
7. On the **Changelog Backend properties** menu, type the number corresponding to the Enabled property.
8. On the **Enabled Property** menu, type the number to change the `Enabled` property to TRUE.
9. On the **Backend Properties** menu, type `f` to apply the change. If you set up the server in a server group, type `g` to update all of the servers in the group. Otherwise, repeat steps 1-10 on the other servers.
10. Verify that changes made to the data are recorded in the changelog.

Changing the LDAP Changelog Database Location

In cases where disk space issues arise, you can change the on-disk location of the LDAP Change Log database. The changelog backend supports a `db-directory` property that specifies the absolute or relative path (i.e., relative to the local server root) to the filesystem directory that is used to hold the Oracle Berkeley DB Java Edition database files containing the data for this backend.

If you change the changelog database location, you must stop and then restart the Data Store for the change to take effect. If the changelog backend is already enabled, then the database files must be manually moved or copied to the new location while the server is stopped.

To Change the LDAP Changelog Location Using dsconfig Non-Interactive Mode

1. Use `dsconfig` to change the database location for the LDAP Changelog, which by default is at `<server-root>/db`. The following command sets the LDAP changelog backend to `<server-root>/db2`. Remember to include the LDAP connection parameters (e.g., hostname, port, bindDN, bindPassword).

```
$ bin/dsconfig set-backend-prop --backend-name changelog \
  --set "db-directory:db2" --set "enabled:true"
```

The database files are stored under `<server-root>/db2/changelog`. The files for this backend are stored in a sub-directory named after the `backend-id` property.

2. Stop and restart the server. Since the LDAP changelog backend was previous disabled, there is no need to manually relocate any existing database files.

```
$ bin/stop-ds
$ bin/start-ds
```

To Reset the LDAP Changelog Location Using dsconfig Non-Interactive Mode

1. If you have changed the LDAP Changelog location, but want to reset it to its original location, use `dsconfig` to reset it. The following command resets the LDAP changelog backend to `<server-root>/db` location. Remember to include the LDAP connection parameters (e.g., hostname, port, bindDN, bindPassword).

```
$ bin/dsconfig set-backend-prop --backend-name changelog \
  --reset "db-directory"
```

2. The server attempts to use whatever it finds in the configured location when it starts. If there is nothing there, it will create an empty database. If the LDAP changelog backend at the previous location is enabled at the time, stop the server, manually copy the database files to the new LDAP changelog location, and then restart the server.

Viewing the LDAP Changelog Parameters in the Root DSE

The Root DSE is a special entry that holds operational information about the server. The entry provides information about the LDAP controls, extended operations, and SASL mechanisms available in the server as well as the state of the data within the changelog. For changelog parameters, the attributes of interest include:

- **firstChangeNumber**. Change number for the first (oldest) change record contained in the LDAP changelog.
- **lastChangeNumber**. Change number for the last (most recent) change record contained in the LDAP changelog.
- **lastPurgedChangeNumber**. Change number for the last change that was purged from the LDAP changelog. It can be 0 if no changes have yet been purged.
- **firstReplicaChange**. Information about the first (oldest) change record for a change received from the specified replica. This is a multi-valued attribute and should include a value for each server in the replication topology.
- **lastReplicaChange**. Information about the last (most recent) change record for a change received from the specified replica.

The `firstReplicaChange` and `lastReplicaChange` attributes use the following syntax:

```
serverID:CSN:changeNumber
```

where:

- **serverID**. Specifies the unique identifier for the server updating the change log.
- **CSN**. Specifies the Change Sequence Number, which is the time when the update was made to the given replica.
- **changeNumber**. Specifies the order of the change that is logged to the LDAP changelog.

The `firstReplicaChange` and `lastReplicaChange` attributes can be used to correlate information in the local LDAP Change Log with data in the LDAP Change Log of other servers in the replication topology. The order of the individual changes in the LDAP Change Log can vary between servers based on the order in which they were received from a replica.

To View the LDAP Changelog Parameters

- Use `ldapsearch` to view the Root DSE.

  ```
  $ bin/ldapsearch --baseDN "" --searchScope base "(objectclass=*)" "+"
  ```

Viewing the LDAP Changelog Using ldapsearch

All records in the changelog are immediate children of the `cn=changelog` entry and are named with the `changeNumber` attribute. You can view changelog entries using `ldapsearch`. Changes are represented in the form documented in the *draft-good-ldap-changelog* specification with the targetDN attribute providing the DN of the updated entry, the `changeType` attribute providing the type of operation (add, delete, modify, or modDN), and the changes attribute providing a base64-encoded representation of the attributes included in the entry (for add operations) or the changes made (for modify operations) in LDIF form. You can view the changes by decoding the encoded value using the `base64 decode` utility. The UnboundID LDAP SDK for Java also provides support for parsing changelog entries.

To View the LDAP Changelog Using ldapsearch

1. Grant access to the `cn=changelog` backend to the `uid=admin` account using access control rules. By default, only the root user has access to this backend.

```
$ bin/ldapmodify
dn: cn=changelog
changetype: modify
add: aci
aci: (targetattr="*||+")
  (version 3.0; acl "Access to the changelog backend for the admin account";
  allow (all) userdn="ldap:///uid=admin,dc=example,dc=com";)
```

2. Use `ldapsearch` to view the changelog.

```
$ bin/ldapsearch --baseDN cn=changelog --dontWrap "(objectclass=*)"
```

```
dn: cn=changelog
objectClass: top
objectClass: untypedObject
cn: changelog

dn: changeNumber=1,cn=changelog
objectClass: changeLogEntry
objectClass: top
targetDN: uid=user.0,ou=People,dc=example,dc=com
changeType: modify
changes:: cmVwbGFjZTogbW9iaWxlCm1vYmlsZTogKzEgMDIwIDE1NCA5Mzk4Ci0KcmVwbGFjZToga
G9tZVBob25lCmhvbWVQaG9uZTogKzEgMjI1IDIxNiA0OTQ5Ci0KcmVwbGFjZTogZ2l2ZW5OYW1lCmdp
dmVuTmFtZTogQWFyb24KLQpyZXBsYWNlOiBkZXNjcmlwdGlvbgpkZXNjcmlwdGlvbjogdGhpcyBpcyB
0aGUgZGVzY3JpcHRpb24gZm9yIEFhcm9uIEF0cC4KLQpyZXBsYWNlOiBtb2RpZmllcnNOYW1lCm1vZG
lmaWVyc05hbWU6IGNuPURpcmVjdG9yeSBNYW5hZ2VyLGNuPVJvb3QgRE5zLGNuPWNvbmZpZwotCnJlc
GxhY2U6IGRzLXVwZGF0ZS10aW1lCmRzLXVwZGF0ZS10aW1lOjogQUFBQkhQOHpUR0E9Cgo=
changenumber: 1
dn: changeNumber=2,cn=changelog
objectClass: changeLogEntry
objectClass: top
targetDN: dc=example,dc=com
changeType: modify
changes:: cmVwbGFjZTogZHMtc3luYy1zdGF0ZQpkcy1zeW5jLXN0YXRlOiAwMDAwMDExQ0ZGMzM0Q
zYwNDA5MzAwMDAwMDAyCgo=
changenumber: 2
```

To View the LDAP Change Sequence Numbers

- The changelog displays the server state information, which is important for failover between servers during synchronization operations. The server state information is exchanged between the servers in the network (LDAP servers and replication servers) as part of the protocol start message. It also helps the client application determine which server is most up-to-date. Make sure that the `uid=admin` account has the necessary access rights to the `cn=changelog` backend.

```
$ bin/ldapsearch --baseDN cn=changelog --dontWrap "(objectclass=*)" "+"
```

```
dn: cn=changelog

dn: changeNumber=1,cn=changelog
entry-size-bytes: 182
targetUniqueId: 68147342-1f61-3465-8489-3de58c532130
changeTime: 20111023002624Z
lastReplicaCSN: 0000011D27184D9E303000000001
replicationCSN: 0000011D27184D9E303000000001
replicaIdentifier: 12336
```

```
dn: changeNumber=2,cn=changelog
entry-size-bytes: 263
targetUniqueId: 4e9b7847-edcb-3791-b11b-7505f4a55af4
changeTime: 20111023002624Z
lastReplicaCSN: 0000011D27184F2E303000000002
replicationCSN: 0000011D27184F2E303000000002
replicaIdentifier: 12336
```

To View LDAP Changelog Monitoring Information

The changelog contains a monitor entry that you can access over LDAP, JConsole, the Management Console, or SNMP. Make sure that the `uid=admin` account has the necessary access rights to the `cn=changelog` backend.

- Use `ldapsearch` to view the changelog monitor entry.

```
$ bin/ldapsearch --baseDN cn=changelog,cn=monitor "(objectclass=*)"
```

```
dn: cn=changelog,cn=monitor
objectClass: top
objectClass: ds-monitor-entry
objectClass: extensibleObject
cn: changelog
changelog: cn=changelog
firstchangenumber: 1
lastchangenumber: 8
lastpurgedchangenumber: 0
firstReplicaChange: 16225:0000011D0205237F3F6100000001:5
firstReplicaChange: 16531:0000011CFF334C60409300000002:1
lastReplicaChange: 16225:0000011D02054E8B3F6100000002:7
lastReplicaChange: 16531:0000011CFF334C60409300000002:1
oldest-change-time: 20081015063104Z
...(more data)...
```

Indexing the LDAP Changelog

The Data Store supports attribute indexing in the Changelog Backend to allow Get Changelog Batch requests to filter results that include only changes involving specific attributes. Normally, the data store that receives a request must iterate over the whole range of changelog entries and then match entries based on search criteria for inclusion in the batch. The majority of this processing also involves determining whether the changelog entry includes changes to a particular attribute or set of attributes, or not. Using changelog indexing, client applications can dramatically speed up throughput when targeting the specific attributes.

Administrators can configure attribute indexing using the `index-include-attribute` and `index-exclude-attribute` properties on the Changelog Backend. The properties can accept the specific attribute name or special LDAP values "*" to specify all user attributes or "+" to specify all operational attributes.

To determine if the data store supports this feature, administrators can view the Root DSE for the following entry:

```
supportedFeatures: 1.3.6.1.4.1.30221.2.12.3
```

To Index a Changelog Attribute

1. Use dsconfig to set attribute indexing on an attribute in the Changelog Backend.

   The following command enables the Changelog Backend and sets the backend to include all user attributes ("*") for ADD or MODIFY operations using the changelog-include-attribute property. The changelog-deleted-entry-include-attribute property is set to all attributes ("*") to specify a set of attribute types that should be included in a changelog entry for DELETE operations. Attributes specified in this list will be recorded in the deletedEntryAttrs attribute on the changelog entry when an entry is deleted. The attributes displayName and employeeNumber are indexed using the index-include-attribute property.

   ```
   $ bin/dsconfig set-backend-prop --backend-name changelog \
     --set "enabled:true" \
     --set "changelog-include-attribute:*" \
     --set "changelog-deleted-entry-include-attribute:*" \
     --set "index-include-attribute:displayName" \
     --set "index-include-attribute:employeeNumber"
   ```

2. Add another attribute to index using the dsconfig --add option, which adds the attribute to an existing configuration setting.

   ```
   $ bin/dsconfig set-backend-prop --backend-name changelog \
     --add "index-include-attribute:cn"
   ```

To Exclude Attributes from Indexing

- Use dsconfig to set attribute indexing on all user attributes in the Changelog Backend. The following command includes all user attributes except the description and location attributes.

  ```
  $ bin/dsconfig set-backend-prop --backend-name changelog \
    --set "index-include-attribute:*" \
    --set "index-exclude-attribute:description \
    --set "index-exclude-attribute:location
  ```

Tracking Virtual Attribute Changes in the LDAP Changelog

By default, the LDAP Changelog tracks changes to real attributes only. For client applications that require change tracking to include virtual attributes, administrators can enable the include-virtual-attribute property, so that real and virtual attributes are tracked within the changelog. Once the include-virtual-attribute property is enabled, then properties for virtual attributes that store before/after values, key attributes, and added or deleted entry attributes can be enabled.

To Track Virtual Attribute Changes in the LDAP Changelog

- Use `dsconfig` to enable virtual attribute change tracking in the LDAP Changelog.

  The following command enables the LDAP changelog and sets `include-virtual-attributes` to `add-attributes`, which indicates that virtual attribute be included in the set of attributes listed for an add operation. The `delete-entry-attributes` option indicates that virtual attributes should be included in the set of deleted entry attributes listed for a delete operation. The `before-and-after-values` option indicates that virtual attributes should be included in the set of before and after values for attributes targeted by the changes. The `key-attribute-values` option indicates that virtual attributes should be included in the set of entry key attribute values.

```
$ bin/dsconfig set-backend-prop --backend-name "changelog" \
  --set "enabled:true" \
  --set "include-virtual-attributes:add-attributes" \
  --set "include-virtual-attributes:deleted-entry-attributes" \
  --set "include-virtual-attributes: before-and-after-values" \
  --set "include-virtual-attributes: key-attribute-values"
```

Chapter 16 Managing Security

The UnboundID Data Store provides a full suite of security features to secure communication between the client and the server, to establish trust between components (for example, for replication and administration), and to secure data. Internally, the Data Store uses cryptographic mechanisms that leverage the Java JRE's Java Secure Sockets Extension (JSSE) implementation of the SSL protocol using Key Manager and Trust Manager providers for secure connection integrity and confidentiality, and the Java Cryptography Architecture (JCA) for data encryption.

This chapter presents procedures to configure security and covers the following topics:

Topics:

Summary of the UnboundID Data Store Security Features

The UnboundID Data Store supports a strong set of cryptographic and other mechanisms to secure communication and data. The following security-related features are available:

- **SSL/StartTLS Support**. The Data Store supports the use of SSL and StartTLS to encrypt communication between the client and the server. Administrators can configure different certificates for each connection handler, or use the same certificate for all connection handlers. Additionally, the server allows for more fine-grained control of the key material used in connecting peers in SSL handshakes and trust material for storing certificates.
- **Message Digest/Encryption Algorithms**. The Data Store supports the use of a number of one-way message digests (e.g., CRYPT, 128-bit MD5, 160-bit SHA-1, and 256-bit, 384-bit, and 512-bit SHA-2 digests) as well as a number of reversible encryption algorithms (BASE64, 3DES, AES, RC4, and Blowfish) for storing passwords. Note that even if passwords are encoded using reversible encryption, that encryption is intended for use only within the server itself, and the passwords will not be made available to administrators in unencrypted form. It is generally recommended that encrypted password storage only be used if you anticipate using an authentication mechanism that requires the server to have access to the clear-text representation of passwords, like CRAM-MD5 or DIGEST-MD5.
- **SASL Mechanism Support**. The Data Store supports a number of SASL mechanisms, including ANONYMOUS, CRAM-MD5, DIGEST-MD5, EXTERNAL, PLAIN, and GSSAPI. In some vendors' directory servers, the use of CRAM-MD5 and DIGEST-MD5 requires that the server have access to the clear-text password for a user. In this case, the server supports reversible encryption to store the passwords in a more secure encoding than clear text. The server also supports two types of one-time password (OTP) mechanisms for multi-factor authentication: UNBOUNDID-TOTP SASL and UNBOUNDID-DELIVERED-OTP SASL. The proprietary UNBOUNDID-TOTP SASL mechanism allows multi-factor authentication to the server using the time-based one-time password (TOTP) code. The proprietary UNBOUNDID-DELIVERED-OTP SASL mechanism allows multi-factor authentication to the server by delivering a one-time password to the the end user through some out-of-band channel, such as email or SMS.
- **Password Policy Support**. The Data Store provides extensive password policy support including features, like customizable password attributes, maximum password age, maximum password reset age, multiple default password storage schemes, account expiration, idle account lockout and others. The server also supports a number of password storage schemes, like one-way digests (CRYPT, MD5, SMD5, SHA, SSHA, SSHA256, SSHA384, SSHA512) and reversible encryption (BASE64, 3DES, AES, RC4, BLOWFISH). Administrators can also use a number of password validators, like maximum password length, similarity to current password and the set of characters used. See the chapter on *Password Policies* for more information.
- **Full-Featured Access Control System**. The Data Store provides a full-featured access control subsystem that determines whether a given operation is allowable based on a wide range of criteria. The access control system allows administrators to grant or restrict access to data, restrict the use of specific types of controls and extended operations and provides strong

validation for access control rules before accepting them. See the chapter on *Access Control* for more information.

- **Client Connection Policies Support**. The Data Store provides the ability to control which clients get connected to the server, how they can get connected to the system, and what resources or operations are available to them. For example, administrators can set up client connection criteria that blacklists IP addresses or domains that are known to attempt brute force attacks. Likewise, client connection policies can be configured to restrict the type of operations, controls, extended-operations, SASL mechanisms, search filters and resource limits available to the client. For example, you can configure a client connection policy that limits the number of concurrent connections or rejects all requests on unsecured connections.
- **Backup Protection**. The Data Store provides the ability to protect the integrity of backup contents using cryptographic digests and encryption. When generating a backup, the administrator has an option to generate a cryptographic digest of the backup contents and also optionally to digitally sign that digest. The server also has options to compress and/ or encrypt the contents of the backup. When restoring the backup, the server can verify that the digest matches the content of the backup and generates an error if the backup has been changed from when it was initially written, making it tamper-evident. The server also provides the ability to verify the integrity of a backup without actually restoring it. See chapter on *Backing Up and Restoring Data* for more information.

Performing Data Security Audits

The Data Store provides an `audit-data-security` command-line tool that allows the administrator to assess any potential security risks in the your data. The tool invokes a configurable set of data security auditors to identify the audit type, current account, password, and privilege settings. Each data security auditor generates a time-stamped report that the administrator can review and take action on. Reports from consecutive runs may be compared to see if changes made in the Data Store resolved one or more identified issues.

The `audit-data-security` tool also provides refined auditing capabilities by allowing the administrator to specify the backends to audit as well as the specific severity and verbosity levels for each event. The tool can execute on backends from one of the following supported types: Local DB, LDIF, and Configuration. Note that only one data security audit can run on any Local DB backend at any given time. If multiple backends are audited (for example, Local DB and Configuration), the Data Security Auditors scan these backends simultaneously. The tool can be executed immediately or scheduled to run at a later time. If scheduled for a specific time, the tool invokes a Data Store task that runs one or more Data Security Auditors on the selected backends.

Due to the sensitive nature of this process, only administrators with the `audit-data-security` privilege can execute data security audits.

Reports

Each Data Security Auditor generates a detailed report file named after the type of auditor used. By default, the security audit report files are saved in LDIF format to the `<server-root>/reports/audit-data-security/<timestamp>` directory. In the top-level reports directory, there is a `summary.ldif` file that provides an overview of the audit results. Subdirectories for each backend store the detailed report files for that particular backend.

To View a Data Security Audit Report

- Open a report file using a text editor. The following command opens the `entries-with-acis.ldif` report for the `userRoot` backend.

```
$ cat /UnboundID-DS/reports/audit-data-security/20110811201049Z/userRoot/entries-
with-acis.ldif
```

```
dn: dc=example,dc=com
objectClass: ds-audit-report-aci-entry
objectClass: extensibleObject
ds-audit-severity: notice
ds-audit-reason: presence of access control information
aci: (targetattr!="userPassword")
  (version 3.0; acl "Allow anonymous read access for anyone";
    allow (read,search,compare) userdn="ldap:///anyone";)
aci: (targetattr="*")
  (version 3.0; acl "Allow users to update their own entries";
    allow (write) userdn="ldap:///self";)
aci: (targetattr="*")
  (version 3.0; acl "Grant full access for the admin user";
    allow (all) userdn="ldap:///uid=admin,dc=example,dc=com";)
```

Data Security Auditors

The following table shows the available Data Security Auditors in the Data Store. Each auditor is enabled by default but can be disabled or modified using the `dsconfig` command:

Table 28: Data Security Auditors

Auditor	Description
ACCESS-CONTROL	Reports all entries with access control information.
DISABLED-ACCOUNT	Reports all disabled accounts.
EXPIRED-PASSWORD	Reports all accounts with expired passwords, accounts with passwords about to expire as well as accounts with passwords exceeding a specified age.
LOCKED-ACCOUNT	Reports locked accounts including the reason for locking.
MULTIPLE-PASSWORD	Reports entries with multiple password values. It is possible to configure the auditor to only report those entries that have multiple passwords using different password storage schemes.
PRIVILEGE	Reports entries with privileges. The report distinguishes between directly assigned privileges and privileges assigned by a virtual attribute.
WEAKLY-ENCODED-PASSWORDS	Reports all entries that use one of the specified weak password storage schemes.

Configuring the Data Security Auditors

The Data Security Auditors can be configured using the `dsconfig` command-line utility. Each Data Security Auditor may be independently enabled or disabled. They may also be configured to include one or more attributes from the audited entry in the detailed report.

For more detailed information, each Data Security Auditor can be configured to report events at a specific severity and verbosity level. The three possible severity values are: Error, Warning, and Verbose. If the Warning level is selected, then both error and warning events are included in the reports. Similarly, if the Verbose level is selected, then the report will include events with any severity. By default, all Data Security Auditors are configured with the Warning audit severity.

To Configure the Data Security Auditors

1. Run the `dsconfig` command and enter the connection parameters for your system.

2. Change to the **Advanced** menu option by entering "**o**" (the letter) and selecting **Advanced**.

3. On the Configuration Console main menu, enter the number corresponding to **Data Security Auditor**.

4. On the **Data Security Auditor management** menu, enter the number corresponding to **View and edit an existing Data Auditor**.

5. From the displayed list, enter the number corresponding to a Data Auditor that you want to modify.

6. For the specific Data Auditor, add or change any properties that you want to include in your security audit. Then, enter `f` to apply the changes.

The audit-data-security Tool

The `audit-data-security` tool runs in either interactive mode or non-interactive mode. By default, the tool executes security audits on all enabled Data Security Auditors on all supported backends (i.e., Local DB, LDIF, and Configuration). Administrators can adjust these settings using the `dsconfig` tool.

In non-interactive mode, the administrator can specify which Data Security Auditors should be executed during the audit, which backends the audit should scan, what entries should be included in the audit as well as specify an alternate output directory for the reports.

To Run the audit-data-security Tool

1. Run the `audit-data-security` tool to perform a full audit of the Data Store.

```
$ bin/audit-data-security
```

2. Open the `summary.ldif` to view the summary audit report, which will be in the time-stamped directory created by the audit.

```
$ cat UnboundID-DS/reports/audit-data-security/20110811201049Z
```

3. To view a specific audit report, open the report in the backend subdirectory. For example, the following command opens an auditor report for `entries-with-acis.ldif` for the `userRoot` backend.

```
$ cat UnboundID-DS/reports/audit-data-security/20110811201049Z/userRoot/entries-with-
acis.ldif
```

To Run a Security Audit on a Subset of Entries

- Run the `audit-data-security` tool to perform a security audit on a subset of entries in the userRoot backend but do not report on entries having privileges:

```
$ bin/audit-data-security --backendID userRoot --excludeAuditor PRIVILEGE \
  --reportFilter "(employeeType=contactor)"
```

Data Store SSL and StartTLS Support

The UnboundID Data Store supports the use of SSL and/or StartTLS to secure communication with clients and other components in your environment.

Note: Although the term "SSL" (Secure Sockets Layer) has been superceded by "TLS" (Transport-Layer Security), the older term "SSL" will continue to be used in this document to make it easier to distinguish between the use of TLS as a general mechanism for securing communication and the specific use of the StartTLS extended operation.

The supported versions of SSL or StartTLS are determined by what the underlying JVM supports. The server will automatically look at the supported protocols and attempt to determine the best one to use.

When using Oracle Java SE 1.7, version TLSv1.2 is preferred by the server. A particular protocol can be specified by setting the `com.unboundid.util.SSLUtil.defaultSSLProtocol` property

LDAP-over-SSL (LDAPS)

The Data Store provides the option of using dedicated connection handlers for LDAPS connections. LDAPS differs from LDAP in that upon connect, the client and server establish an SSL session before any LDAP messages are transferred. LDAPS connection handlers with SSL enabled may only be used for secure communication, and connections must be closed when the SSL session is shut down.

StartTLS Support

The StartTLS extended operation provides a means to add SSL encryption to an existing plain-text LDAP connection. The client opens an unencrypted TCP connection to the server and, after processing zero or more LDAP operations over that clear-text connection, sends a StartTLS extended request to the server to indicate that the client-server communication should be encrypted.

To require the use of SSL for client connections accepted by a connection handler, set `use-ssl` to true for that connection handler. To allow clients to use StartTLS on a connection handler, the administrator must configure that connection handler to allow StartTLS. Because SSL and StartTLS are mutually exclusive, you cannot enable both SSL and StartTLS for the same connection handler (although you can have some connection handlers configured to use SSL and others configured to use StartTLS).

Managing Certificates

You can generate and manage certificates using a variety of commonly available tools, such as the Java `keytool` utility, which is a key and certificate management utility provided with the Java SDK. The `keytool` utility can be used to create keystores, which hold key material used in the course of establishing an SSL session, and truststores, which may be consulted to determine whether a presented certificate should be trusted.

Because there are numerous ways to create or obtain certificates, the procedures in this section will only present basic steps to set up your certificates. Many companies have their own certificate authorities or have existing certificates that they use in the servers, and in such environments you should follow the guidelines specific to your company’s implementation.

The UnboundID Data Store supports three keystore types: Java Keystore (JKS), PKCS#12, and PKCS#11.

- **Java Keystore (JKS)**. In most Java SE implementations, the JKS Keystore is the default and preferred keystore format. JKS Keystores may be used to hold certificates for other Java-based applications, but such keystores are likely not compatible with non-Java-based applications.
- **PKCS#12**. This keystore type is a well-defined standard format for storing a certificate or certificate chain, and may be used to hold certificates already in use for other types of servers. Most other servers that provide a proprietary format for storing certificates provide a mechanism for converting those certificates to PKCS#12.
- **PKCS#11**. Also, known as Cryptoki (pronounced "crypto-key") is a format for cryptographic token interfaces for devices, such as cryptographic smart cards, hardware accelerators, and high performance software libraries. PKCS#11 tokens may also offer a higher level of security than other types of keystores, and many of them have been FIPS 140-2 certified and may be tamper-evident or tamper-resistant.

Authentication Using Certificates

The Data Store supports two different mechanisms for certificate-based authentication:

- **Client Certificate Validation**. The Data Store can request the client to present its own certificate for client authentication during the SSL or StartTLS negotiation process. If the client presents a certificate, then the server will use the trust manager provider configured for the associated connection handler to determine whether to continue the process of establishing the SSL or StartTLS session. If the client certificate is not accepted by the trust manager provider, then the server will terminate the connection. Note that even if the client provides its own certificate to the server during the process of establishing an SSL or StartTLS session, the underlying LDAP connection may remain unauthenticated until the client sends an LDAP bind request over that connection.
- **SASL EXTERNAL Certificate Authentication**. The SASL EXTERNAL mechanism is used to allow a client to authenticate itself to the Data Store using information provided outside of LDAP communication. In the Data Store, that information must come in the form of a client certificate presented during the course of SSL or StartTLS negotiation. Once the client has established a secure connection to the server in which it provided its own client certificate, it may send a SASL EXTERNAL bind request to the server to request that the server attempt to identify the client based on information contained in that certificate. The server will then use a certificate mapper to identify exactly one user entry that corresponds to the provided client certificate, and it may optionally perform additional verification (e.g., requiring the certificate the client presented to be present in the `userCertificate` attribute of the user's entry). If the certificate mapper cannot identify exactly one user entry for that certificate, or if its additional validation is not satisfied, then the bind attempt will fail and the client connection will remain unauthenticated.

Creating Server Certificates using Keytool

Generate and manage certificates using the `keytool` utility, which is available in the Java SDK. The `keytool` utility is a key and certificate management utility that allows users to manage their public/private key pairs, x509 certificate chains and trusted certificates. The utility also stores the keys and certificates in a keystore, which is a password-protected file with a default format of JKS although other formats like PKCS#12 are available. Each key and trusted certificate in the keystore is accessed by its unique alias.

To Create a Server Certificate using Keytool

1. Change to the directory where the certificates will be stored.

```
$ cd /ds/UnboundID-DS/config
```

2. Use the `keytool` utility to create a private/public key pair and a keystore. The `keytool` utility is part of the Java SDK. If you cannot access the utility, make sure to change your path to include the Java SDK (`${JAVA_HOME}/bin`) directory.

The following command creates a keystore named "keystore", generates a public/private key pair and creates a self-signed certificate based on the key pair. This certificate can be used as the server certificate or it can be replaced by a CA-signed certificate chain if additional `keytool` commands are executed. Self-signed certificates are only convenient for testing purposes, they are not recommended for use in deployments in which the set of clients is not well-defined and carefully controlled. If clients are configured to blindly trust any server certificate, then they may be vulnerable to man-in-the-middle attacks.

The `-dname` option is used to specify the certificate's subject, which generally includes a CN attribute with a value equal to the fully-qualified name that clients will use to communicate with the Data Store. Some clients may refuse to establish an SSL or StartTLS session with the server if the certificate subject contains a CN value which does not match the address that the client is trying to use, so this should be chosen carefully. If the `-dname` option is omitted, you will be prompted for input. The certificate will be valid for 180 days.

```
$ keytool -genkeypair \
  -dname "CN=server.example.com,ou=Data Store Certificate,
     O=Example Company,C=US"\
  -alias server-cert \
  -keyalg rsa \
  -keystore keystore \
  -keypass changeit \
  -storepass changeit \
  -storetype JKS \
  -validity 180 \
  -noprompt
```

Note: The `-keypass` and `-storepass` arguments can be omitted to cause the tool to interactively prompt for the password. Also, the key password should match the keystore password.

3. View the keystore. Notice the entry type is `privateKeyEntry` which indicates that the entry has a private key associated with it, which is stored in a protected format to prevent unauthorized access. Also note that the Owner and the Issuer are the same, indicating that this certificate is self-signed.

```
$ keytool -list -v -keystore keystore -storepass changeit
```

```
Keystore type: JKS
Keystore provider: SUN

Your keystore contains 1 entry

Alias name: server-cert
Creation date: Sep 30, 2011
Entry type: PrivateKeyEntry
Certificate chain length: 1
Certificate[1]:
Owner: CN=server.example.com, OU=Data Store Certificate, O=Example Company, C=US
Issuer: CN=server.example.com, OU=Data Store Certificate, O=Example Company, C=US
Serial number: 4ac3695f
Valid from: Wed Sep 30 09:21:19 CDT 2011 until: Mon Mar 29 09:21:19 CDT 2012
Certificate fingerprints:
  MD5: 3C:7B:99:BA:95:A8:41:3B:08:85:11:91:1B:E1:18:00
  SHA1: E9:7E:38:0F:1C:68:29:29:C0:B4:8C:08:2B:7C:DA:14:BF:41:DE:F5
  Signature algorithm name: SHA1withRSA
  Version: 3
```

4. If you are going to have your certificate signed by a Certificate Authority, skip to step 7. Otherwise export the self-signed certificate. Then examine the certificate.

```
$ keytool -export -alias server-cert -keystore keystore -rfc -file server.crt
Enter keystore password:
Certificate stored in file <server.crt>
```

```
$ cat server.crt
-----BEGIN CERTIFICATE-----
MIICVTCCAb6gAwIBAgIESsNpXzANBgkqhkiG9w0BAQUFADBvMQswCQYDVQQGEwJVUzEYMBYGA1UEChMPRXhhb
XBsZSBDb21wYW55MS8wLQYDVQQLEyZVbmJvdW5kaWQgRGlyZWN0b3J5IFNlcnZlciBD ZXJ0aWZpY2F0ZTEVM
BMGA1UEAxMMMTcyLjE2LjE5My4xMB4XDTA5MDkzMDE0MjExOVoXDTEwMDMyOTE0MjExOVowbzELMAkGA1UEBh
MCVVMxGDAWBgNVBAoTD0V4YW1wbGUgQ29tcGFueTEvMC0GA1UE CxMmVW5ib3VuZGlkIERpcmVjdG9yeSBRZX
J2ZXIgQ2VydGlmaWNhdGUxFTATBgNVBAMTDDE3Mi4x Ni4xOTMuMTCBnzANBgkqhkiG9w0BAQEFAAOBjQAwgY
kCgYEAmRBpSeRcqur4XP8PjJWcGDVR31wE cItmMImbjpf0rTq+KG8Ssp8+se+LjLHLaeNg3itR3xMBwp7mQ4
E42i2PBIIZ0PwOKBRPxZDxpsITsSy3o9anTsopIVg1pUpST2iHGBQ+j+VY33cdcc5EoJwYykZ4d1iu45yc834
VByXjiKUCAwEAATANBgkqhkiG9w0BAQUFAAOBgQCJIZfsfQuUig4F0kPC/0fFbhW96TrLTOi6AMIOTork1SuJ
lkxp/nT+eD8eGoE+zshyJWTfVnzMDIlFMJwDIIVvnYmyeR1vlCchyJE6JyFiLpBWs6RuLD8iuHydYEwK8NkEF
YvVb/UIKqJlZ8H8+1Ippt0bENRnGD7zMwJv5ZE49w==
-----END CERTIFICATE-----
```

5. Import the self-signed certificate into a truststore, and then type `yes` to trust the certificate.

```
$ keytool -importcert -alias server-cert -file server.crt \
  -keystore truststore -storepass changeit
```

```
Owner: CN=server.example.com, OU=Data Store Certificate, O=Example Company, C=US
Issuer: CN=server.example.com, OU=Data Store Certificate, O=Example Company, C=US
Serial number: 4ac3695f
Valid from: Wed Sep 30 09:21:19 CDT 2011 until: Mon Mar 29 09:21:19 CDT 2012
Certificate fingerprints:
  MD5: 3C:7B:99:BA:95:A8:41:3B:08:85:11:91:1B:E1:18:00
  SHA1: E9:7E:38:0F:1C:68:29:29:C0:B4:8C:08:2B:7C:DA:14:BF:41:DE:F5
  Signature algorithm name: SHA1withRSA
  Version: 3
Trust this certificate? [no]: yes
Certificate was added to keystore
```

6. View the truststore with the self-signed certificate. If you intend to use this self-signed certificate as your server certificate, you are done. *Again, it is not recommended to use self-signed certificate in production deployments.* Note that the entry type of `trustedCertEntry` indicates that the keystore owner trusts that the public key in the certificate belongs to the entity identified by the owner of the certificate.

```
$ keytool -list -v -keystore truststore -storepass changeit
```

```
Keystore type: JKS
Keystore provider: SUN

Your keystore contains 1 entry

Alias name: server-cert
Creation date: Sep 30, 2011
Entry type: trustedCertEntryOwner: CN=server.example.com, OU=Data Store Certificate,
 O=Example Company, C=US
Issuer: CN=server.example.com, OU=Data Store Certificate, O=Example Company, C=US
Serial number: 4ac3695f Valid from: Wed Sep 30 09:21:19 CDT 2011 until: Mon Mar 29
 09:21:19 CDT 2012
Certificate fingerprints:
  MD5: 3C:7B:99:BA:95:A8:41:3B:08:85:11:91:1B:E1:18:00
  SHA1: E9:7E:38:0F:1C:68:29:29:C0:B4:8C:08:2B:7C:DA:14:BF:41:DE:F5
  Signature algorithm name: SHA1withRSA
  Version: 3
```

7. Create the Certificate Signing Request (CSR) by writing to the file `server.csr`. Follow the instructions of the third-party Certificate Authority (CA), and submit the file to a CA. The CA authenticates you and then returns a certificate reply, which you can save as signed.crt.

```
$ keytool -certreq -v -alias server-cert -keystore keystore \
  -storepass changeit -file server.csr
```

```
Certification request stored in file <server.csr>
```

```
Submit this to your CA
```

8. If you are working with a third-party CA or if your company has your own CA server, then both the key and trust stores should include information about the CA's root certificate as well as any intermediate certificates used to sign the Data Store certificate. Obtain the CA root and any intermediate certificates to set up a chain of trust in your keystore. View the trusted CA and intermediate certificates to check that the displayed certificate fingerprints match the expected ones.

```
$ keytool -v -printcert -file root.crt
$ keytool -v -printcert -file intermediate.crt
```

9. Import the CA's root certificate in the keystore and truststore. If there are other intermediate certificates, then import them using the same commands, giving them each different aliases in the key and trust stores.

```
$ keytool -importcert -v -trustcacerts -alias cacert \
  -keystore keystore -storepass changeit -file root.crt
$ keytool -importcert -v -trustcacerts -alias cacert -keystore truststore \
  -storepass changeit -file root.crt
```

10. Import the Data Store certificate signed by the CA into your keystore, which will replace the existing self-signed certificate created when the private key was first generated.

```
$ keytool -importcert -v -trustcacerts -alias server-cert -keystore keystore -
storepass changeit -file signed.crt
```

```
Owner: CN=server.example.com, OU=Data Store Certificate, O=Example Company, C=US
Issuer: EMAILADDRESS=whatever@example.com, CN=Cert Auth, OU=My Certificate Authority,
 O=Example Company, L=Austin, ST=Texas, C=US
Serial number: e19cb2838441dbb6 Valid from: Wed Sep 30 10:10:30 CDT 2011 until: Thu
 Sep 30 10:10:30 CDT 2012
Certificate fingerprints:
  MD5: E0:C5:F7:CF:0D:13:F5:FC:2D:A6:A4:87:FD:4C:36:1A
  SHA1: E4:15:0B:ED:99:1C:13:47:29:66:76:A0:3B:E3:4D:60:33:F1:F8:21
  Signature algorithm name: SHA1withRSA
  Version: 1
Trust this certificate? [no]: yes
Certificate was added to keystore [Storing changeit]
```

11. Add the certificate to the truststore.

```
$ keytool -importcert -v -trustcacerts -alias server-cert \
  -keystore truststore -storepass changeit -file signed.crt
```

Client Certificates

Client certificates can be used when stronger client authentication is desired but are not required for SSL connections to be established. The process for creating client certificates usually involve following an organization's certificate management policies. There are two important considerations to take into account:

- If a client presents its own certificate to the server, then the server must trust that certificate. This generally means that self-signed client certificates are not acceptable for anything but testing purposes or cases in which there are very small number of clients that will be presenting their own certificates. Otherwise, it is not feasible to configure the server to trust every client certificate.

- If the client certificates will be used for LDAP authentication via SASL EXTERNAL, then the certificate must contain enough information to allow the Data Store to associate it with exactly one user entry. The requirements for this are dependent upon the certificate mapper configured for use in the server, but this may impose constraints on the certificate (for example, the format of the certificate's subject).

Creating PKCS#12 Certificates

PKCS#12 is an industry standard format for deploying X.509 certificates (or certificate chains) and a private key as a single file. PKCS#12 is part of the family of standards called the Public-Key Cryptography Standard (PKCS) developed by RSA Laboratories.

To Generate PKCS#12 Certificates using Keytool

- To create a new certificate in PKCS#12 format, follow the same procedures as in *Creating Server Certificates using Keytool*, except use the `--storetype pkcs12` argument. For example, to create a PKCS#12 self-signed certificate and keystore, use the following command:

```
$ keytool -genkeypair \
  -dname "CN=server.example.com,ou=Data Store Certificate,O=Example Company,C=US" \
  -alias server-cert -keyalg rsa -keystore keystore.p12 -keypass changeit \
  -storepass changeit -storetype pkcs12 -validity 180 -noprompt
```

To Export a Certificate from an NSS Database in PKCS#12 Format

Some directory servers, including the Sun/Oracle DSEE Directory Server, use the Network Security Services (NSS) library to manage certificates. If you have such a directory server and wish to migrate its certificates for use with the UnboundID Data Store, then PKCS#12 can be used to accomplish this task. Use the `pk12util` NSS command-line utility to export a certificate from an NSS certificate database in PKCS12 format. You can use the PKCS#12 certificate when using QuickSetup or setting up SSL.

- Run the following `pk12util` command.

```
$ pk12util -o server.p12 -n server-cert -k /tmp/pwdfile \
  -w /tmp/pwdfile -d . -P "ds-"
```

```
nss-pk12util: PKCS12 EXPORT SUCCESSFUL
```

Working with PKCS#11 Tokens

The Cryptographic Token Interface Standard, PKCS#11, defines the native programming interfaces to cryptographic tokens, like Smartcards and hardware cryptographic accelerators. A security token provides cryptographic services. PKCS#11 provides an interface to cryptographic devices via "slots". Each slot, which corresponds to a physical reader or other device interface, may contain a token. A token is typically a PKCS#11 hardware token implemented in physical devices, such as hardware accelerators or smart cards. A software token is a PKCS#11 token implemented entirely in software.

Note: Because different types of PKCS#11 tokens have different mechanisms for creating, importing, and managing certificates, it may or may not be possible to achieve this using common utilities like `keytool`. In some cases (particularly for devices with strict Note FIPS 140-2 compliance), it may be necessary to use custom tools specific to that PKCS#11 token for managing its certificates. Consult the documentation for your PKCS#11 token for information about how to configure certificates for use with that token.

Configuring the Key and Trust Manager Providers

Java uses key managers to get access to certificates to use for SSL and StartTLS communication. Administrators use the Data Store's key manager providers to provide access to keystore contents. There are three types of key manager providers:

- **JKS Key Manager Provider**. Provides access to certificates stored in keystores using the Java-default JKS format.
- **PKCS#11 Key Manager Provider**. Provides access to certificates maintained in PKCS#11 tokens.
- **PKCS#12 Key Manager Provider**. Provides access to certificates in PKCS#12 files.

Trust manager providers are used to determine whether to trust any client certificate that may be presented during the process of SSL or StartTLS negotiation. The available trust manager provider types include:

- **Blind Trust Manager Provider**. Automatically trusts any client certificate presented to the server. This should only be used for testing purposes. Never use it for production environments, because it can be used to allow users to generate their own certificates to impersonate other users in the server.
- **JKS Trust Manager Provider**. Attempts to determine whether to trust a client certificate, or the certificate of any of its issuers, is contained in a JKS-formatted file.
- **PKCS#12 Trust Manager Provider**. Attempts to determine whether to trust a client certificate, or the certificate of any of its issuers, is contained in a PKCS#12 file.

Configuring the JKS Key and Trust Manager Provider

The following procedures are identical to those in the previous section except that the `dsconfig` tool in non-interactive mode commands are presented from the command line.

To Configure the JKS Key Manager Provider

1. Change to the server root.

```
$ cd /ds/UnboundID-DS
```

2. Create a text file containing the password for the certificate keystore. It is recommended that file permissions (or filesystem ACLs) be configured so that the file is only readable by the Data Store user.

```
$ echo ’changeit’ > config/keystore.pin
$ chmod 0400 keystore.pin
```

3. Use the `dsconfig` tool to enable the key manager provider.

```
$ bin/dsconfig set-key-manager-provider-prop \
  --provider-name JKS --set enabled:true
```

4. Use `dsconfig` to enable the trust manager provider.

```
$ bin/dsconfig set-trust-manager-provider-prop \
  --provider-name JKS --set enabled:true
```

5. Use `dsconfig` to enable the LDAPS connection handler. Port 636 is typically reserved for LDAPS, but if your server is using the port, you should specify another port, like 1636. If the certificate alias differs from the default "server-cert", use the `--set ssl-cert-nick-name:<aliasname>` to set it, or you can let the server decide by using the `--reset ssl-cert-nickname` option. For example, if the server certificate has an alias of "server," add the option `--set ssl-cert-nickname:server` to the command.

```
$ bin/dsconfig set-connection-handler-prop \
  --handler-name "LDAPS Connection Handler" \
  --set listen-port:1636 --set enabled:true
```

6. Test the listener port for SSL-based client connection on port 1636 to return the Root DSE. Type `yes` to trust the certificate.

```
$ bin/ldapsearch --port 1636 --useSSL --baseDN "" --searchScope base \
  "(objectclass=*)"
```

```
The server is using the following certificate:
  Subject DN: CN=179.13.201.1, OU=Data Store Certificate, O=Example Company,
 L=Austin, ST=Texas, C=US
  Issuer DN: EMAILADDRESS=whatever@example.com, CN=Cert Auth, OU=My Certificate
 Authority, O=Example Company, L=Austin, ST=Texas, C=US
  Validity: Fri Sep 25 15:21:10 CDT 2011 through Sat Sep 25 15:21:10 CDT 2012
  Do you wish to trust this certificate and continue connecting to the server?
  Please enter 'yes' or 'no':yes
```

7. If desired, you may disable the LDAP Connection Handler so that communication can only go through SSL.

```
$ bin/dsconfig set-connection-handler-prop \
  --handler-name "LDAP Connection Handler" \
  --set enabled:false
```

Configuring the PKCS#12 Key Manager Provider

PKCS#12 (sometimes referred to as the Personal Information Exchange Syntax Standard) is a standard file format used to store private keys with its accompanying public key certificates, protected with a password-based symmetric key.

To Configure the PKCS#12 Key Manager Provider

1. Change to the data store root.

   ```
   $ cd /ds/UnboundID-DS
   ```

2. Create a text file containing the password for the certificate keystore. It is recommended that file permissions (or filesystem ACLs) be configured so that the file is only readable by the Data Store user.

   ```
   $ echo ’changeit’ > config/keystore.pin
   $ chmod 0400 keystore.pin
   ```

3. Use the `dsconfig` tool to configure and enable the PKCS#12 key manager provider.

   ```
   $ bin/dsconfig set-key-manager-provider-prop \
     --provider-name PKCS12 \
     --set enabled:true \
     --set key-store-file:/config/keystore.p12 \
     --set key-store-type:PKCS12 \
     --set key-store-pin-file:/config/keystore.pin
   ```

4. Use the `dsconfig` tool to configure and enable the PKCS#12 trust manager provider.

   ```
   $ bin/dsconfig set-trust-manager-provider-prop \
     --provider-name PKCS12 \
     --set enabled:true \
     --set trust-store-file:/config/truststore.p12
   ```

5. Use `dsconfig` to enable the LDAPS connection handler. Port 636 is typically reserved for LDAPS, but if your server is using the port, you should specify another port, like 1636. If the certificate alias differs from the default "server-cert", use the `--set ssl-cert-nick-name:<aliasname>` to set it, or you can let the server decide by using the `--reset ssl-cert-nickname` option. For example, if the server certificate has an alias of "server," add the option `--set ssl-cert-nickname:server` to the command.

   ```
   $ bin/dsconfig set-connection-handler-prop \
     --handler-name "LDAPS Connection Handler" \
     --set enabled:true \
     --set listen-port:2636 \
     --set ssl-cert-nickname:1 \
     --set key-manager-provider:PKCS12 \
     --set trust-manager-provider:PKCS12
   ```

Configuring the PKCS#11 Key Manager Provider

The Cryptographic Token Interface (Cryptoki), or PKCS#11, format defines a generic interface for cryptographic tokens used in single sign-on or smartcard systems. The Data Store supports PKCS#11 keystores.

To Configure the PKCS#11 Key Manager Provider

1. Change to the server root.

   ```
   $ cd /ds/UnboundID-DS
   ```

2. Create a text file containing the password for the certificate keystore. It is recommended that file permissions (or filesystem ACLs) be configured so that the file is only readable by the Data Store user.

   ```
   $ echo ’changeit’ > config/keystore.pin
   $ chmod 0400 keystore.pin
   ```

3. Use the `dsconfig` tool to configure and enable the PKCS#11 key manager provider.

   ```
   $ bin/dsconfig set-key-manager-provider-prop \
     --provider-name PKCS11 \
     --set enabled:true \
     --set key-store-type:PKCS11 \
     --set key-store-pin-file:/config/keystore.pin
   ```

4. Use the `dsconfig` tool to enable the trust manager provider. Since there is no PKCS#11 trust manager provider, then you must use one of the other truststore provider types (for example, JKS or PKCS#12).

   ```
   $ bin/dsconfig set-trust-manager-provider-prop \
     --provider-name JKS \
     --set enabled:true \
     --set trust-store-file:/config/truststore.jks
   ```

5. Use `dsconfig` to enable the LDAPS connection handler. Port 636 is typically reserved for LDAPS, but if your server is using the port, you should specify another port, like 1636.
   If the certificate alias differs from the default "server-cert", use the `--set ssl-cert-nickname:<aliasname>` to set it, or you can let the server decide by using the `--reset ssl-cert-nickname` option. For example, if the server certificate has an alias of "server," add the option `--set ssl-cert-nickname:server` to the command.

   ```
   $ bin/dsconfig set-connection-handler-prop \
     --handler-name "LDAPS Connection Handler" \
     --set enabled:true \
     --set listen-port:1636 \
     --set ssl-cert-nickname:1 \
     --set key-manager-provider:PKCS11 \
     --set trust-manager-provider:JKS
   ```

Configuring the Blind Trust Manager Provider

The Blind Trust Manager provider accepts any peer certificate presented to it and is provided for testing purposes only. This trust manager should not be used in production environments, because it can allow any client to generate a certificate that could be used to impersonate any user in the server.

To Configure the Blind Trust Manager Provider

1. Change to the Data Store install root.

```
$ cd /ds/UnboundID-DS
```

2. Use the `dsconfig` tool to enable the blind trust manager provider.

```
$ bin/dsconfig set-trust-manager-provider-prop \
  --provider-name "Blind Trust" --set enabled:true
```

3. Use `dsconfig` to enable the LDAPS connection handler. Port 636 is typically reserved for LDAPS, but if your server is using the port, you should specify another port, like 1636. If the certificate alias differs from the default "server-cert", use the `--set ssl-cert-nick-name:<aliasname>` to set it, or you can let the server decide by using the `--reset ssl-cert-nickname` option. For example, if the server certificate has an alias of "server," add the option `--set ssl-cert-nickname:server` to the command.

Configuring SSL in the Data Store

The UnboundID Data Store provides a means to enable SSL or StartTLS at installation time, using either an existing certificate or by automatically generating a self-signed certificate. However, if SSL was not configured at install time, then it may be enabled at any time using the following process. These instructions assume that the certificate is available in a JKS-formatted keystore, but a similar process may be used for certificates available through other mechanisms like a PKCS#12 file or a PKCS#11 token.

To Configure SSL in the Data Store

1. Change to the server root directory.

```
$ cd /ds/UnboundID-DS
```

2. Create a text file containing the password for the certificate keystore. It is recommended that file permissions (or filesystem ACLs) be configured so that the file is only readable by the Data Store user.

```
$ echo ’changeit’ > config/keystore.pin
$ chmod 0400 config/keystore.pin
```

3. Run the `dsconfig` command with no arguments in order to launch the `dsconfig` tool in interactive mode. Enter the connection parameters when prompted.

4. On the **Data Store Configuration Console main** menu, enter `o` (lowercase letter "o") to change the complexity of the configuration objects menu. Select the option to show objects at the Standard menu.

5. On the **Data Store Configuration Console main** menu, enter the number corresponding to the Key Manager Provider.

6. On the **Key Manager Provider management** menu, select the option to view and edit an existing key manager.

7. On the **Key Manager Provider** menu, enter the option for JKS. You will see other options, like Null, PKCS11, and PKCS12.

8. Make any necessary changes to the JKS key manager provider for the keystore that you will be using. The `enabled` property must have a value of TRUE, the `key-store-file` property must reflect the path to the keystore file containing the server certificate, and the `key-store-pin-file` property should reflect the path to a file containing the password to use to access the keystore contents.

9. On the **Enabled Property** menu, enter the option to change the value to TRUE.

10. On the **File Based Key Manager Provider**, type `f` to save and apply the changes.

11. Return to the **dsconfig main** menu, and enter the number corresponding to Trust Manager Provider.

12. On the **Trust Manager Provider management** menu, enter the option to view and edit an existing trust manager provider.

13. On the **Trust Manager Provider** menu, enter the option for JKS. You will see other options for Blind Trust (accepts any certificate) and PKCS12 reads information about trusted certificates from a PKCS#12 file.

14. Ensure that the JKS trust manager provider is enabled and that the `trust-store-file` property has a value that reflects the path to the truststore file to consult when deciding whether to trust any presented certificates.

15. On the **File Based Trust Manager Provider** menu, type `f` to save and apply the changes.

16. Return to the **dsconfig main** menu, enter the number corresponding to Connection Handler.

17. On the **Connection Handler management** menu, enter the option to view and edit and existing connection handler.

18. On the **Connection Handler** menu, enter the option for LDAPS Connection Handler. You will see other options for JMX Connection Handler and LDAP Connection Handler.

19. On the **LDAP Connection Handler** menu, ensure that the connection handler has an appropriate configuration for use. The `enabled` property should have a value of TRUE, the

`listen-port` property should reflect the port on which to listen for SSL-based connections, and the `ssl-cert-nickname` property should reflect the alias for the target certificate in the selected keystore. Finally, when completing the changes, type `f` to save and apply the changes.

20. Verify that the server is properly configured to accept SSL-based client connections using an LDAP-based tool like `ldapsearch`. For example:

```
$ bin/ldapsearch --port 1636 --useSSL --baseDN "" \
  --searchScope base "(objectclass=*)"
```

```
The server is using the following certificate:
    Subject DN: CN=179.13.201.1, OU=Data Store
    Certificate, O=Example Company, L=Austin, ST=Texas,
    C=US Issuer DN: EMAILADDRESS=whatever@example.com,
    CN=Cert Auth, OU=My Certificate Authority, O=Example
    Company, L=Austin, ST=Texas, C=US
    Validity: Fri Sep 25 15:21:10 CDT 2011 through Sat Sep 25 15:21:10 CDT 2012
Do you wish to trust this certificate and continue connecting to the server?
Please enter 'yes' or 'no':yes
```

21. If desired, you may disable the LDAP connection handler so only the LDAPS connection handler will be enabled and the server will only accept SSL-based connections.

Configuring StartTLS

The StartTLS extended operation is used to initiate a TLS-secured communication channel over a clear-text connection, such as an insecure LDAP connection. The main advantage of StartTLS is that it provides a way to use a single connection handler capable of both secure and insecure communication rather than requiring a dedicated connection handler for secure communication.

To Configure StartTLS

1. Use `dsconfig` to configure the Connection Handler to allow StartTLS. The `allow-start-tls` property cannot be set if SSL is enabled. The connection handler must also be configured with a key manager provider and a trust manager provider.

```
$ bin/dsconfig set-connection-handler-prop \
 --handler-name "LDAP Connection Handler" \
 --set allow-start-tls:true \
 --set key-manager-provider:JKS \
 --set trust-manager-provider:JKS
```

2. Use `ldapsearch` to test StartTLS.

```
$ bin/ldapsearch -p 1389 --useStartTLS -b "" -s base "(objectclass=*)"
```

```
The server is using the following certificate:
   Subject DN: CN=Server Cert, OU=Data Store Certificate,
     O=Example Company, L=Austin, ST=Texas, C=US
   Issuer DN: EMAILADDRESS=whatever@example.com, CN=Cert Auth,
     OU=My Certificate Authority, O=Example Company, L=Austin, ST=Texas, C=US
   Validity: Thu Oct 29 10:29:59 CDT 2011 through Fri Oct 29 10:29:59 CDT 2012

   Do you wish to trust this certificate and continue connecting to the server?
   Please enter 'yes' or 'no':yes
```

```
dn:
objectClass: ds-root-dse
objectClass: top
startupUUID: 6fa8f196-d112-40b4-b8d8-93d6d44d59ea
```

Authentication Mechanisms

The UnboundID Data Store supports the use of both simple and Simple Authentication and Security Layer (SASL) authentication.

Simple Authentication

Simple authentication allows a client to identify itself to the Data Store using the DN and password of the target user. Because the password is provided in the clear, simple authentication is inherently insecure unless the client communication is encrypted using a mechanism like SSL or StartTLS.

If both the DN and password of a simple bind request are empty (i.e., zero-length strings), then the server will process it as an anonymous bind. This will have no effect if the client is not already authenticated, but it can be used to destroy any previous authentication session and revert the connection to an unauthenticated state as if no bind had ever been performed on that connection.

Working with SASL Authentication

SASL (Simple Authentication and Security Layer, defined in RFC 4422) provides an extensible framework that can be used to add suport for a range of authentication and authorization mechanisms. The UnboundID Data Store provides support for a number of common SASL mechanisms.

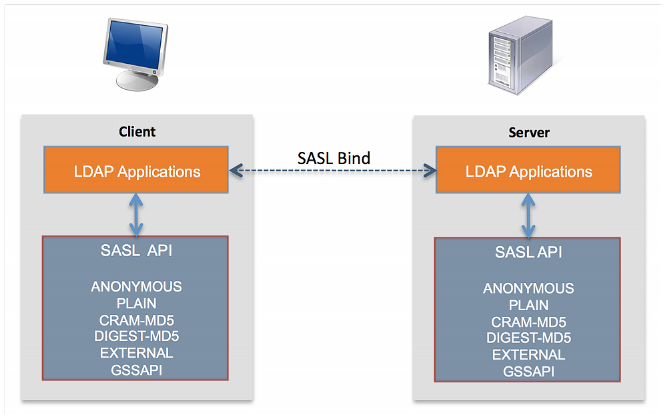


Figure 6: Simple Authentication and Security Layer

Working with the SASL ANONYMOUS Mechanism

The ANONYMOUS SASL mechanism does not actually perform any authentication or authorization, but it can be used to destroy an existing authentication session. It also provides an option to allow the client to include a trace string, which can be used to identify the purpose of the connection. Because there is no authentication, the content of the trace string cannot be trusted.

The SASL ANONYMOUS mechanism is disabled by default but can be enabled if desired using the `dsconfig` tool. The SASL configuration options are available as an **Advanced menu** option using `dsconfig` in interactive mode.

The LDAP client tools provided with the Data Store support the use of SASL ANONYMOUS. The optional "trace" SASL option may be used to specify the trace string to include in the bind request.

To Configure SASL ANONYMOUS

1. Use `dsconfig` to enable the SASL ANONYMOUS mechanism.

```
$ bin/dsconfig set-sasl-mechanism-handler-prop \
  --handler-name ANONYMOUS --set enabled:true
```

2. Use `ldapsearch` to view the root DSE and enter a trace string in the access log.

```
$ bin/ldapsearch --port 1389 --saslOption mech=ANONYMOUS \
  --saslOption "trace=debug trace string" --baseDN "" \
  --searchScope base "(objectclass=*)"
```

```
dn:
objectClass: ds-root-dse
objectClass: top
startupUUID: 59bab79d-4429-49c8-8a88-c74a86792f26
```

3. View the access log using a text editor in `/ds/UnboundID-DS/logs` folder.

```
[26/Oct/2011:16:06:33 -0500] BIND RESULT conn=2 op=0 msgID=1 resultCode=0
additionalInfo="trace='debug trace string'" etime=345.663
 clientConnectionPolicy="default"
```

Working with the SASL PLAIN Mechanism

SASL PLAIN is a password-based authentication mechanism which uses the following information:

- **Authentication ID**. Used to identify the target user to the server. It should be either "dn:" followed by the DN of the user or "u:" followed by a username. If the "u:"-style syntax is used, then an identify mapper will be used to map the specified username to a user entry. An authentication ID of "dn:" that is not actually followed by a DN may be used to request an anonymous bind.

- **Clear-text Password**. Specifies the password for the user targeted by the authentication ID. If the given authentication ID was "dn:", then this should be an empty string.
- **Optional Authorization ID**. Used to request that operations processed by the client be evaluated as if they had been requested by the user specified by the authorization ID rather than the authentication ID. It can allow one user to issue requests as if he/she had authenticated as another user. The use of an alternate authorization identity will only be allowed for clients with the `proxied-auth` privilege and the proxy access control permission.

Because the bind request includes the clear-text password, SASL PLAIN bind requests are as insecure as simple authentication. To avoid an observer from capturing passwords sent over the network, it is recommended that SASL PLAIN binds be issued over secure connections.

By default, the SASL PLAIN mechanism uses an Exact Match Identity Mapper that expects the provided username to exactly match the value of a specified attribute in exactly one entry (for example, the provided user name must match the value of the `uid` attribute). However, an alternate identity mapper may be configured for this purpose which can identify the user in other ways (for example, transforming the provided user name with a regular expression before attempt to find a user entry with that transformed value).

LDAP clients provided with the server can use SASL PLAIN with the following SASL options:

- **authID**. Specifies the authentication ID to use for the bind. This must be provided.
- **authzID**. Specifies an optional alternate authorization ID to use for the bind.

To Configure SASL PLAIN

1. Use `dsconfig` to enable the SASL PLAIN mechanism.

```
$ bin/dsconfig set-sasl-mechanism-handler-prop \
  --handler-name PLAIN --set enabled:true
```

2. Use `ldapsearch` to view the root DSE using the authentication ID (`authid`) with the username jdoe. The `authid` option is required. Enter a password for the authentication ID.

```
$ bin/ldapsearch --port 1389 --saslOption mech=PLAIN \
  --saslOption "authid=u:jdoe" --baseDN "" \
  --searchScope base "(objectclass=*)"
Password for user 'u:jdoe':
```

Note: You can also specify the fully DN of the user when using the SASL PLAIN option:

```
$ bin/ldapsearch --port 1389 --saslOption mech=PLAIN \
  --saslOption "authid=dn:uid=jdoe,ou=People,dc=example,dc=com" \
  --baseDN "" --searchScope base "(objectclass=*)"
Password for user 'dn:uid=jdoe,ou=People,dc=example,dc=com':
```

```
dn:
objectClass: ds-root-dse
objectClass: top
startupUUID: 59bab79d-4429-49c8-8a88-c74a86792f26
```

Working with the SASL CRAM-MD5 Mechanism

CRAM-MD5 is a password-based SASL mechanism that prevents exposure of the clear-text password by authenticating through the use of an MD5 digest generated from a number of elements, including the clear-text password, the provided authentication ID, and a challenge comprised of randomly-generated data. This ensures that the clear-text password itself is not transmitted, and the inclusion of server-generated random data protects against replay attacks.

During the CRAM-MD5 session, the client sends a bind request of type SASL CRAM-MD5. The Data Store sends a response with a SASL "Bind in Progress" result code plus credential information that includes a randomly generated challenge string to the LDAP client. The client combines that challenge with other information, including the authentication ID and clear-text password and uses that to generate an MD5 digest to be included in the SASL credentials, along with a clear-text version of the authentication ID. When the Data Store receives the second request, it will receive the clear-text password from the target user’s entry and generate the same digest. If the digest that the server generates matches what the client provided, then the client will have successfully demonstrated that it knows the correct pass- word.

Note that although CRAM-MD5 does offer some level of protection for the password, so that it is not transferred in the clear, the MD5 digest that it uses is not as secure as the encryption used by SSL or StartTLS. As such, authentication mechanisms that use a clear-text password are more secure communication channel. However, the security that CRAM-MD5 offers may be sufficient for cases in which the performance overhead that SSL/StartTLS can incur. It is available for use in the UnboundID Data Store because some clients may require it.

Also note that to successfully perform CRAM-MD5 authentication, the Data Store must be able to obtain the clear-text password for the target user. By default, the Data Store encodes passwords using a cryptographically secure one-way digest that does not allow it to determine the clear-text representation of the password. As such, if CRAM-MD5 is used, then the password storage schemes for any users that authenticate in this manner should be updated, so that they will use a password storage scheme that supports reversible encryption. It will be necessary for any existing users to change their passwords so that those passwords will be stored in reversible form. The reversible storage schemes supported by the Data Store include:

- 3DES
- AES
- BASE64
- BLOWFISH
- CLEAR
- RC4

CRAM-MD5 uses an authentication ID to identify the user as whom to authenticate. The format of that authentication ID may be either "dn:" followed by the DN of the target user (or just "dn:" to perform an anonymouse bind), or "u:" followed by a username. If the "u:"-style syntax is chosen, then an identity mapper will be used to identify the target user based on that username. The `dsconfig` tool may be used to configure the identify mapper to use CRAM-MD5 authentication.

The LDAP client tools provided with the Data Store support the use of CRAM-MD5 authentication. The `authID` SASL option should be used to specify the authentication ID for the target user.

To Configure SASL CRAM-MD5

1. Use `dsconfig` to enable the SASL CRAM-MD5 mechanism if it is disabled. By default, the CRAM-MD5 mechanism is enabled.

   ```
   $ bin/dsconfig set-sasl-mechanism-handler-prop \
     --handler-name CRAM-MD5 --set enabled:true
   ```

2. For this example, create a password policy for CRAM-MD5 using a reversible password storage scheme, like 3DES.

   ```
   $ bin/dsconfig create-password-policy \
     --policy-name "Test UserPassword Policy" \
     --set password-attribute:userpassword \
     --set default-password-storage-scheme:3DES
   ```

3. Use `ldapmodify` to add the `ds-pwp-password-policy-dn` attribute to an entry to indicate the Test UserPassword Policy should be used for that entry. After you have typed the change, press **CTRL-D** to process the modify operation. This step assumes that you have already configured the Test Password Policy.

   ```
   $ bin/ldapmodify
   dn: uid=jdoe,ou=People,dc=example,dc=com
   changetype: modify
   add: ds-pwp-password-policy-dn
   ds-pwp-password-policy-dn: cn=Test UserPassword Policy,cn=Password Policies,cn=config
   ```

   ```
   Processing MODIFY request for uid=jdoe,ou=People,dc=example,dc=com
   MODIFY operation successful for DN uid=jdoe,ou=People,dc=example,dc=com
   ```

4. Use `ldapmodify` to change the `userPassword` to a reversible password storage scheme. The password storage scheme is specified in the user's password policy.

   ```
   $ bin/ldapmodify
   dn: uid=jdoe,ou=People,dc=example,dc=com
   changetype: modify
   replace: userPassword
   userPassword: secret
   ```

   An alternate method to change the `userPassword` attribute password storage scheme is to deprecate the old scheme and then bind as the user using simple authentication or SASL PLAIN. This action will cause any existing password encoding using a deprecated scheme to be re-encoded with the existing scheme.

5. Use `ldapsearch` to view the root DSE using the authentication ID (`authid`) option with the username jdoe. The `authid` option is required. Enter a password for the user.

   ```
   $ bin/ldapsearch --port 1389 --saslOption mech=CRAM-MD5 \
     --saslOption "authid=u:jdoe" --baseDN "" --searchScope base "(objectclass=*)"
   Password for user 'u:jdoe':
   ```

   ```
   dn:
   objectClass: ds-root-dse
   objectClass: top
   startupUUID: 50567aa3-acd2-4106-a077-37a092275363
   ```

Working with the SASL DIGEST-MD5 Mechanism

The Data Store supports the SASL DIGEST-MD5 mechanism, which is a stronger mechanism than SASL CRAM-MD5. Like the SASL CRAM-MD5 mechanism, the client authenticates to the Data Store using a stronger digest of the authentication ID plus other information without exposing its clear-text password over the network.

During the DIGEST-MD5 session, the client sends a bind request of type SASL DIGEST-MD5. The Data Store sends a response with a "Bind in Progress" message plus credential information that includes a random challenge string to the LDAP client. The client responds by sending a bind response that includes a digest of the server’s random string, a separately generated client string, the authentication ID, the authorization ID if supplied, the user’s clear-text password and some other information. The client then sends its second bind request. The Data Store also calculates the digest of the client's credential. The Data Store validates the digest and retrieves the client’s password. Upon completion, the server sends a success message to the client.

As with SASL CRAM-MD5, the client and the server must know the clear-text password for the user. By default, the Data Store encodes passwords using a one-way storage scheme (Salted SHA-1) that stores an encoded representation of the password and does not allow it to determine the clear-text representation of the password. Any users requiring SASL DIGEST-MD5 authentication must use a password policy that supports two-way, reversible encryption, in which the password is encoded, stored, and later decoded when requested. The following password storage schemes are reversible:

- 3DES
- AES
- BASE64
- BLOWFISH
- CLEAR
- RC4

By default, SASL DIGEST-MD5 uses the Exact Match Identity Mapper, which returns a success result if the authorization ID is an exact match for the value of the `uid` attribute. Administrators can configure the SASL DIGEST-MD5 mechanism to use other identity mappers, such as the Regular Expression Identity Mapper or a custom Identity Mapper written using the UnboundID Server SDK.

In many ways, the DIGEST-MD5 SASL mechanism is very similar to the CRAM-MD5 mechanism. It avoids exposing the clear-text password through the use of an MD5 digest generated from the password and other information. It also supports the use of an alternate authorization ID to indicate that operations be processed under the authority of another user. Like CRAM-MD5, DIGEST-MD5 provides better security than mechanisms like SASL-PLAIN that send the clear-text password over an *unencrypted* channel.

DIGEST-MD5 is considered a stronger mechanism than CRAM-MD5, because it includes additional information in the digest that makes it harder to decipher, such as randomly-generated data from the client in addition to the server-provided challenge as well as other elements like a realm and digest URI. DIGEST-MD5 is also considered weaker than sending a clear-text password over an *encrypted* connection, because it requires the server to store passwords in reversible form, which can be a security risk. We recommend that CRAM-MD5 and DIGEST-MD5 be avoided unless required by clients.

The LDAP client tools provided with the Data Store provide the ability to use DIGEST-MD5 authentication using the following properties:

- **authID**. Specifies the authentication ID for the target user, in either the "dn:" or "u:" forms. This property is required.
- **authzID**. Specifies an optional authorization ID that should be used for operations processed on the connection.
- **realm**. The realm in which the authentication should be processed. This may or may not be required, based on the server configuration.
- **digest-uri**. The digest URI that should be used for the bind. It should generally be "ldap://" followed by the fully-qualified address for the Data Store. If this is not provided, then a value will be generated.
- **qop**. The quality of protection to use for the bind request. At present, only `auth` is supported (indicating that the DIGEST-MD5 bind should only be used for authentication and should not provide any subsequent integrity or confidentiality protection for the connection), and if no value is provided then `auth` will be assumed.

To Configure SASL DIGEST-MD5

1. Use `dsconfig` to enable the SASL DIGEST-MD5 mechanism if it is disabled. By default, the DIGEST-MD5 mechanism is enabled.

```
$ bin/dsconfig set-sasl-mechanism-handler-prop \
  --handler-name DIGEST-MD5 --set enabled:true
```

2. Set up a reversible password storage scheme as outlined *Working with the SASL CRAM-MD5 Mechanism*, steps 2–4, which is also required for DIGEST-MD5.

3. Use `ldapsearch` to view the root DSE using the authentication ID with the username `jdoe`. The `authid` option is required. Enter a password for the authentication ID.

```
$ bin/ldapsearch --port 1389 --saslOption mech=DIGEST-MD5 \
  --saslOption "authid=u:jdoe" --baseDN "" \
  --searchScope base "(objectclass=*)"
Password for user 'u:jdoe':
```

```
dn:
objectClass: ds-root-dse
objectClass: top
startupUUID: 2188e4d4-c2bb-4ab9-8e1c-848e0168c9de
```

4. The user identified by the authentication ID requires the `proxied-auth` privilege to allow it to perform operations as another user.

```
$ bin/ldapmodify

dn: uid=jdoe,ou=People,dc=example,dc=com
changetype: modify
add: ds-privilege-name
ds-privilege-name: proxied-auth
```

5. Use `ldapsearch` with the `authid` (required) and `authzid` option to test SASL DIGEST-MD5.

```
$ bin/ldapsearch --port 1389 --saslOption mech=DIGEST-MD5 \
  --saslOption authid=u:jdoe \
  --saslOption authzid=dn:uid=admin,dc=example,dc=com \
  --base "" --searchScope base "(objectclass=*)"
Password for user 'u:jdoe':
```

```
dn:
objectClass: ds-root-dse
objectClass: top
startupUUID: 2188e4d4-c2bb-4ab9-8e1c-848e0168c9de
```

Working with the SASL EXTERNAL Mechanism

The SASL EXTERNAL mechanism allows a client to authenticate using information about the client, which is available to the server, but is not directly provided over LDAP. In the UnboundID Data Store, SASL EXTERNAL requires the use of a client certificate provided during SSL or StartTLS negotiation. This is a very secure authentication mechanism that does not require the use of passwords, although its use on a broad scale is generally only feasible in environments with a PKI deployment.

Prior to the SASL EXTERNAL session exchange, the client should have successfully established a secure communication channel using SSL or StartTLS, and the client must have presented its own certificate to the server in the process. The SASL EXTERNAL bind request itself does not contain any credentials, and the server will use only the information contained in the provided client certificate to identify the target user.

The Data Store’s configuration settings for SASL EXTERNAL includes three important properties necessary for its successful operation:

- **certificate-validation-policy**. Indicates whether to check to see if the certificate presented by the client is present in the target user’s entry. Possible values are:
  - **always -** `Always` require the peer certificate to be present in the user’s entry. Authentication will fail if the user’s entry does not contain any certificates, or if it contains one or more certificates and the certificate presented by the client is not included in the user’s entry.
  - **ifpresent -** (Default) If the user’s entry contains one or more certificates, require that one of them match the peer certificate. Authentication will be allowed to succeed if the user’s entry does not have any certificates, but it will fail if the user’s entry has one or more certificates and the certificate provided by the client is not included in the user’s entry.
  - **never -** Do not look for the peer certificate to be present in the user’s entry. Authentication may succeed if the user’s entry does not contain any client certificates, or if the user’s entry contains one or more certificates regardless of whether the provided certificate is included in that set.
- **certificate-attribute**. Specifies the name of the attribute that holds user certificates to be examined if the `ds-cfg-certificate-validation-policy` attribute has a value of `ifpresent` or `always`. This property must specify the name of a valid attribute type defined in the server schema. Default value is `userCertificate`. Note that LDAP generally requires certificate values to use the "`;binary`" attribute modifier, so certificates should actually

be stored in user entries using the attribute "`userCertificate;binary`" rather than just "`userCertificate`".

- **certificate-mapper**. Specifies the certificate mapper that will be used to identify the target user based on the certificate presented by the client. For more information on certificate mappers, see *Configuring Certificate Mappers*. The LDAP client tools provided with the Data Store support the use of SASL EXTERNAL authentication. This mechanism does not require any specific SASL options to be provided (other than `mech=EXTERNAL` to indicate that SASL EXTERNAL should be used). However, additional arguments are required to use SSL or StartTLS, and to provide a keystore so that a client certificate will be available.

To Configure SASL EXTERNAL

1. Change to the server root directory.

```
$ cd /ds/UnboundID-DS
```

2. Determine the `certificate-validation-policy` property. If you do not need to store the DER-encoded representation of the client’s certificate in the user’s entry, skip to the next step.

If you select `Always`, you must ensure that the user’s entry has the attribute present with a value. If you select `ifpresent`, you can optionally have the `userCertificate` attribute present. You can store the client’s certificate in the user entry using `ldapmodify`.

```
$ bin/ldapmodify
dn: uid=jdoe,ou=People,dc=example,dc=com
changetype: modify
add: userCertificate;binary
userCertificate;binary:<file:///path/to/client.der
```

3. If you have an attribute other than `userCertificate`, than specify it using the `certificate-attribute` property. You may need to update your schema to support the attribute.

4. Determine the `certificate-mapper` property. For more information on certificate mappers, see *Configuring Certificate Mappers*.

5. Use `dsconfig` to enable the SASL EXTERNAL mechanism if it is disabled. By default, the SASL mechanism is enabled. For this example, set the `certificate-mapper` property to "Subject Attribute to User Attribute". All other defaults are kept.

```
$ bin/dsconfig set-sasl-mechanism-handler-prop \
  --handler-name EXTERNAL --set enabled:true \
  --set "certificate-mapper:Subject Attribute to User Attribute"
```

6. Use `ldapsearch` to test SASL EXTERNAL.

```
$ bin/ldapsearch --port 1636 --useSSL \
  --keyStorePath /path/to/clientkeystore \
  --keyStorePasswordFile /path/to/clientkeystore.pin \
  --trustStorePath /path/to/truststore \
  --saslOption mech=EXTERNAL --baseDN "" \
  --searchScope base "(objectClass=*)
```

Working with the GSSAPI Mechanism

The SASL GSSAPI mechanism provides the ability to authenticate LDAP clients using Kerberos V, which is a single sign-on mechanism commonly used in enterprise environments. In these environments, user credentials are stored in the Kerberos key distribution center (KDC) rather than the Data Store. When an LDAP client attempts to authenticate to the Data Store using GSSAPI, a three-way exchange occurs that allows the client to verify its identity to the server through the KDC.

The Data Store's support for GSSAPI is based on the Java Authentication and Authorization Service (JAAS). By default, the server will automatically generate a JAAS configuration that should be appropriate for the most common use cases. For more complex deployments, it is possible for an administrator to supply a custom JAAS configuration that is most appropriate for that environment.

While the GSSAPI specification includes a provision for protecting client-server communication through integrity (in which the communication is not encrypted, but is signed so that it is possible to guarantee that it was not be altered in transit) or confidentiality (in which the communication is encrypted so that it cannot be examined by third-party observers), the Data Store currently supports GSSAPI only for the purpose of authenticating clients but not for securing their communication with the server.

Preparing the Kerberos Environment for GSSAPI Authentication

To implement GSSAPI authentication in the Data Store, it is assumed that you already have a working Kerberos V deployment in which the Data Store and LDAP clients will participate. The process for creating such a deployment is beyond the scope of this documentation, and you should consult the documentation for your operating system to better understand how to construct a Kerberos deployment. However, there are a few things to keep in mind:

- It is recommended that the KDC be configured to use "aes128-cts" as the TKT and TGS encryption type, as this encryption type should be supported by all Java VMs. Some other encryption types may not be available by default in some Java runtime environments. In Kerberos environments using the MIT libraries, this can be achieved by ensuring that the following lines are present in the [libdefaults] section of the `/etc/krb.conf` configuration file on the KDC system:

  ```
  default_tkt_enctypes = aes128-cts
  default_tgs_enctypes = aes128-cts
  permitted_enctypes = aes128-cts
  ```

- When a client uses Kerberos to authenticate to a server, the addresses of the target server and the KDC are used in cryptographic operations. It is important to ensure that all systems agree on the addresses of the Data Store and KDC systems. It is therefore strongly recommended that DNS be configured so that the primary addresses for the KDC and Data Store systems are the addresses that clients will use to communicate with them.

- Kerberos authentication is time-sensitive and if system clocks are not synchronized, then authentication may fail. It is therefore strongly recommended that NTP or some other form of time synchronization be used for all KDC, Data Store, and client systems.

To authenticate itself to the Kerberos environment, the KDC should include both host and service principals for all Data Storesystems. The host principal is in the form "host/ " followed by the fully-qualified address of the server system, and the service principal should generally be "ldap/" followed by the fully-qualified address (for example, "`host/directory.example.com`" and "`ldap/directory.example.com`", respectively). In a MIT Kerberos environment, the `kadmin` utility may be used to create these principals, as follows:

```
# /usr/sbin/kadmin -p kws/admin
Authenticating as principal kws/admin with password.
Password for kws/admin@EXAMPLE.COM:
kadmin: add_principal -randkey host/directory.example.com
WARNING: no policy specified for host/directory.example.com@EXAMPLE.COM;
  defaulting to no policy
Principal "host/directory.example.com@EXAMPLE.COM" created.
kadmin: ktadd host/directory.example.com
Entry for principal host/directory.example.com with kvno 3, encryption type AES-128
  CTS mode with 96-bit SHA-1 HMAC added to keytab WRFILE:/etc/krb5/krb5.keytab.
kadmin: add_principal -randkey ldap/directory.example.com
WARNING: no policy specified for ldap/directory.example.com@EXAMPLE.COM;
  defaulting to no policy
Principal "ldap/directory.example.com@EXAMPLE.COM" created.
kadmin: quit
```

On each Data Store system, the service principal for that instance must be exported to a keytab file, which may be accomplished using a command as follows:

```
# /usr/sbin/kadmin -p kws/admin
Authenticating as principal kws/admin with password.
Password for kws/admin@EXAMPLE.COM:
kadmin: ktadd -k /ds/UnboundID-DS/config/server.keytab ldap/directory.example.com
Entry for principal ldap/directory.example.com with kvno 4, encryption type AES-128
  CTS mode with 96-bit SHA-1 HMAC added to keytab WRFILE:/ds/UnboundID-DS/config/
  server.keytab.
kadmin: quit
```

Because this file contains the credentials that the Data Store will use to authenticate to the KDC, it is strongly recommended that appropriate protection be taken to ensure that it is only accessible to the Data Store itself (for example, by configuring file permissions and/or file system access controls).

Configuring the GSSAPI SASL Mechanism Handler

The GSSAPI SASL mechanism handler provides the following configuration options:

- **enabled**. Indicates whether the GSSAPI SASL mechanism handler is enabled for use in the server. By default, it is disabled.
- **kdc-address**. Specifies the address that the Data Store should use to communicate with the KDC. If this is not specified, then the server will attempt to determine it from the underlying system configuration.
- **server-fqdn**. Specifies the fully-qualified domain name that clients will use to communicate with the Data Store. If this is not specified, the server will attempt to determine it from the underlying system configuration.
- **realm**. Specifies the Kerberos realm that clients will use. If this is not specified, the server will attempt to determine it from the underlying system configuration.

- **kerberos-service-principal**. Specifies the service principal that the Data Store will use to authenticate itself to the KDC. If this is not specified, the service principal will be "ldap/" followed by the fully-qualified server address (for example, `ldap/directory.example.com`).
- **keytab**. Specifies the path to the keytab file that holds the credentials for the Kerberos service principal that the Data Store will use to authenticate itself to the KDC. If this is not specified, the server will use the system-wide keytab.
- **identify-mapper**. Specifies the identify mapper that the Data Store will use to map a client's Kerberos principal to the entry of the corresponding user account in the server. In the default configuration, the server will use a regular expression identity mapper that will look for an entry with a `uid` value equal to the username portion of the Kerberos principal For example, for a Kerberos principal of jdoe@EXAMPLE.COM, the identity mapper will perform an internal search with a filter of `(uid=jdoe)`.
- **enable-debug**. Indicates whether the Data Store should write debugging information about Kerberos-related processing (including JAAS processing) that the server performs. If enabled, this information will be written to standard error, which will appear in the `logs/server.out` log file.
- **jaas-config file**. Specifies the path to a JAAS configuration file that the server should use. If this is not specified, the server will generate a JAAS configuration file based on the values of the other configuration properties. It is recommended that this only be used in extraordinary circumstances in which the server-generated JAAS configuration is not acceptable.

Testing GSSAPI Authentication

Once the GSSAPI SASL mechanism handler has been enabled and configured in the Data Store, then clients should be able to use GSSAPI to authenticate to the server using Kerberos. The `ldapsearch` tool provided with the Data Store may be used to test this, with a command like:

```
$ bin/ldapsearch --hostname directory.example.com --port 389 \
  --saslOption mech=GSSAPI --saslOption authID=jdoe@EXAMPLE.COM \
  --baseDN "" --searchScope base "(objectClass=*)"
```

If the client already has a valid Kerberos session authenticated with a principal of jdoe@EXAMPLE.COM, then this command should make use of that existing session and proceed without requiring any further credentials. If there is no existing Kerberos session, then the `ldapsearch` command will prompt for the Kerberos password for that user (or it may be supplied using either the `--bindPassword` or `--bindPasswordFile` arguments).

The `--saslOption` command-line argument may be used to specify a number of properties related to SASL authentication, with values to that option be given in "name=value" format. When using SASL authentication, the mech property must always be used to specify the SASL mechanism to use, and `--saslOption mech=GSSAPI` indicates that the GSSAPI mechanism will be used. When the GSSAPI mechanism has been selected, then the following additional SASL options are available for use:

- **authid**. Specifies the authentication ID, which is the Kerberos principal for the user authenticating to the server. This option must always be provided when using GSSAPI.

- **authzID**. Specifies the authorization ID that should be used. At present, the Data Store does not support the use of an alternate authorization identity, so this should either be omitted or identical to the value of the `authID` property.
- **kdc**. Specifies the address of the KDC that the client should use during the authentication processing. If this is not provided, the client will attempt to determine it from the system's Kerberos configuration.
- **realm**. Specifies the Kerberos realm that should be used. If this is not provided, the client will attempt to determine it from the system's Kerberos configuration.
- **protocol**. Specifies the protocol that the Data Store uses for its service principal (i.e., the portion of the service principal that appears before the slash and fully-qualified server address). If this is not provided, a default protocol of "ldap" will be used.
- **useTicketCache**. Indicates whether the client should attempt to make use of a Kerberos ticket cache to leverage an existing Kerberos session, which may allow the client to authenticate to the server without the need to supply any additional credentials. If this is not provided, or if it is provided with a value of TRUE, then a ticket cache will be used if available. The use of a ticket cache may be disabled by providing this option with a value of FALSE.
- **requireCache**. Indicates whether to require the use of a ticket cache in order to leverage an existing Kerberos session rather than allowing the use of user-supplied credentials for authentication. By default, this will be assumed to have a value of FALSE, but if it is provided with a value of TRUE, then authentication will only be successful if the user already has an existing Kerberos session. This will be ignored if the `useTicketCache` option has been provided with a value of FALSE.
- **ticketCache**. Specifies the path to the file to use as the Kerberos ticket cache. If this is not provided, the default ticket cache file path will be assumed. This will be ignored if the `useTicketCache` option has been provided with a value of FALSE.
- **renewTGT**. Indicates whether to attempt to renew the user's ticket-granting ticket when authenticating with an existing Kerberos session. If this is not provided, a default value of FALSE will be used.
- **debug**. Indicates whether to write debug information about the GSSAPI authenication processing to standard error. By default, no debug information will be written, but it may be enabled with a value of TRUE.
- **configFile**. Used to specify the path to a JAAS configuration file that the client should use when performing GSSAPI processing. If this is not specified, then a default JAAS configuration file will be generated based on other properties.

These options are available for use with all tools supplied with the Data Store which support SASL authentication.

Working with the UNBOUNDID-TOTP SASL Mechanism

The Data Store supports a proprietary multifactor authentication mechanism that allows the server to use the Time-based One-Time Password (TOTP) algorithm, specified in RFC 6238.

The TOTP algorithm is an extension of the Hash-based Message Authentication Code One-Time Password (HTOP) algorithm, specified in RFC 4226. The TOTP algorithm computes a temporary code using the current time and a secret key that is shared between the client app (e.g., Google Authenticator) and the server. When combined with a static password, a TOTP code can provide a means of multifactor authentication that offers dramatically better security than can be achieved using a static password by itself.

This proprietary security mechanism, UNBOUNDID-TOTP SASL, issues a bind request that includes at least an authentication ID and a TOTP code, but may also include an authorization ID and/or a static password. When the Data Store receives such a bind request, it first uses the authentication ID to identify the user that is authenticating and then retrieves the shared secret from the user's entry (stored as a base32-encoded value in the `ds-auth-totp-shared-secret` operational attribute) and uses that in conjunction with the current time to generate a TOTP code. If that matches the code that the user entered, then that confirms that the client knows the shared secret. If a static password was also provided, then the server will confirm that it matches what is stored in the `userPassword` attribute (or whatever password attribute is specified in the user's password policy). By default, the server will require the client to provide a static password, since without it, the client will only be performing single-factor authentication.

The Commercial Edition of the LDAP SDK for Java provides the necessary client-side support for the UNBOUNDID-TOTP SASL mechanism and provides a `com.unboundid.ldap.sdk.unboundidds.OneTimePassword` class to generate HOTP and TOTP codes for testing purposes.

Notes about the UnboundID-TOTP SASL Mechanism

The UnboundID-TOTP SASL mechanism supports some new features of interest that add extra security to your system:

- **Limiting the Reuse of the One-Time Password**. Although TOTP passwords are only valid for a limited period of time, it is possible that an individual observing an unencrypted TOTP authentication could replay the bind request in order to reuse the TOTP code as long as the server considers it valid. To avoid this, the `prevent-totp-reuse` property may be used to cause the server to store information in the user's entry about TOTP codes that have been used to successfully authenticate and may still be valid. Subsequent TOTP authentication attempts will then ensure that the provided TOTP code does not match a previously-used value.

- **Implementing the Validate TOTP Extended Operation**. The Data Store supports a Validate TOTP Extended Operation, which validates the TOTP password without performing any authentication on the user. This feature is enabled by default. This is not needed for UNBOUNDID-TOTP SASL support and nor does it alter the authentication state of a connection in any way, but it may be useful for third-party applications to use TOTP as a type of "step-up" authentication mechanism or to add extra assurance about the identity of an already authenticated user.

- **Using Sensitive Attributes with the TOTP Shared Secret**. You can use a sensitive attribute definition to prevent clients from retrieving TOTP shared secrets from the server and to ensure that all shared secret changes occur over secure connections. Note that this sensitive attribute definition must be referenced from the `sensitive-attribute` property of a client connection policy or the global `sensitive-attribute` property to be enabled.

To Configure UNBOUNDID-TOTP SASL

1. Configure the server so that `ds-auth-totp-shared-secret` is a sensitive attribute that can only be set over a secure connection and cannot ever be retrieved from the server. Create the sensitive attribute and reference it from the global configuration using `dsconfig`.

   ```
   $ bin/dsconfig create-sensitive-attribute \
     --attribute-name ds-auth-totp-shared-secret \
     --set attribute-type:ds-auth-totp-shared-secret \
     --set allow-in-returned-entries:suppress \
     --set allow-in-filter:reject \
     --set allow-in-compare:reject \
     --set allow-in-add:secure-only \
     --set allow-in-modify:secure-only

   $ bin/dsconfig set-global-configuration-prop \
     --add sensitive-attribute:ds-auth-totp-shared-secret
   ```

2. Update a user entry so that it contains a `ds-auth-totp-shared-secret` attribute with a value that holds the base32-encoded shared secret that will be used for TOTP authentication. If you put the sensitive attribute in place, then you will need to do this over a secure connection, such as over SSL or StartTLS. There is no maximum limit to the length of the `ds-auth-totp-shared-secret` string, but there is a minimum length of 16 base32-encoded characters. Note that Google Authenticator requires a base32 string whose length is a multiple of 8, and it cannot include the padding character ("=").

   ```
   dn: uid=user.0,ou=People,dc=example,dc=com
   changetype: modify
   add: ds-auth-totp-shared-secret
   ds-auth-totp-shared-secret: ONSWG4TFORRW6ZDF
   ```

3. To test this feature, install a TOTP client. For this example, you can use the Google Authenticator app on your Android, iOS, and Blackberry mobile device. On the Google Authenticator app, choose the **Add Account** option to manually add an account. Enter a name and the same base32-encoded key that you assigned to the user in the previous step. The default account type is "Time Based"; do not choose "Counter Based". You should see an item with the name you selected and a six-digit code that will change every 30 seconds.

   Note: The Google Authenticator app only needs to know the current time and the shared secret in order to compute the TOTP code. It does not require a Google account, nor does it require a data connection or the ability to perform network communication.

4. The Data Store's tools provide support for the UNBOUNDID-TOTP SASL mechanism. You can run an LDAP search using the UNBOUNDID-TOTP SASL mechanism in the same way as any other SASL component.

   ```
   $ bin/ldapsearch  --saslOption mech=UNBOUNDID-TOTP \
     --saslOption authID=u:user.0 \
     --saslOption totpPassword=628094 \
     --bindPassword password \
     --baseDN "" \
     --searchScope base \
     "(objectClass=*)"
   ```

Working with the UNBOUNDID-DELIVERED-OTP SASL

The Data Store now includes support for a new form of two-factor authentication, *UNBOUNDID-DELIVERED-OTP SASL*, which uses one-time passwords (OTPs) that are delivered to the end user through some out-of-band mechanism. Out of the box, the server provides support for e-mail (through the same SMTP external server approach used for email) and SMS (through the Twilio web service). The Server SDK also provides support for creating custom delivery mechanisms.

The process for authenticating using this new mechanism involves two steps:

- The client must first send a "deliver one-time password" extended request to the server. This request includes an authentication ID (either "dn:" followed by the DN or "u:" followed by the username), the user's static password, and an optional set of allowed delivery mechanisms. If successful, this will cause the server to generate a one-time password, store it in the user's entry, and send it to the user through some mechanism.
- Once the user has received the one-time password, the client should perform an UNBOUNDID-DELIVERED-OTP SASL bind (which may be on the same connection or a different connection as was used to process the "deliver one-time password" extended operation). The credentials for this SASL mechanism include an authentication ID to identify the user, an optional authorization ID (if operations performed by the client should be authorized as a different user), and the one-time password that was delivered to them.

The static password is not included in the SASL bind request, but because the user must provide the static password in order to obtain the one-time password, it still qualifies as a form of multifactor authentication. Unlike UNBOUNDID-TOTP SASL, there is no need to have a shared secret between the client and the server, or any special client-side software to generate the one-time password, or a need to worry about whether the client and server clocks are roughly in sync.

To Configure the UNBOUNDID-DELIVERED OTP SASL

1. Add support for one or more OTP delivery mechanisms. For email, you first need to create an SMTP external server and associate it with the global configuration before you can create the delivery mechanism.

```
$ bin/dsconfig create-external-server \
  --server-name "Intranet SMTP Server" \
  --type smtp \
  --set server-host-name:server.example.com

$ bin/dsconfig set-global-configuration-prop \
  --add "smtp-server:Intranet SMTP Server"

$ bin/dsconfig create-otp-delivery-mechanism \
  --mechanism-name E-Mail \
  --type email \
  --set enabled:true \
  --set 'sender-address:otp@example.com' \
  --set "email-address-attribute-type:mail" \
  --set "message-subject:Your one-time password" \
  --set "message-text-before-otp:Your one-time password: "
```

2. If you have a Twilio account, you can use it to configure the server to deliver one-time passwords over SMS.

```
dsconfig create-otp-delivery-mechanism \
--mechanism-name SMS \
--type twilio \
--set enabled:true
--set twilio-account-sid:xxxxx \
--set twilio-auth-token:xxxxx \
--set "sender-phone-number:xxxxx" \
--set phone-number-attribute-type:mobile \
--set "message-text-before-otp:Your one-time password: "
```

3. Once you have your OTP delivery mechanisms, you can configure the extended operation handler.

```
$ bin/dsconfig create-extended-operation-handler \
  --handler-name "Deliver One-Time Password" \
  --type deliver-otp \
  --set enabled:true \
  --set "identity-mapper:Exact Match" \
  --set "password-generator:One-Time Password Generator" \
  --set default-otp-delivery-mechanism:SMS \
  --set default-otp-delivery-mechanism:E-Mail
```

4. Next, configure the SASL mechanism handler.

```
$ bin/dsconfig create-sasl-mechanism-handler \
  --handler-name UNBOUNDID-DELIVERED-OTP \
  --type unboundid-delivered-otp \
  --set enabled:true \
  --set "identity-mapper:Exact Match" \
  --set "otp-validity-duration:5 minutes"
```

5. Make sure the server contains a user account with the account needed to deliver the one-time password to the user (i.e., a valid email address or mobile number).

6. Next, use the deliver one-time password extended operation to have the server generate and send a one-time password to the user. The Commercial Edition of UnboundID LDAP SDK contains support for the extended request and response needed to do this. In actual production deployments, you can create a web form to allow the user to enter the information and click a button. The server comes with a new deliver-one-time-password command-line tool that can achieve the same result.

```
$ bin/deliver-one-time-password \
  --userName jdoe \
  --promptForBindPassword \
  --deliveryMechanism SMS
Enter the static password for the user:

Successfully delivered a one-time password via mechanism 'SMS' to '123-456-7890'
```

   If processed successfully, you will receive a text as follows:

```
Your one-time password: 123456
```

7. Finally, authenticate to the server using the UNBOUNDID-DELIVERED-OTP SASL mechanism. The Commercial Edition of the LDAP SDK can help you accomplish this so that the user sees an interface. Or, you can use `ldapsearch` or some other tool to accomplish the same result.

```
$ bin/ldapsearch \
  -o mech=UNBOUNDID-DELIVERED-OTP \
  -o authID=u:jdoe \
  -o otp=123456 \
  -b '' \
  -s base '(objectClass=*)' \
  ds-supported-otp-delivery-mechanism
```

The search returns:

```
dn:
ds-supported-otp-delivery-mechanism: E-Mail
ds-supported-otp-delivery-mechanism: SMS
```

Configuring Pass-Through Authentication

Pass-through authentication (PTA) is a mechanism by which one Data Store receives the bind request and can consult another Data Store to authenticate the bind request. Administrators can implement this functionality by configuring a PTA plug-in that enables the Data Store to accept simple password-based bind operations.

To Configure Pass-Through Authentication

1. First, use `dsconfig` to define the external servers for the instances that will be used to perform the authentication. The bind DN is set to `uid=pass-through-user,dc=example,dc=com`, which is used to bind to the target LDAP server for simple authentication. The `verify-credentials-method` property ensures that a single set of connections for processing binds and all other types of operations is in place without changing the identity of the associated connection.

```
$ bin/dsconfig create-external-server \
--server-name "ds-with-pw-1.example.com:389" \
--type unboundid-ds \
--set server-host-name:ds-with-pw-1.example.com \
--set server-port:389 \
--set "bind-dn:uid=pass-through-user,dc=example,dc=com" \
--set authentication-method:simple \
--set verify-credentials-method:retain-identity-control
```

2. Repeat step 1 so that you have multiple external servers in case one of them becomes unavailable.

```
$ bin/dsconfig create-external-server \
  --server-name "ds-with-pw-2.example.com:389" \
  --type unboundid-ds \
  --set server-host-name:ds-with-pw-2.example.com \
  --set server-port:389 \
  --set "bind-dn:uid=pass-through-user,dc=example,dc=com" \
  --set authentication-method:simple \
  --set verify-credentials-method:retain-identity-control
```

3. Create an instance of the pass-through authentication plug-in that will use the external server(s) as a source of authentication. Based on this configuration, the server will first try to process a local bind as the target user (`try-local-bind:true`). The `try-local-bind:true` together with the `override-local-password:true` means that if the local bind fails for any reason, then it will try sending the request to either `ds-with-pw-1.example.com:389` or `ds-with-pw-2.example.com:389` (`server-access-mode:round-robin`). If the bind succeeds against the remote server, then the local entry will be updated to store the password that was used (`update-local-password:true`). The number of connections to initially establish to

the LDAP external server is set to 10 (`initial-connections:10`). The maximum number of connections maintained to the LDAP external server is 10 (`max-connections:10`).

```
$ bin/dsconfig create-plugin \
  --plugin-name "Pass-Through Authentication" \
  --type pass-through-authentication \
  --set enabled:true \
  --set server:ds-with-pw-1.example.com:389 \
  --set server:ds-with-pw-2.example.com:389 \
  --set try-local-bind:true \
  --set override-local-password:true \
  --set update-local-password:true \
  --set server-access-mode:round-robin \
  --set initial-connections:10 \
  --set max-connections:10
```

Note:

The `try-local-bind` property works in conjunction with the `override-local-password` property. If `try-local-bind` is `true` and `override-local-password` is set to its default value of `false`, then the server attempts a local bind first. If it fails *because no password is set*, then it will forward the bind request to a remote server. If the password was set but still fails, the server will not send the request to the remote server.

If `try-local-bind` is `true` and `override-local-password` is `true`, then a local bind will be attempted. The server will forward the request to the remote server if the local bind fails for any reason.

Adding Operational Attributes that Restrict Authentication

The Data Store provides a number of operational attributes that can be added to user entries in order to restrict the way those users can authenticate and the circumstances under which they can be used for proxied authorization. The operational attributes are as follows:

- **ds-auth-allowed-address**. Used to indicate that the user should only be allowed to authenticate from a specified set of client systems. Values should be specified as individual IP addresses, IP address patterns (using wildcards like "1.2.3.*", CIDR notation like "1.2.3.0/24", or subnet mask notation like "1.2.3.0/255.255.255.0"), individual DNS addresses, or DNS address patterns (using wildcards like "*.example.com"). If no allowed address values are present in a user entry, then no client address restrictions will be enforced for that user.

- **ds-auth-allowed-authentication-type**. Used to indicate that the user should only be allowed to authenticate in certain ways. Allowed values include "simple" (to indicate that the user should be allowed to bind using simple authentication) or "sasl {mech}" (to indicate that the user should be allowed to bind using the specified SASL mechanism, like "sasl PLAIN"). If no authentication type values are present in a user entry, then no authentication type restrictions will be enforced for that user.

- **ds-auth-require-secure-authentication**. Used to specify whether the user should be required to authenticate in a secure manner. If this attribute is present with a value of "true", then that user will only be allowed to authenticate over a secure connection or using a mechanism that does not expose user credentials (e.g., the CRAM-MD5, DIGEST-MD5, and GSSAPI SASL mechanisms). If this attribute is present with a value of "false", or it is not present in the user's entry, then the user will not be required to authenticate in a secure manner.

- **ds-auth-require-secure-connection**. Used to specify whether the user should be required to communicate with the server over a secure connection. If this attribute is present in a user entry with a value of "true", then that user will only be allowed to communicate with the server over a secure connection (using SSL or StartTLS). If this attribute is present with a value of "false", or if it is not present in the user's entry, then the user will not be required to use a secure connection.
- **ds-auth-is-proxyable**. Used to indicate whether the user can be used as the target of proxied authorization (using the proxied authorization v1 or v2 control, the intermediate client control, or a SASL mechanism that allows specifying an alternate authorization identity). If this attribute is present in a user entry with a value of "required", then that user will not be allowed to authenticate directly to the server but instead will only be allowed to be referenced by proxied authorization. If this attribute is present with a value of "prohibited", then that user will not be allowed to be the target of proxied authorization but may only authenticate directly to the server. If this attribute is present with a value of "allowed", or if it is not present in the user's entry, then the user may authenticate directly against the server or be the target of proxied authorization.
- **ds-auth-is-proxyable-by**. Used to restrict the set of accounts that may target the user for proxied authorization. If this attribute is present in a user's entry, then its values must be the DNs of the users that can target the user for proxied authorization (as long as those users have sufficient rights to use proxied authorization). If it is absent from the user's entry, then any account with appropriate rights may target the user via proxied authorization.

Configuring Certificate Mappers

SASL EXTERNAL requires that a certificate mapper be configured in the server. The certificate mapper is used to identify the entry for the user to whom the certificate belongs. The Data Store supports a number of certificate mapping options including:

- **Subject Equals DN**. The Subject Equals DN mapper expects the subject of the certificate to exactly match the DN of the associated user entry. This option is not often practical as certificate subjects (e.g., `cn=jdoe,ou=Client Cert,o=Example Company,c=Austin,st=Texas,c=US`) are not typically in the same form as an entry (e.g., `cn=jdoe,ou=People,o=Example Company`, or `uid=jdoe,ou=People,dc=example,dc=com`).
- **Fingerprint**. The Fingerprint mapper expects the user's entry to contain an attribute (`ds-certficate-fingerprint` by default, although this is configurable), whose values are the SHA-1 or MD5 fingerprints of the certificate(s) that they can use to authenticate. This attribute must be indexed for equality.
- **Subject Attribute to User Attribute**. The Subject Attribute to User Attribute mapper can be used to build a search filter to find the appropriate user entry based on information contained in the certificate subject. For example the default configuration expects the `cn` value from

the certificate subject to match the `cn` value of the user's entry, and the `e` value from the certificate subject to match the `mail` value of the user's entry.

- **Subject DN to User Attribute**. The Subject DN to User Attribute mapper expects the user's entry to contain an attribute (`ds-certificate-subject-dn` by default, although this is configurable), whose values are the subjects of the certificate(s) that they can use to authenticate. This multi-valued attribute can contain the subjects of multiple certificates. The attribute must be indexed for equality.

Configuring the Subject Equals DN Certificate Mapper

The Subject Equals DN Certificate Mapper is the default mapping option for the SASL EXTERNAL mechanism. The mapper requires that the subject of the client certificate exactly match the distinguished name (DN) of the corresponding user entry. The mapper, however, is only practical if the certificate subject has the same format as your Data Store's entries.

To Configure the Subject Equals DN Certificate Mapper

- Change the certificate mapper for the SASL EXTERNAL mechanism.

```
$ bin/dsconfig --no-prompt set-sasl-mechanism-handler-prop \
  --handler-name EXTERNAL \
  --set "certificate-mapper:Subject Equals DN"
```

Configuring the Fingerprint Certificate Mapper

The Fingerprint Mapper causes the server to compute an MD5 or SHA-1 fingerprint of the certificate presented by the client and performs a search to find that fingerprint value in a user's entry (`ds-certificate-fingerprint` by default). The `ds-certificate-fingerprint` attribute can be added to the user's entry together with the `ds-certificate-user` auxiliary object class. For multiple certificates, the attribute can have separate values for each of the acceptable certificates. If you decide to use this attribute, you must index the attribute as it is not indexed by default.

The following example will use this certificate:

```
Alias name: client-cert
Creation date: Oct 29, 2011
Entry type: PrivateKeyEntry

Certificate chain length: 1 Certificate[1]:
Owner: CN=jdoe, OU=Client Cert, O=Example Company, L=Austin, ST=Texas, C=US
Issuer: EMAILADDRESS=whatever@example.com, CN=Cert Auth, OU=My Certificate Authority,
O=Example Company, L=Austin, ST=Texas, C=US
Serial number: e19cb2838441dbcd
Valid from: Thu Oct 29 13:07:10 CDT 2011 until: Fri Oct 29 13:07:10 CDT 2012
Certificate fingerprints:
     MD5: 40:73:7C:EF:1B:4A:3F:F4:9B:09:C3:50:2B:26:4A:EB
     SHA1: 2A:89:71:06:1A:F5:DA:FF:51:7B:3D:2D:07:2E:33:BE:C6:5D:97:13
     Signature algorithm name: SHA1withRSA
     Version: 1
```

To Configure the Fingerprint Certificate Mapper

1. Create an LDIF file to hold a modification that adds the `ds-certificate-user` object class and `ds-certificate-fingerprint` attribute to the target user's entry.

```
dn: uid=jdoe,ou=People,dc=example,dc=com
changetype: modify
add: objectClass
objectClass: ds-certificate-user
-
add: ds-certificate-fingerprint
ds-certificate-fingerprint: 40:73:7C:EF:1B:4A:3F:F4:9B:09:C3:50:2B:26:4A:EB
```

2. Then, apply the change to the entry using `ldapmodify`:

```
$ bin/ldapmodify --filename add-cert-attr.ldif
```

```
dn: uid=jdoe,ou=People,dc=example,dc=com
ds-certificate-fingerprint:40:73:7C:EF:1B:4A:3F:F4:9B:09:C3:50:2B:26:4A:EB
```

3. Check that the attribute was added to the entry using `ldapsearch`.

```
$ bin/ldapsearch --baseDN dc=example,dc=com "(uid=jdoe)" \

ds-certificate-fingerprint
dn:uid=jdoe,ou=People,dc=example,dc=com
ds-certificate-fingerprint:40:73:7C:EF:1B:4A:3F:F4:9B:09:C3:50:2B:26:4A:EB
```

4. Create an index for the `ds-certificate-fingerprint` attribute. If the server is configured with multiple data backends, then the attribute should be indexed in each of those backends.

```
$ bin/dsconfig create-local-db-index --backend-name userRoot \
  --index-name ds-certificate-fingerprint --set index-type:equality
```

5. Use the `rebuild-index` tool to cause an index to be generated for this attribute.

```
$ bin/rebuild-index --task --baseDN dc=example,dc=com \
  --index ds-certificate-fingerprint
```

```
[14:56:28] The console logging output is also available in
'/ds/UnboundID-DS/logs/tools/rebuild-index.log'
[14:56:29] Due to changes in the configuration, index
dc_example_dc_com_ds-certificate-fingerprint.equality is currently
operating in a degraded state and must be rebuilt before it can used
[14:56:29] Rebuild of index(es) ds-certificate-fingerprint started with 161 total
records to process
[14:56:29] Rebuild complete. Processed 161 records in 0 seconds
(average rate 1125.9/sec)
```

6. Change the certificate mapper for the SASL EXTERNAL mechanism.

```
$ bin/dsconfig --no-prompt set-sasl-mechanism-handler-prop \
  --handler-name EXTERNAL \
  --set "certificate-mapper:Fingerprint Mapper"
```

Configuring the Subject Attribute to User Attribute Certificate Mapper

The Subject Attribute to User Attribute Certificate Mapper maps common attributes from the subject of the client certificate to the user's entry. The generated search filter must match exactly one entry within the scope of the base DN(s) for the mapper. If no match is returned or if multiple matchines entries are found, the mapping fails.

Given the subject of the client certificate:

```
Owner: CN=John Doe, OU=Client Cert, O=Example Company, L=Austin, ST=Texas, C=US
```

We want to match to the following user entry:

```
dn: uid=jdoe,ou=People,dc=example,dc=com
objectClass: top
objectClass: person
objectClass: organizationalPerson
objectClass: inetOrgPerson
uid: jdoe
givenName: John
sn: Doe
cn: John Doe
mail: jdoe@example.com
```

To Configure the Subject Attribute to User Attribute Certificate Mapper

- Change the certificate mapper for the SASL EXTERNAL mechanism.

  ```
  $ bin/dsconfig --no-prompt set-sasl-mechanism-handler-prop \
    --handler-name EXTERNAL \
    --set "certificate-mapper:Subject Attribute to User Attribute"
  ```

Configuring the Subject DN to User Attribute Certificate Mapper

The Subject DN to User Attribute Certificate mapper expects the user’s entry to contain an attribute (`ds-certificate-subject-dn` by default) whose values match the subjects of the certificates that the user can use to authenticate. The `ds-certificate-subject-dn` attribute can be added to the user’s entry together with the `ds-certificate-user` auxiliary object class. The attribute is multi-valued and can contain the Subject DNs of multiple certificates. The certificate mapper must match exactly one entry, or the mapping will fail.

If you decide to use this attribute, you must add an equality index for this attribute in all data backends.

To Configure the Subject DN to User Attribute Certificate Mapper

1. Create an LDIF file to hold a modification that adds the `ds-certificate-user` object class and `ds-certificate-subject-dn` attribute to the target user’s entry.

   ```
   dn: uid=jdoe,ou=People,dc=example,dc=com
   changetype: modify
   add: objectClass
   objectClass: ds-certificate-user
   -
   add: ds-certificate-subject-dn
   ds-certificate-subject-dn:CN=John Doe,OU=Client Certificate,O=Example
    Company,L=Austin,ST=Texas,C=US
   ```

2. Then, apply the change to the entry using `ldapmodify`:

   ```
   $ bin/ldapmodify --filename add-cert-attr.ldif
   ```

3. Check that the attribute was added to the entry using `ldapsearch`.

```
$ bin/ldapsearch --baseDN dc=example,dc=com "(uid=jdoe)" \
  ds-certificate-subject-dn
```

```
dn: uid=jdoe,ou=People,dc=example,dc=com
ds-certificate-fingerprint:CN=jdoe, OU=Client Cert, O=Example Company,
  L=Austin, ST=Texas, C=US
```

4. Create an index to the `ds-certificate-subject-dn` attribute.

```
$ bin/dsconfig create-local-db-index --backend-name userRoot \
  --index-name ds-certificate-subject-dn --set index-type:equality
```

5. Use the `rebuild-index` tool to ensure that the index is properly generated in all appropriate backends.

```
$ bin/rebuild-index --task --baseDN dc=example,dc=com \
  --index ds-certificate-subject-dn
```

```
[15:39:19] The console logging output is also available in
'/ds/UnboundID-DS/logs/ tools/rebuild-index.log'
[15:39:20] Due to changes in the configuration, index
dc_example_dc_com_ds-certificate-subject-dn.equality is currently operating
in a degraded state and must be rebuilt before it can used
[15:39:20] Rebuild of index(es) ds-certificate-subject-dn started with 161 total
records to process
[15:39:20] Rebuild complete. Processed 161 records in 0 seconds
(average rate 2367.6/sec)
```

6. Change the certificate mapper for the SASL EXTERNAL mechanism.

```
$ bin/dsconfig --no-prompt set-sasl-mechanism-handler-prop \
  --handler-name EXTERNAL \
  --set "certificate-mapper:Subject DN to User Attribute"
```

Chapter 17 Managing Access Control

The UnboundID Data Store provides a fine-grained access control model to ensure that users are able to access the information they need, but are prevented from accessing information that they should not be allowed to see. It also includes a privilege subsystem that provides even greater flexibility and protection in many key areas.

This chapter presents the access control model and provides examples that illustrate the use of key access control functionality.

Topics:

Overview of Access Control

The access control model uses access control instructions (ACIs), which are stored in the `aci` operational attribute, to determine what a user or a group of users can do with a set of entries, down to the attribute level. The operational attribute can appear on any entry and affects the entry or any subentries within that branch of the directory information tree (DIT).

Access control instructions specifies four items:

- **Resources**. *Resources* are the targeted items or objects that specifies the set of entries and/or operations to which the access control instruction applies. For example, you can specify access to certain attributes, such as the `cn` or `userPassword` password.
- **Name**. *Name* is the descriptive label for each access control instruction. Typically, you will have multiple access control instructions for a given branch of your DIT. The access control name helps describe its purpose. For example, you can configure an access control instructions labelled "ACI to grant full access to administrators."
- **Clients**. *Clients* are the users or entities to which you grant or deny access. You can specify individual users or groups of users using an LDAP URL. For example, you can specify a group of administrators using the LDAP URL: `groupdn="ldap:///cn=admins,ou=groups,dc=example,dc=com."`
- **Rights**. *Rights* are permissions granted to users or client applications. You can grant or deny access to certain branches or operations. For example, you can grant `read` or `write` permission to a `telephoneNumber` attribute.

Key Access Control Features

The UnboundID Data Store provides important access control features that provide added security for the Data Store's entries.

Improved Validation and Security

The Data Store provides an access control model with strong validation to help ensure that invalid ACIs are not allowed into the server. For example, the Data Store ensures that all access control rules added over LDAP are valid and can be fully parsed. Any operation that attempts to store one or more invalid ACIs are rejected. The same validation is applied to ACIs contained in data imported from an LDIF file. Any entry containing a malformed `aci` value will be rejected.

As an additional level of security, the Data Store examines and validates all ACIs stored in the data whenever a backend is brought online. If any malformed ACIs are found in the backend, then the server generates an administrative alert to notify administrators of the problem and places itself in lockdown mode. While in lockdown mode, the server only allows requests from users who have the `lockdown-mode` privilege. This action allows administrators to correct the malformed ACI while ensuring that no sensitive data is inadvertently exposed due to an access control instruction not being enforced. When the problem has been corrected, the administrator can use the `leave-lockdown-mode` tool or restart the server to allow it to resume normal operation.

Global ACIs

Global ACIs are a set of ACIs that can apply to entries anywhere in the server (although they can also be scoped so that they only apply to a specific set of entries). They work in conjunction with access control rules stored in user data and provide a convenient way to define ACIs that span disparate portions of the DIT.

In the UnboundID Data Store, global ACIs are defined within the server configuration, in the `global-aci` property of configuration object for the access control handler. They can be viewed and managed using configuration tools like `dsconfig` and the web administration console.

The global ACIs available by default in the UnboundID Data Store include:

- Allow anyone (including unauthenticated users) to access key attributes of the root DSE, including: `namingContexts`, `subschemaSubentry`, `supportedAuthPasswordSchemes`, `supportedControl`, `supportedExtension`, `supportedFeatures`, `supportedLDAPVersion`, `supportedSASLMechanisms`, `vendorName`, and `vendorVersion`.
- Allow anyone (including unauthenticated users) to access key attributes of the subschema subentry, including: `attributeTypes`, `dITContentRules`, `dITStructureRules`, `ldapSyntaxes`, `matchingRules`, `matchingRuleUse`, `nameForms`, and `objectClasses`.
- Allow anyone (including unauthenticated users) to include the following controls in requests made to the server: authorization identity request, manage DSA IT, password policy, real attributes only, and virtual attributes only.
- Allow anyone (including unauthenticated users) to request the following extended operations: get symmetric key, password modify request, password policy state, StartTLS, and Who Am I?

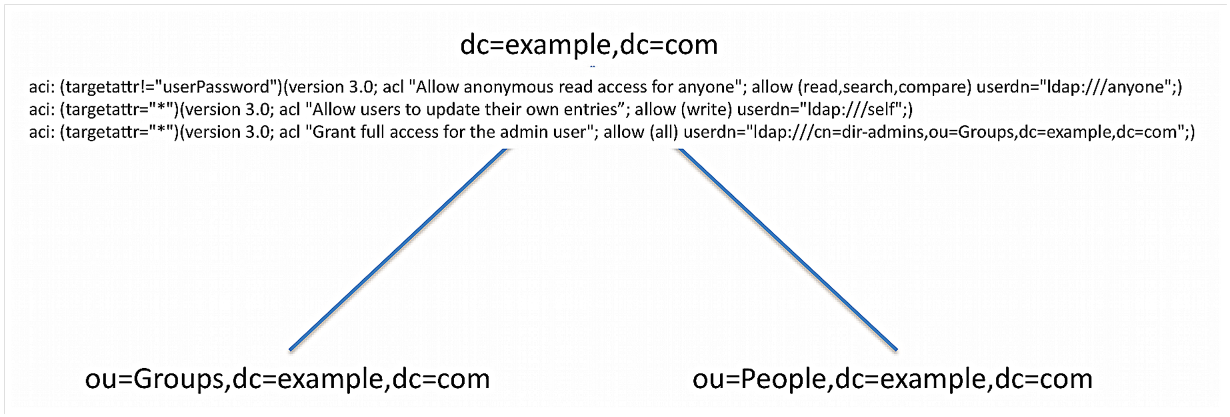
Access Controls for Public or Private Backends

The UnboundID Data Store classifies backends as either public or private, depending on their intended purpose. A private backend is one whose content is generated by the Data Store itself (for example, the root DSE, monitor, and backup backends), is used in the operation of the server (for example, the configuration, schema, task, and trust store backends), or whose content is maintained by the server (for example, the LDAP changelog backend). A public backend is intended to hold user-defined content, such as user accounts, groups, application data, and device data.

The UnboundID Data Store access control model also supports the distinction between public backends and private backends. Many private backends do not allow writes of any kind from clients, and some of the private backends that do allow writes only allow changes to a specific set of attributes. As a result, any access control instruction intended to permit or restrict access to information in private backends should be defined as global ACIs, rather than attempting to add those instructions to the data for that private backend.

General Format of the Access Control Rules

Access control instructions (ACIs) are represented as strings that are applied to one or more entries within the Directory Information Tree (DIT). Typically, an ACI is placed on a subtree, such as `dc=example,dc=com`, and applies to that base entry and all entries below it in the tree. The Data Store iterates through the DIT to compile the access control rules into an internally-used list of denied and allowed targets and their permissable operations. When a client application, such as `ldapsearch`, enters a request, the Data Store checks that the user who binds with the server has the necessary access rights to the requested search targets. ACIs are cumulatively applied, so that a user who may have an ACI at an entry, may also have other access rights available if ACIs are defined higher in the DIT and are applicable to the user. In most environments, ACIs are defined at the root of a main branch or a subtree, and not on individual entries unless absolutely required.



```
aci: (targetattr!="userPassword")(version 3.0; acl "Allow anonymous read access for anyone"; allow (read,search,compare) userdn="ldap:///anyone";)
aci: (targetattr="*")(version 3.0; acl "Allow users to update their own entries"; allow (write) userdn="ldap:///self";)
aci: (targetattr="*")(version 3.0; acl "Grant full access for the admin user"; allow (all) userdn="ldap:///cn=dir-admins,ou=Groups,dc=example,dc=com";)
```

Figure 7: ACI

An access control rule has a basic syntax as follows:

```
aci : (targets) (version 3.0; acl "name"; permissions bind rules;)
```

Table 29: Access Control Components

Access Control Component	Description
targets	Specifies the set of entries and/or attributes to which an access control rule applies. Syntax: *(target keyword = || != expression)*
name	Specifies the name of the ACI.
permissions	Specifies the type of operations to which an access control rule might apply. Syntax: *allow||deny (permission)*
bind rules	Specifies the criteria that indicate whether an access control rule should apply to a given requestor. Syntax: *bind rule keyword = ||!= expression;*. The bind rule syntax requires that it be terminated with a ";".

Summary of Access Control Keywords

This section provides an overview of the keywords supported for use in the UnboundID Data Store access control implementation.

Targets

A target expression specifies the set of entries and/or attributes to which an access control rule applies. The *keyword* specifies the type of target element. The *expression* specifies the items that is targeted by the access control rule. The operator is either the equal ("=") or not-equal ("!="). Note that the "!=" operator cannot be used with `targattrfilters` and `targetscope` keywords. For specific examples on each target keyword, see the section *Working with Targets*.

```
(keyword [=||!=]expression)
```

The following keywords are supported for use in the target portion of ACIs:

Table 30: Summary of Access Control Target Keywords

Target Keyword	Description	Wildcards
extop	Specifies the OIDs for any extended operations to which the access control rule should apply.	No
target	Specifies the set of entries, identified using LDAP URLs, to which the access control rule applies.	**Yes**
targattrfilters	Identifies specific attribute values based on filters that may be added to or removed from entries to which the access control rule applies.	**Yes**
targetattr	Specifies the set of attributes to which the access control rule should apply.	**Yes**
targetcontrol	Specifies the OIDs for any request controls to which the access control rule should apply.	No
targetfilter	Specifies one or more search filters that may be used to indicate the set of entries to which the access control should apply.	**Yes**
targetscope	Specifies the scope of entries, relative to the defined target entries or the entry containing the ACI fi there is no target, to which the access control rule should apply.	No

Permissions

Permissions indicate the types of operations to which an access control rule might apply. You can specify if the user or group of users are allowed or not allowed to carry out a specific operation. For example, you would grant read access to a targeted entry or entries using "allow (read)" permission. Or you can specifically deny access to the target entries and/or attributes using the "deny (read)" permission. You can list out multiple permissions as required in the ACI.

```
allow (permission1 ...,permission2,...permissionN)
```

```
deny (permission1 ...,permission2,...permissionN)
```

The following keywords are supported for use in the permissions portion of ACIs:

Table 31: Summary of Access Control Permissions

Permission	Description
add	Indicates that the access control should apply to add operations.

Permission	Description
compare	Indicates that the access control should apply to compare operations, as well as to search operations with a base-level scope that targets a single entry.
delete	Indicates that the access control should apply to delete operations.
export	Indicates that the access control should only apply to modify DN operations in which an entry is moved below a different parent by specifying a new superior DN in the modify DN request. The requestor must have the `export` permission for operations against the entry's original DN. The requestor must have the `import` permission for operations against the entry's new superior DN. For modify DN operations that merely alter the RDN of an entry but keeps it below the same parent (i.e., renames the entry), only the `write` permission is required. This is true regardless of whether the entry being renamed is a leaf entry or has subordinate entries.
import	See the description for the `export` permission.
proxy	Indicates that the access control rule should apply to operations that attempt to use an alternate authorization identity (for example, operations that include a proxied authorization request control, an intermediate client request control with an alternate authorization identity, or a client that has authenticated with a SASL mechanism that allows an alternate authorization identify to be specified).
read	Indicates that the access control rule should apply to search result entries returned by the server.
search	Indicates that the access control rule should apply to search operations with a non-base scope.
selfwrite	Indicates that the access control rule should apply to operations in which a user attempts to add or remove his or her own DN to the values for an attribute (for example, whether users may add or remove themselves from groups).
write	Indicates that the access control rule should apply to modify and modify DN operations.
all	An aggregate permission that includes all other permissions except “proxy.” This is equivalent to providing a permission of “add, compare, delete, read, search, selfwrite, write.”

Bind Rules

The Bind Rules indicate whether an access control rule should apply to a given requester. The syntax for the target keyword is shown below. The *keyword* specifies the type of target element. The expression specifies the items that is targeted by the access control rule. The operator is either equals ("=") or not-equals ("!="). The semi-colon delimiter symbol (";") is required after the end of the final bind rule.

```
keyword [=||!= ] expression;
```

Multiple bind rules can be combined using boolean operations (AND, OR, NOT) for more access control precision. The standard Boolean rules for evaluation apply: innermost to outer parentheses first, left to right expressions, NOT before AND or OR. For example, an ACI that includes the following bind rule targets all users who are not `uid=admin,dc=example,dc=com` and use simple authentication.

```
(userdn!="ldap:///uid=admin,dc=example,dc=com" and authmethod="simple");
```

The following bind rule targets the `uid=admin,dc=example,dc=com` and authenticates using SASL EXTERNAL or accesses the server from a loopback interface.

```
(userdn="ldap:///uid=admin,dc=example,dc=com and (authmethod="SSL" or ip="127.0.0.1"));
```

The following keywords are supported for use in the bind rule portion of ACIs:

Table 32: Summary of Bind Rule Keywords

Bind Rule Keyword	Description

authmethod	Indicates that the requester's authentication method should be taken into account when determining whether the access control rule should apply to an operation. Wildcards are not allowed in this expression. The keyword's syntax is as follows:
	
	`authmethod = method`
	
	where *method* is one of the following representations:
	
	➢ none
	➢ simple. Indicates that the client is authenticated to the server using a bind DN and password.
	➢ ssl. Indicates that the client is authenticated with an SSL/TLS certificate (e.g., via SASL EXTERNAL), and not just over a secure connection to the server.
	➢ sasl {sasl_mechanism}. Indicates that the client is authenticated to the server using a specified SASL Mechanism.
	
	The following example allows users who authenticate with an SSL/TLS certificate (e.g., via SASL EXTERNAL) to update their own entries:
	
	`aci: (targetattr="*")`
	`  (version 3.0; acl "Allow users to update their own entries";`
	`   allow (write) (userdn="ldap:///self" and authmethod="ssl");)`

dayofweek	Indicates that the day of the week should be taken into account when determining whether the access control rule should apply to an operation. Wildcards are not allowed in this expression. Multiple day of week values may be separated by commas. The keyword's syntax is as follows:
	
	`dayofweek = day1, day2, ...`
	
	where *day* is one of the following representations:
	
	➢ sun
	➢ mon
	➢ tues
	➢ wed
	➢ thu
	➢ fri
	➢ sat
	
	The following example allows users who authenticate with an SSL/TLS certificate (e.g., via SASL EXTERNAL) on weekdays to update their own entries:
	
	`aci: (targetattr="*")`
	`  (version 3.0; acl "Allow users to update their own entries";`
	`   allow (write) (dayofweek!="sun,sat" and userdn="ldap:///self"`
	`   and authmethod="ssl");)`

dns	Indicates that the requester's DNS-resolvable host name should be taken into account when determining whether the access control rule should apply to an operation. Wildcards are allowed in this expression. Multiple DNS patterns may be separated by commas. The keyword's syntax is as follows:
	
	`dns = dns-host-name`
	
	The following example allows users on hostname `server.example.com` to update their own entries:
	
	`aci: (targetattr="*")`
	`  (version 3.0; acl "Allow users to update their own entries";`
	`   allow (write) (dns="server.example.com" and userdn="ldap:///self");)`

Bind Rule Keyword	Description

groupdn	Indicates that the requester’s group membership should be taken into account when determining whether the access control rule should apply to any operation. Wildcards are not allowed in this expression.
	
	`groupdn [ = || != ] "ldap:///groupdn [ || ldap:///groupdn ] ..."`
	
	The following example allows users in the managers group to update their own entries:
	
	`aci: (targetattr="*")`
	`  (version 3.0; acl "Allow users to update their own entries";`
	`   allow (write)`
	`   (groupdn="ldap:///cn=managers,ou=groups,dc=example,dc=com");)`

ip	Indicates that the requester’s IP address should be taken into account when determining whether the access control rule should apply to an operation. Wildcards are allowed in this expression. Multiple IP address patterns may be separated by commas. The keyword’s syntax is as follows:
	
	`ip` `[ = || != ]` *`ipAddressList`*
	
	where *ipAddressList* is one of the following representations:
	
	➢ A specific IPv4 address: 127.0.0.1
	➢ An IPv4 address with wildcards to specify a subnetwork: 127.0.0.*
	➢ An IPv4 address or subnetwork with subnetwork mask: 123.4.5.0+255.255.255.0
	➢ An IPv4 address range using CIDR notation: 123.4.5.0/24
	➢ An IPv6 address as defined by RFC 2373.
	
	The following example allows users on 10.130.10.2 and localhost to update their own entries:
	
	`aci: (targetattr="*")`
	`  (version 3.0; acl "Allow users to update their own entries";`
	`   allow (write) (ip="10.130.10.2,127.0.0.1" and userdn="ldap:///`
	`self");)`

timeofday	Indicates that the time of day should be taken into account when determining whether the access control rule should apply to an operation. Wildcards are not allowed in this expression. The keyword’s syntax is as follows:
	
	`timeofday [ = || != || >= || > || <= || < ] time`
	
	where *time* is one of the following representations:
	
	➢ 4-digit 24-hour time format (0000 to 2359, where the first two digits represent the hour of the day and the last two represent the minute of the hour)
	➢ Wildcards are not allowed in this expression
	
	The following example allows users to update their own entries if the request is received before 12 noon.
	
	`aci: (targetattr="*")`
	`  (version 3.0; acl "Allow users who authenticate before noon`
	`    to update their own entries";`
	`    allow (write) (timeofday<1200 and userdn="ldap:///self"`
	`    and authmethod="simple");)`

userattr	Indicates that the requester’s relation to the value of the specified attribute should be taken into account when determining whether the access control rule should apply to an operation. A bindType value of `USERDN` indicates that the target attribute should have a value which matches the DN of the authenticated user. A bindType value of `GROUPDN` indicates that the target attribute should have a value which matches the DN of a group in which the authenticated user is a member. A bindType value of `LDAPURL` indicates that the target attribute should have a value that is an LDAP URL whose criteria matches the entry for the authenticated user. Any value

Bind Rule Keyword	Description

	other than `USERDN`, `GROUPDN`, or `LDAPURL` is expected to be present in the target attribute of the authenticated user’s entry. The keyword’s syntax is as follows:
	
	`userattr = attrName# [ bindType || attrValue ]`
	
	where:
	
	➢ *attrName* = name of the attribute for matching
	➢ *bindType* = USERDN, GROUPDN, LDAPURL
	➢ *attrValue* = an attribute value. Note that the *attrVALUE* of the attribute must match on both the bind entry and the target of the ACI.
	
	The following example allows a manager to change employee's entries. If the bind DN is specified in the *manager* attribute of the targeted entry, the bind rule is evaluated to TRUE.
	
	`aci: (targetattr="*")`
	`  (version 3.0; acl "Allow a manager to change employee entries";`
	`   allow (write) userattr="manager#USERDN";)`
	
	The following example allows any member of a group to change employee's entries. If the bind DN is a member of the group specified in the *allowEditors* attribute of the targeted entry, the bind rule is evaluated to TRUE.
	
	`aci: (targetattr="*")`
	`  (version 3.0; acl "Allow allowEditors to change employee entries";`
	`   allow (write) userattr="allowEditors#GROUPDN";)`
	
	The following example allows allows a user's manager to edit that user's entry and any entries below the user's entry up to two levels deep. You can specify up to five levels (0, 1, 2, 3, 4) below the targeted entry, with zero (0) indicating the targeted entry.
	
	`aci: (targetattr="*")`
	`  (version 3.0; acl "Allow managers to change employees entries two`
	` levels below";`
	`    allow (write) userattr="parent[0,1,2].manager#USERDN";)`
	
	The following example allows any member of the engineering department to update any other member of the engineering department at or below the specified ACI.
	
	`aci: (targetattr="*")`
	`  (version 3.0; acl "Allow any member of Eng Dept to update any other`
	` member of the`
	`   enginering department at or below the ACI";`
	`   allow (write) userattr="department#ENGINEERING";)`
	
	The following example allows an entry to be updated by any user whose entry matches the criteria defined in the LDAP URL contained in the `allowedEditorCriteria` attribute of the target entry.
	
	`aci: (targetattr="*")`
	`  (version 3.0; acl "Allow a user that matches the filter to change`
	` entries";`
	`   allow (write) userattr="allowedEditorCriteria#LDAPURL";)`

userdn	Indicates that the user’s DN should be taken into account when determining whether the access control rule should apply to an operation. The keyword’s syntax is as follows: `userdn [ = || != ] "ldap:///value [ || "ldap:///value ..."]` where *value* is one of the following representations: ➢ The DN of the target user ➢ A value of `anyone` to match any client, including unauthenticated clients. ➢ A value of `all` to match any authenticated client.

Bind Rule Keyword	Description

	➢ A value of `parent` to match the client authenticated as the user defined in the immediate parent of the target entry.
	➢ A value of `self` to match the client authenticated as the user defined in the target entry.
	
	If the value provided is a DN, then that DN may include wildcard characters to define patterns. A single asterisk will match any content within the associated DN component, and two consecutive asterisks may be used to match zero or more DN components.
	
	The following example allows users to update their own entries:
	
	`aci: (targetattr="*")`
	`  (version 3.0; acl "Allow users to update their own entries";`
	`    allow (write) userdn="ldap:///self";)`

Working with Targets

The following section presents a detailed look and examples of the target ACI keywords: `target`, `targetattr`, `targetfilter`, `targattrfilters`, `targetscope`, `targetcontrol`, and `extop`.

target

The `target` keyword indicates that the ACI should apply to one or more entries at or below the specified distinguished name (DN). The target DN must be equal or subordinate to the DN of the entry in which the ACI is placed. For example, if you place the ACI at the root of `ou=People,dc=example,dc=com`, you can target the DN, `uid=user.1,ou=People,dc=example,dc=com` within your ACI rule. The DN must meet the string representation specification of distinguished names, outlined in RFC 4514, and requires that special characters be properly escaped.

The `target` clause has the following format, where DN is the distinguished name of the entry or branch:

```
(target = ldap:///DN)
```

For example, to target a specific entry, you would use a clause such as the following:

```
(target = ldap:///uid=john.doe,ou=People,dc=example,dc=com)
```

Note that, in general, specifying a target DN is not recommended. It is better to have the ACI defined in that entry and omit the `target` element altogether. For example, although you can have `(target="ldap:///uid=john.doe,ou=People,dc=example,dc=com)` in any of the `dc=example,dc=com` or `ou=People` entries, it is better for it to be defined in the `uid=john.doe` entry and not explicitly include the `target` element.

The expression allows for the "not equal" (!=) operator to indicate that all entries within the scope of the given branch that do NOT match the expression be targeted for the ACI. Thus, the following expression targets all entries within the subtree that do not match `uid=john.doe`.

```
(target != ldap:///uid=john.doe,ou=People,dc=example,dc=com)
```

The `target` keyword also supports the use of asterisk (*) characters as wildcards to match elements within the distinguished name. The following target expression matches all entries that contains and begins with "john.d, " so that entries like "`john.doe,ou=People,dc=example,dc=com`," and "`john.davies,ou=People,dc=example,dc=com`" would match.

```
(target = ldap:///uid=john.d*,ou=People,dc=example,dc=com)
```

The following target expression matches all entries whose DN begins with "john.d," and matches the `ou` attribute. Entries like "`john.doe,ou=People,dc=example,dc=com`," and "`john.davies,ou=asia-branch,dc=example,dc=com`" would match.

```
(target = ldap:///uid=john.d*,ou=*,dc=example,dc=com)
```

Another example of a complete ACI targets the entries in the `ou=People,dc=example,dc=com` branch and the entries below it, and grants the users the privilege to modify all of their user attributes within their own entries.

```
aci:(target="ldap:///ou=People,dc=example,dc=com")
  (targetattr="*")
  (version 3.0; acl "Allow all the ou=People branch to modify their own entries";
  allow (write) userdn="ldap:///self";)
```

targetattr

The `targetattr` keyword targets the attributes for which the access control instruction should apply. There are four general forms that it can take in the UnboundID Data Store:

- **(targetattr="*")**. Indicates that the access control rule applies to all user attributes. Operational attributes will not automatically be included in this set.
- **(targetattr="+")**. Indicates that the access control rule applies to all operational attributes. User attributes will not automatically be included in this set.
- **(targetattr="attr1||attr2||attr3||...||attrN")**. Indicates that the access control rule applies only to the named set of attributes.
- **(targetattr!="attr1||attr2||attr3||...||attrN")**. Indicates that the access control rule applies to all user attributes except the named set of attributes. It will not apply to any operational attributes.

The targeted attributes can be classified as user attributes and operational attributes. User attributes define the actual data for that entry, while operational attributes provide additional metadata about the entry that can be used for informational purposes, such as when the entry was created, last modified and by whom. Metadata can also include attributes specifying which password policy applies to the user, or overrided default constraints like size limit, time limit, or look-through limit for that user.

The UnboundID Data Store distinguishes between these two types of attributes in its access control implementation. The Data Store does not automatically grant any access at all to operational attributes. For example, the following clause applies only to user attributes and not to operational attributes:

```
(targetattr="*")
```

You can also target multiple attributes in the entry. The following clause targets the common name (cn), surname (sn) and state (st) attribute:

```
(targetattr="cn||sn||st")
```

You can use the "+" symbol to indicate that the rule should apply to all operational attributes, as follows:

```
(targetattr="+")
```

To include all user and all operational attributes, you use both symbols, as follows:

```
(targetattr="*||+")
```

If there is a need to target a specific operational attribute rather than all operational attributes, then it can be specifically included in the values of the `targetattr` clause, as follows:

```
(targetattr="ds-rlim-size-limit")
```

Or if you want to target all user attributes and a specific operational attribute, then you can use them in the `targetattr` clause, as follows:

```
(targetattr="*||ds-rlim-size-limit")
```

The following ACIs are placed on the `dc=example,dc=com` tree and allows any user anonymous read access to all entries except the `userPassword` attribute. The second ACI allows users to update their own contact information. The third ACI allows the `uid=admin` user full access privileges to all user attributes in the `dc=example,dc=com` subtree.

```
aci: (targetattr!="userPassword")(version 3.0; acl "Allow anonymous
   read access for anyone"; allow (read,search,compare) userdn="ldap:///anyone";)
aci: (targetattr="telephonenumber||street||homePhone||l||st")
  (version 3.0; acl "Allow users to update their own contact info";
   allow (write) userdn="ldap:///self";)
aci: (targetattr="*")(version 3.0; acl "Grant full access for the admin user";
  allow (all) userdn="ldap:///uid=admin,dc=example,dc=com";)
```

An important note must be made when assigning access to user and operational attributes, which can be outlined in an example to show the implications of the Data Store not distinguishing between these attributes. It can be easy to inadvertently create an access control instruction that grants far more capabilities to a user than originally intended. Consider the following example:

```
aci: (targetattr!="uid||employeeNumber")
  (version 3.0; acl "Allow users to update their own entries";
    allow (write) userdn="ldap:///self";)
```

This instruction is intended to allow a user to update any attribute in his or her own entry with the exception of `uid` and `employeeNumber`. This ACI is a very common type of rule and seems relatively harmless on the surface, but it has very serious consequences for a Data Store that does not distinguish between user attributes and operational attributes. It allows users to update operational attributes in their own entries, and could be used for a number of malicious purposes, including:

- A user could alter password policy state attributes to become exempt from password policy restrictions.
- A user could alter resource limit attributes and bypass size limit, time limit, and look-through-limit constraints.
- A user could add access control rules to his or her own entry, which could allow them to make their entry completely invisible to all other users including administrators granted full rights by access control rules, but excluding users with the `bypass-acl` privilege, allow them

to edit any other attributes in their own entry including those excluded by rules like `uid` and `employeeNumber` in the example above, or add, modify, or delete any entries below his or her own entry.

Because the UnboundID Data Store does not automatically include operational attributes in the target attribute list, these kinds of ACIs do not present a security risk for it. Also note that users cannot add ACIs to any entries unless they have the `modify-acl` privilege.

Another danger in using the `(targetattr!="x")` pattern is that two ACIs within the same scope could have two different `targetattr` policies that cancel each other out. For example, if one ACI has `(targetattr!="cn||sn")` and a second ACI has `(targetattr!="userPassword")`, then the net effect is `(targetattr="*")`, because the first ACI inherently allows `userPassword`, and the second allows `cn` and `sn`.

targetfilter

The `targetfilter` keyword targets all attributes that match results returned from a filter. The `targetfilter` clause has the following syntax:

```
(targetfilter = ldap_filter)
```

For example, the following clause targets all entries that contain "ou=engineering" attribue:

```
(targetfilter = "(ou=engineering)")
```

You can only specify a single filter, but that filter can contain multiple elements combined with the OR operator. The following clause targets all entries that contain "ou=engineering," "ou=accounting," and "ou=marketing."

```
(targetfilter = "(|(ou=engineering)(ou=accounting)(ou=marketing)")
```

The following example allows the user, `uid=eng-mgr`, to modify the `departmentNumber`, `cn`, and `sn` attributes for all entries that match the filter `ou=engineering`.

```
aci:(targetfilter="(ou=engineering)")
  (targetattr="departmentNumber||cn||sn")
  (version 3.0; acl "example"; allow (write)
   userdn="ldap:///uid=eng-mgr,dc=example,dc=com";)
```

targattrfilters

The `targattrfilters` keyword targets specific attribute *values* that match a filtered search criteria. This keyword allows you to set up an ACI that grants or denies permissions on an attribute value if that value meets the filter criteria. The `targattrfilters` keyword applies to individual values of an attribute, not to the whole attribute. The keyword also allows the use of wildcards in the filters.

The keyword clause has the following formats:

```
(target = "add=attr1:Filter1 && attr2:Filter2... && attrn:FilterN,
del=attr1:Filter1 && attr2:Filter2 ... && attrN:FilterN" )
```

where

- **add** represents the operation of adding an attribute value to the entry

- **del** represents the operation of removing an attribute value from the entry
- **attr1, attr2... attrN** represents the targeted attributes
- **filter1, filter2 ... filterN** represents filters that identify matching attribute values

The following conditions determine when the attribute must satisfy the filter:

- When adding or deleting an entry containing an attribute targeted a `targattrfilters` element, each value of that attribute must satisfy the corresponding filter.
- When modifying an entry, if the operation adds one or more values for an attribute targeted by a `targattrfilters` element, each value must satisfy the corresponding filter. If the operation deletes one or more values for a targeted attribute, each value must satisfy the corresponding filter.
- When replacing the set of values for an attribute targeted by a `targattrfilters` element, each value removed must satisfy the delete filters, and each value added must satisfy the add filters.

The following example allows any user who is part of the `cn=data store admins` group to add the `soft-delete-read` privilege.

```
aci:(targattrfilter="add=ds-privilege-name:(ds-privilege-name=soft-delete-read)")
  (version 3.0; acl "Allow members of the data store admins group to grant the
   soft-delete-read privilege"; allow (write)
   groupdn="ldap:///cn=data store admins,ou=group,dc=example,dc=com";)
```

targetscope

The `targetscope` keyword is used to restrict the scope of an access control rule. By default, ACIs use a subtree scope, which means that they are applied to the target entry (either as defined by the target clause of the ACI, or the entry in which the ACI is define if it does not include a target), and all entries below it. However, adding the `targetscope` element into an access control rule can restrict the set of entries to which it applies.

The following `targetscope` keyword values are allowed:

- **base**. Indicates that the access control rule should apply only to the target entry and not to any of its subordinates.
- **onelevel**. Indicates that the access control rule should apply only to entries that are the immediate children of the target entry and not to the target entry itself, nor to any subordinates of the immediate children of the target entry.
- **subtree**. Indicates that the access control rule should apply to the target entry and all of its subordinates. This is the default behavior if no `targetscope` is specified.
- **subordinate**. Indicates that the access control rule should apply to all entries below the target entry but not the target entry itself.

The following ACI targets all users to view the operational attributes (`supportedControl`, `supportedExtension`, `supportedFeatures`, `supportedSASLMechanisms`, `vendorName`, and `vendorVersion`) present in the root DSE entry. The `targetscope` is base to limit users to view only those attributes in the root DSE.

```
aci: (target="ldap:///")(targetscope="base")
    (targetattr="supportedControl||supportedExtension||
     supportedFeatures||supportedSASLMechanisms||vendorName||vendorVersion")
    (version 3.0; acl "Allow users to view Root DSE Operational Attributes";
     allow (read,search,compare) userdn="ldap:///anyone")
```

targetcontrol

The `targetcontrol` keyword is used to indicate whether a given request control can be used by those users targeted in the ACI. Multiple OIDs can be provided by separating them with the two pipe characters (optionally surrounded by spaces). Wildcards are not allowed when specifying control OIDs.

The following ACI example shows the controls required to allow an administrator to use and manage the Soft-Delete feature. The Soft Delete Request Control allows the user to soft-delete an entry, so that it could be undeleted at a later time. The Hard Delete Request Control allows the user to permanently remove an entry or soft-deleted entry. The Undelete Request Control allows the user to undelete a currently soft-deleted entry. The Soft-Deleted Entry Access Request Control allows the user to search for any soft-deleted entries in the server.

```
aci: (targetcontrol="1.3.6.1.4.1.30221.2.5.20||1.3.6.1.4.1.30221.2.5.22||
   1.3.6.1.4.1.30221.2.5.23||1.3.6.1.4.1.30221.2.5.24")
  (version 3.0; acl "Allow admins to use the Soft Delete Request Control,
   Hard Delete Request Control,Undelete Request Control, and
   Soft-deleted entry access request control";
   allow (read) userdn="ldap:///uid=admin,dc=example,dc=com";)
```

extOp

The `extop` keyword can be used to indicate whether a given extended request operation can be used. Multiple OIDs can be provided by separating them with the two pipe characters (optionally surrounded by spaces). Wildcards are not allowed when specifying extended request OIDs.

The following ACI allows the `uid=user-mgr` to use the Password Modify Request (i.e., OID=1.3.6.1.4.1.4203.1.11.1) and the StartTLS (i.e., OID=1.3.6.1.4.1.1466.20037) extended request OIDs.

```
aci:(extop="1.3.6.1.4.1.4203.1.11.1 || 1.3.6.1.4.1.1466.20037")
  (version 3.0; acl "Allows the mgr to use the Password Modify Request and StartTLS;
   allow(read) userdn="ldap:///uid=user-mgr,ou=people,dc=example,dc=com";)
```

Examples of Common Access Control Rules

This section provides a set of examples that demonstrate access controls that are commonly used in your environment. Note that to be able to alter access control definitions in the server, a user must have the `modify-acl` privilege as discussed later in this chapter.

Administrator Access

The following ACI can be used to grant any member of the "`cn=admins,ou=groups,dc=example,dc=com`" group to add, modify and delete entries, reset passwords and read operational attributes such as `isMemberOf` and password policy state:

```
aci: (targetattr="+")(version 3.0; acl "Administrators can read, search or compare
 operational attributes";
allow (read,search,compare) groupdn="ldap:///cn=admins,ou=groups,dc=example,dc=com";)
```

```
aci: (targetattr="*")(version 3.0; acl "Administrators can add, modify and delete
 entries";
allow (all) groupdn="ldap:///cn=admins,ou=groups,dc=example,dc=com";)
```

Anonymous and Authenticated Access

The following ACI allow anonymous read, search and compare on select attributes of `inetOrgPerson` entries while authenticated users can access several more. The authenticated user will inherit the privileges of the anonymous ACI. In addition, the authenticated user can change `userPassword`:

```
aci: (targetattr="objectclass || uid || cn || mail || sn || givenName")
(targetfilter="(objectClass=inetorgperson)")
(version 3.0; acl "Anyone can access names and email addresses of entries representing
 people";
allow (read,search,compare) userdn="ldap:///anyone";)
aci: (targetattr="departmentNumber || manager || isMemberOf")
(targetfilter="(objectClass=inetorgperson)")
(version 3.0; acl "Authenticated users can access these fields for entries representing
 people";
allow (read,search,compare) userdn="ldap:///all";)
aci: (targetattr="userPassword")(version 3.0; acl "Authenticated users can change
 password";
allow (write) userdn="ldap:///all";)
```

If no unauthenticated access should be allowed to the data store, the preferred method for preventing unauthenticated, or anonymous access is to set the Global Configuration property `reject-unauthenticated-requests` to false.

Delegated Access to a Manager

The following ACI can be used to allow an employee's manager to edit the value of the employee's `telephoneNumber` attribute. This ACI uses the `userattr` keyword with a bind type of `USERDN`, which indicates that the target entry’s manager attribute must have a value equal to the DN of the authenticated user:

```
aci: (targetattr="telephoneNumber")
(version 3.0; acl "A manager can update telephone numbers of her direct reports";
allow (read,search,compare,write) userattr="manager#USERDN";)
```

Proxy Authorization

The following ACIs can be used to allow the application "`cn=OnBehalf,ou=applications,dc=example,dc=com`" to use the proxied authorization v2 control to request that operations be performed using an alternate authorization identity. The application user is also required to have the `proxied-auth` privilege as discussed later in this chapter:

```
aci: (version 3.0;acl "Application OnBehalf can proxy as another entry";
allow (proxy) userdn="ldap:///cn=OnBehalf,ou=applications,dc=example,dc=com";)
```

Validating ACIs Before Migrating Data

Many directory servers allow for less restrictive application of their access control instructions, so that they accept invalid ACIs. For example, if Sun/Oracle encounters an access control rule that it cannot parse, then it will simply ignore it without any warning, and the server may not offer the intended access protection. Rather than unexpectedly exposing sensitive data, the UnboundID Data Store rejects any ACIs that it cannot interpret, which ensures data access is properly limited as intended, but it can cause problems when migrating data with existing access control rules to an UnboundID Data Store.

To validate an access control instruction, the UnboundID Data Store provides a `validate-acis` tool in the `bin` directory (UNIX or Linux systems) or `bat` directory (Windows systems) that identifies any ACI syntax problems before migrating data. The tool can examine access control rules contained in either an LDIF file or an LDAP directory and write its result in LDIF with comments providing information about any problems that were identified. Each entry in the output will contain only a single ACI, so if an entry in the input contains multiple ACIs, then it may be present multiple times in the output, each time with a different ACI value. The entries contained in the output contains only ACI values, and all other attributes will be ignored.

To Validate ACIs from a File

The `validate-acis` tool can process data contained in an LDIF file. It will ignore all attributes except `aci`, and will ignore all entries that do not contain the `aci` attribute, so any existing LDIF file that contains access control rules may be used.

1. Run the `bin/validate-acis` tool (UNIX or Linux systems) or `bat\validate-acis` (Win dows systems) by specifying the input file and output file. If the output file already exists, the existing contents will be re-written. If no output file is specified, then the results will be written to standard output.

```
$ bin/validate-acis --ldifFile test-acis.ldif --outputFile validated-acis.ldif
```

```
# Processing complete # Total entries examined: 1
# Entries found with ACIs: 1
# Total ACI values found: 3
# Malformed ACI values found: 0
# Other processing errors encountered: 0
```

2. Review the results by opening the output file. For example, the `validated-acis.ldif` file that was generated in the previous step reads as follows:

```
# The following access control rule is valid
dn: dc=example,dc=com
aci: (targetattr!="userPassword")
  (version 3.0; acl "Allow anonymous read access for anyone";
    allow (read,search,compare) userdn="ldap:///anyone";)

# The following access control rule is valid
dn: dc=example,dc=com
aci: (targetattr="*")
  (version 3.0; acl "Allow users to update their own entries";
    allow (write) userdn="ldap:///self";)

# The following access control rule is valid
dn: dc=example,dc=com
```

```
aci: (targetattr="*")
  (version 3.0; acl "Grant full access for the admin user";
    allow (all) userdn="ldap:///uid=admin,dc=example,dc=com";)
```

3. If the input file has any malformed ACIs, then the generated output file will show what was incorrectly entered. For example, remove the quotation marks around `userPassword` in the original `test-acis.ldif` file, and re-run the command. The following command uses the `--onlyReportErrors` option to write any error messages to the output file only if a malformed ACI syntax is encountered.

```
$ bin/validate-acis --ldifFIle test-acis.ldif --outputFile validated-acis.ldif \
  --onlyReportErrors
```

```
# Processing complete
# Total entries examined: 1
# Entries found with ACIs: 1
# Total ACI values found: 3
# Malformed ACI values found: 0
# Other processing errors encountered: 0
```

The output file shows the following message:

```
# The following access control rule is malformed or contains an unsupported
# syntax: The provided string '(targetattr!=userPassword)(version 3.0; acl
# "Allow anonymous read access for anyone"; allow (read,search,compare)
# userdn="ldap:///anyone";)' could not be parsed as a valid Access Control
# Instruction (ACI) because it failed general ACI syntax evaluation
dn: dc=example,dc=com
aci: (targetattr!=userPassword)
  (version 3.0; acl "Allow anonymous read access for anyone";
    allow (read,search,compare) userdn="ldap:///anyone";)

# The following access control rule is valid
dn: dc=example,dc=com
aci: (targetattr="*")
  (version 3.0; acl "Allow users to update their own entries";
    allow (write) userdn="ldap:///self";)

# The following access control rule is valid
dn: dc=example,dc=com
aci: (targetattr="*")
  (version 3.0; acl "Grant full access for the admin user";
    allow (all) userdn="ldap:///uid=admin,dc=example,dc=com";)
```

To Validate ACIs in Another Data Store

The `validate-acis` tool also provides the ability to examine ACIs in data that exists in another Data Store that you are planning to migrate to the UnboundID Data Store. The tool helps to determine whether the UnboundID Server accepts those ACIs.

- To use it in this manner, provide arguments that specify the address and port of the target Data Store, credentials to use to bind, and the base DN of the subtree containing the ACIs to validate.

```
$ bin/validate-acis
```

```
# Processing complete # Total entries examined: 1
# Entries found with ACIs: 1
# Total ACI values found: 3
# Malformed ACI values found: 0
# Other processing errors encountered: 0
```

Migrating ACIs from Sun/Oracle to UnboundID Data Store

This section describes the most important differences in access control evaluation between Sun/Oracle and the UnboundID Data Store.

Support for Macro ACIs

Sun/Oracle provides support for macros ACIs, making it possible to define a single ACI that can be used to apply the same access restrictions to multiple branches in the same basic structure. Macros ACIs are infrequently used and can cause severe performance degradation, so support for macros ACIs is not included in the UnboundID Data Store. However, you can achieve the same result by simply creating the same ACIs in each branch.

Support for the roleDN Bind Rule

Sun/Oracle roles are a proprietary, non-standard grouping mechanism that provide little value over standard grouping mechanisms. The UnboundID Data Store does not support DSEE roles and does not support the use of the `roleDN` ACI bind rule. However, the same behavior can be achieved by converting the DSEE roles to standard groups and using the `groupDN` ACI bind rule.

Targeting Operational Attributes

The Sun/Oracle access control model does not differentiate between user attributes and operational attributes. With Sun/Oracle, using `targetattr="*"` will automatically target both user and operational attributes. Using an exclusion list like `targetattr!="userPassword"` will automatically target all operational attributes in addition to all user attributes except `userPassword`. This behavior is responsible for several significant security holes in which users are unintentionally given access to operational attributes. In some cases, it allows users to do things like exempt themselves from password policy restrictions.

In the UnboundID Data Store, operational attributes are treated differently from user attributes and operational attributes are never automatically included. As such, `targetattr="*"` will target all user attributes but no operational attributes, and `targetattr!="userPassword"` will target all users attributes except `userPassword`, but no operational attributes. Specific operational attributes can be targeted by including the names in the list, like `targetattr="creatorsName||modifiersName"`. All operational attributes can be targeted using the `"+"` character. So, `targetattr="+"` targets all operational attributes but no user attributes and `targetattr="*||+"` targets all user and operational attributes.

Specification of Global ACIs

Both DSEE and UnboundID Data Store support global ACIs, which can be used to define ACIs that apply throughout the server. In servers with multiple naming contexts, this feature allows you to define a rule once as a global ACI, rather than needing to maintain an identical rule in each naming context.

In DSEE, global ACIs are created by modifying the root DSE entry to add values of the `aci` attribute. In the UnboundID Data Store, global ACIs are managed with `dsconfig` referenced in the `global-aci` property of the Access Control Handler.

Defining ACIs for Non-User Content

In DSEE, you can write to the configuration, monitor, changelog, and tasks backends to define ACIs. In the UnboundID Data Store, access control for private backends, like configuration, monitor, schema, changelog, tasks, encryption settings, backups, and alerts, should be defined as global ACIs.

Limiting Access to Controls and Extended Operations

DSEE offers limited support for restricting access to controls and extended operations. To the extent that it is possible to control such access with ACIs, DSEE defines entries with a DN such as "`oid={oid},cn=features,cn=config`" where `{oid}` is the OID of the associated control or extended operation. For example, the following DSEE entry defines ACIs for the persistent search control: "`oid=2.16.840.1.113730.3.4.3,cn=features,cn=config`".

In the UnboundID Data Store, the "`targetcontrol`" keyword can be used to define ACIs that grant or deny access to controls. The "`extop`" keyword can be used to define ACIs that grant or deny access to extended operation requests.

Tolerance for Malformed ACI Values

In DSEE, if the server encounters a malformed access control rule, it simply ignores that rule without any warning. If this occurs, then the server will be running with less than the intended set of ACIs, which may prevent access to data that should have been allowed or, worse yet, may grant access to data that should have been restricted.

The UnboundID Data Store is much more strict about the access control rules that it will accept. When performing an LDIF import, any entry containing a malformed or unsupported access control rule will be rejected. Similarly, any add or modify request that attempts to create an invalid ACI will be rejected. In the unlikely event that a malformed ACI does make it into the data, then the server immediately places itself in lockdown mode, in which the server terminates connections and rejects requests from users without the `lockdown-mode` privilege. Lockdown mode allows an administrator to correct the problem without risking exposure to user data.

Note: Consider running the `import-ldif` tool with the `--rejectFile` option so that you can review any rejected ACIs.

About the Privilege Subsystem

In DSEE, only the root user is exempt from access control evaluation. While administrators can create ACIs that give "normal" users full access to any content, they can also create ACIs that would make some portion of the data inaccessible even to those users. In addition, some tasks can only be accomplished by the root user and you cannot restrict the capabilities assigned to that root user.

The UnboundID Data Store offers a privilege subsystem that makes it possible to control the capabilities available to various users. Non-root users can be granted limited access to certain administrative capabilities, and restrictions can be enforced on root users. In addition, certain particularly risky actions (such as the ability to interact with the server configuration, change another user’s password, impersonate another user, or shutdown and restart the server) require that the requester have certain privileges in addition to sufficient access control rights to process the operation.

Identifying Unsupported ACIs

The UnboundID Data Store provides a `validate-acis` tool that can be used to examine content in an LDIF file or data in another directory server (such as a DSEE instance) to determine whether the access control rules contained in that data are suitable for use in the UnboundID Data Store instance. When migrating data from a DSEE deployment into an UnboundID Data Store instance, the `validate-acis` tool should first be used to determine whether ACIs contained in the data are acceptable. If any problems are identified, then the data should be updated to correct or redefine the ACIs so that they are suitable for use in the UnboundID Data Store.

For more information about using this tool, see *Validating ACIs Before Migrating Data*.

Working with Privileges

In addition to the access control implementation, the UnboundID Data Store includes a privilege subsystem that can also be used to control what users are allowed to do. The privilege subsystem works in conjunction with the access control subsystem so that privileged operations are only allowed if they are allowed by the access control configuration and the user has all of the necessary privileges.

Privileges can be used to grant normal users the ability to perform certain tasks that, in most other directories, would only be allowed for the root user. In fact, the capabilities extended to root users in the UnboundID Data Store are all granted through privileges, so you can create a normal user account with the ability to perform some or all of the same actions as root users.

Administrators can also remove privileges from root users so that they are unable to perform certain types of operations. Multiple root users can be defined in the server with different sets of privileges so that the capabilities that they have are restricted to only the tasks that they need to be able to perform.

Available Privileges

The following privileges are defined in the UnboundID Data Store.

Table 33: Summary of Privileges

Privilege	Description
audit-data-security	This privilege is required to initiate a data security audit on the server, which is invoked by the `audit-data-security` tool.
backend-backup	This privilege is required to initiate an online backup through the tasks interface. The server's access control configuration must also allow the user to add the corresponding entry in the tasks backend.
backend-restore	This privilege is required to initiate an online restore through the tasks interface. The server's access control configuration must also allow the user to add the corresponding entry in the tasks backend.
bypass-acl	This privilege allows a user to bypass access control evaluation. For a user with this privilege, any access control determination made by the server immediately returns that the operation is allowed. Note, however, that this does not bypass privilege evaluation, so the user must have the appropriate set of additional privileges to be able to perform any privileged operation (for example, a user with the `bypass-acl` privilege but without the `config-read` privilege is not allowed to access the server configuration).
bypass-pw-policy	This privilege allows a user entry to bypass password policy evaluation. This privilege is intended for cases where external synchronization might require passwords that violate the password validation rules. The privilege is not evaluated for bind operations so that password policy evaluation will still occur when binding as a user with this privilege.
bypass-read-acl	This privilege allows the associated user to bypass access control checks performed by the server for bind, search, and compare operations. Access control evaluation may still be enforced for other types of operations.
config-read	This privilege is required for a user to access the server configuration. Access control evaluation is still performed and can be used to restrict the set of configuration objects that the user is allowed to see.
config-write	This privilege is required for a user to alter the server configuration. The user is also required to have the `config-read` privilege. Access control evaluation is still performed and can be used to restrict the set of configuration objects that the user is allowed to alter.
disconnect-client	This privilege is required for a user to request that an existing client connection be terminated. The connection is terminated through the disconnect client task. The server's access control configuration must also allow the user to add the corresponding entry to the tasks backend.
jmx-notify	This privilege is required for a user to subscribe to JMX notifications generated by the Data Store. The user is also required to have the `jmx-read` privilege.
jmx-read	This privilege is required for a user to access any information provided by the Data Store via the Java Management Extensions (JMX).
jmx-write	This privilege is required for a user to update any information exposed by the Data Store via the Java Management Extensions (JMX). The user is also required to have the `jmx-read` privilege. Note that currently all of the information exposed by the server over JMX is read-only.
ldif-export	This privilege is required to initiate an online LDIF export through the tasks interface. The server's access control configuration must also allow the user to add the corresponding

Privilege	Description
	entry in the Tasks backend. To allow access to the Tasks backend, you can set up a global ACI that allows access to members of an Administrators group.
ldif-import	This privilege is required to initiate an online LDIF import through the tasks interface. The server's access control configuration must also allow the user to add the corresponding entry in the Tasks backend. To allow access to the Tasks backend, configure the global ACI as shown in the previous description of the `ldif-export` privilege.
lockdown-mode	This privilege allows the associated user to request that the server enter or leave lockdown mode, or to perform operations while the server is in lockdown mode.
modify-acl	This privilege is required for a user to add, modify, or remove access control rules defined in the server. The server's access control configuration must also allow the user to make the corresponding change to the `aci` operational attribute.
password-reset	This privilege is required for one user to be allowed to change another user's password. This privilege is not required for a user to be allowed to change his or her own password. The user must also have the access control instruction privilege to write the `userPassword` attribute to the target entry.
privilege-change	This privilege is required for a user to change the set of privileges assigned to a user, including the set of privileges, which are automatically granted to root users. The server's access control configuration must also allow the user to make the corresponding change to the `ds-privilege-name` operational attribute.
proxied-auth	This privilege is required for a user to request that an operation be performed with an alternate authorization identity. This privilege applies to operations that include the proxied authorization v1 or v2 control operations that include the intermediate client request control with a value set for the client identity field, or for SASL bind requests that can include an authorization identity different from the authentication identity.
server-restart	This privilege is required to initiate a server restart through the tasks interface. The server's access control configuration must also allow the user to add the corresponding entry in the tasks backend.
server-shutdown	This privilege is required to initiate a server shutdown through the tasks interface. The server's access control configuration must also allow the user to add the corresponding entry in the tasks backend.
soft-delete-read	This privilege is required for a user to access a soft-deleted-entry.
stream-values	This privilege is required for a user to perform a stream values extended operation, which obtains all entry DNs and/or all values for one or more attributes for a specified portion of the DIT.
unindexed-search	This privilege is required for a user to be able to perform a search operation in which a reasonable set of candidate entries cannot be determined using the defined index and instead, a significant portion of the database needs to be traversed to identify matching entries. The server's access control configuration must also allow the user to request the search.
update-schema	This privilege is required for a user to modify the server schema. The server's access control configuration must allow the user to update the operational attributes that contain the schema elements.

Privileges Automatically Granted to Root Users

The special abilities that root users have are granted through privileges. Privileges can be assigned to root users in two ways:

- By default, root users may be granted a specified set of privileges. Note that it is possible to create root users which are not automatically granted these privileges by including the `ds-cfg-inherit-default-root-privileges` attribute with a value of FALSE in the entries for those root users.
- Individual root users can have additional privileges granted to them, and/or some automatically-granted privileges may be removed from that user.

The set of privileges that are automatically granted to root users is controlled by the `default-root-privilege-name` property of the Root DN configuration object. By default, this set of privileges includes:

- audit-data-security
- backend-backup
- backend-restore
- bypass-acl
- config-read
- config-write
- disconnect-client
- ldif-export
- lockdown-mode
- modify-acl
- password-reset
- privilege-change
- server-restart
- server-shutdown
- soft-delete-read
- stream-values
- unindexed-search
- update-schema

The privileges not granted to root users by default includes:

- bypass-read-acl
- jmx-read
- jmx-write
- jmx-notify
- proxied-auth
- bypass-pw-policy

The set of default root privileges can be altered to add or remove values as necessary. Doing so will require the `config-read`, `config-write`, and `privilege-change` privileges, as well as either the `bypass-acl` privilege or sufficient permission granted by the access control configuration to make the change to the server's configuration.

Assigning Additional Privileges for Administrators

To allow access to the Tasks backend, set up a global ACI that allows access to members of an Administrators group as follows:

```
$ dsconfig set-access-control-handler-prop \
  --add 'global-aci:(target="ldap:///cn=tasks")(targetattr="*||+")
        (version 5.0; acl "Access to the tasks backend for administrators";
         allow (all) groupdn="ldap:///
         cn=admins,ou=groups,dc=example,dc=com";)'
```

Assigning Privileges to Normal Users and Individual Root Users

Privileges can be granted to normal users on an individual basis. This can be accomplished by adding the `ds-privilege-name` operational attribute to that user's entry with the names of the desired privileges. For example, the following change will grant the `proxied-auth` privilege to the `uid=proxy,dc=example,dc=com` account:

```
dn: uid=proxy,dc=example,dc=com
changetype: modify
add: ds-privilege-name
ds-privilege-name: proxied-auth
```

The user making this change will be required to have the `privilege-change` privilege, and the server's access control configuration must also allow the requester to write to the `ds-privilege-name` attribute in the target user's entry.

This same method can be used to grant privileges to root users that they would not otherwise have through the set of default root privileges. You can also remove default root privileges from root users by prefixing the name of the privilege to remove with a minus sign. For example, the following change grants a root user the `jmx-read` privilege in addition to the set of default root privileges, and removes the `server-restart` and `server-shutdown` privileges:

```
dn: cn=Sync Root User,cn=Root DNs,cn=config
changetype: modify
add: ds-privilege-name
ds-privilege-name: jmx-read
ds-privilege-name: -server-restart
ds-privilege-name: -server-shutdown
```

Note that because root user entries exist in the configuration, this update requires the `config-read` and `config-write` privileges in addition to the `privilege-change` privilege.

Disabling Privileges

Although the privilege subsystem in the UnboundID Data Store is a very powerful feature, it might break some applications if they expect to perform some operation that requires a privilege that they do not have. In the vast majority of these cases, you can work around the problem by simply assigning the necessary privilege manually to the account used by that application. However, if this workaround is not sufficient, or if you need to remove a particular privilege (for example, to allow anyone to access information via JMX without requiring the `jmx-read` privilege), then privileges can be disabled on an individual basis.

The set of disabled privileges is controlled by the `disabled-privilege` property in the global configuration object. By default, no privileges are disabled. If a privilege is disabled, then the server behaves as if all users have that privilege.

Working with Proxied Authorization

The Data Store supports the Proxied Authorization Control (RFC 4370) to allow an authorized LDAP client to authenticate to the server as another user. Typically, LDAP servers are deployed as backend authentication systems that store user credentials and authorization privileges necessary to carry out an operation. Single sign-on (SSO) systems can retrieve user credentials from the Data Store and then issue permissions that allow the LDAP client to request operations under the identity as another user. The use of the proxied authorization control provides a means for client applications to securely process requests without the need to bind or re-authenticate to the server for each and every operation.

The Data Store supports the proxied authorization V1 and V2 request controls. The proxied authorization V1 request control is based on early versions of the draft-weltman-ldapv3-proxy Internet draft and is available primarily for legacy systems. It is recommended that deployments use the proxied authorization V2 request control based on RFC 4370.

The proxied authorization V2 control is used to request that the associated operation be performed as if it has been requested by some other user. This control may be used in conjunction with add, delete, compare, extended, modify, modify DN, and search requests. In that case, the associated operation will be processed under the authority of the specified authorization identity rather than the identity associated with the client connection (i.e., the user as whom that connection is bound). The target authorization identity for this control is specified as an "authzid" value, which should be either "dn:" followed by the distinguished name of the target user, or "u:" followed by the username.

Note that because of the inherent security risks associated with the use of the proxied authorization control, most directory servers that support its use enforce strict restrictions on the users that are allowed to request this control. If a user attempts to use the proxied authorization V2 request control and does not have sufficient permission to do so, then the server will return a failure response with the `AUTHORIZATION_DENIED` result code.

Configuring Proxied Authorization

Configuring proxied authorization requires a combination of access control instructions and the `proxied-auth` privilege to the entry that will perform operations as another user.

Note: You cannot use the `cn=Directory Manager` root DN as a proxying DN.

To Configure Proxied Authorization

1. Open a text editor and create a user entry, such as `uid=clientApp`, which is the user entry that will request operations as another user, `uid=admin,dc=example,dc=com`. The client application entry also requires the `proxied-auth` privilege to allow it to run proxied authorization requests. Save the file as `add-user.ldif`.

```
dn: ou=Applications,dc=example,dc=com
objectClass: top
objectClass: organizationalUnit
objectClass: extensibleObject
ou: Admins
ou: Applications

dn: uid=clientApp,ou=Applications,dc=example,dc=com
objectClass: top
objectClass: person
objectClass: organizationalPerson
objectClass: inetOrgPerson
givenName: Client
uid: clientApp
cn: Client App
sn: App
userPassword: password
ds-privilege-name: proxied-auth
```

2. Add the file using `ldapmodify`.

```
$ bin/ldapmodify --defaultAdd --filename add-user.ldif
```

3. The client application targets a specific subtree in the Directory Information Tree (DIT) for its operations. For example, some client may need access to an accounts subtree to retrieve customer information. Another client may need access to another subtree, such as a subscriber subtree. In this example, we want the client application to target the `ou=People,dc=example,dc=com` subtree. To allow the target, open a text editor and create an LDIF file to assign an ACI to that branch so that the client app user can access it as a proxy auth user. Note that the ACI should be on a single line of text. The example shows the ACI over multiple lines for readability. Add the file using the `ldapmodify`.

```
dn: ou=People,dc=example,dc=com
changetype: modify
add: aci
aci:  (version 3.0; acl "People Proxy Access"; allow(proxy)
  userdn="ldap:///uid=clientApp,ou=Applications,dc=example,dc=com";)
```

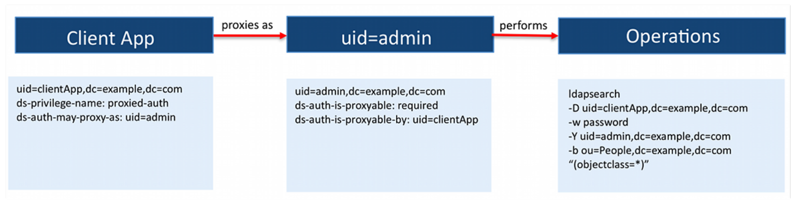
4. Run a search to test the configuration using the bind DN `uid=clientApp` and the `proxyAs` option, which requires that you prefix "dn:" to the proxying entry or "u:" to the username. The `uid=clientApp` binds to the server and proxies as `uid=admin` to access the `ou=People,dc=example,dc=com` subtree.

```
$ bin/ldapsearch --port 1389 \
  --bindDN "uid=clientApp,ou=Applications,dc=example,dc=com" \
  --bindPassword password \
  --proxyAs "dn:uid=admin,dc=example,dc=com" \
  --baseDN ou=People,dc=example,dc=com \
  "(objectclass=*)"
```

Restricting Proxy Users

The Data Store provides a set of operational attributes that restricts the proxied authorization capabilities of a client application and its proxyable target entry. When present in an entry, the Data Store evaluates each operational attribute together to form a whitelist of potential users that can be proxied. If none of those attributes is present, then the user may potentially proxy as anyone.

The Data Store supports a two-tier provision system that, when configured, can restrict specific users for proxied authorization. The first tier is a set of `ds-auth-may-proxy-as-*` operational attributes on the client entry that will bind to the server and carry out operations under the identity of another user. The second tier is a set of `ds-auth-is-proxyable-*` operational attributes on the user entry that defines whether access is allowed, prohibited, or required by means of proxied authorization. If allowed or required, the attributes define which client entries can proxy as the user.



```
uid=clientApp,dc=example,dc=com
ds-privilege-name: proxied-auth
ds-auth-may-proxy-as: uid=admin
```

```
uid=admin,dc=example,dc=com
ds-auth-is-proxyable: required
ds-auth-is-proxyable-by: uid=clientApp
```

```
ldapsearch
-D uid=clientApp,dc=example,dc=com
-w password
-Y uid=admin,dc=example,dc=com
-b ou=People,dc=example,dc=com
“(objectclass=*)”
```

Figure 8: Proxying Operational Attributes

For example, if a client application, such as `uid=clientApp`, is requesting to search the `ou=People,dc=example,dc=com` branch as the user `uid=admin`, the command would look like this:

```
ldapsearch --bindDN uid=clientApp,dc=example,dc=com \
--bindPassword password \
--proxyAs uid=admin,dc=example,dc=com \
--baseDN ou=People,dc=example,dc=com \
"(object-class=*)
```

At bind, the Data Store evaluates the list of users in the `uid=clientApp` entry based on the presence of any `ds-auth-may-proxy-as-*` attributes. In the figure below, the `uid=clientApp` entry has a `ds-auth-may-proxy-as` attribute with a value, `uid=admin`, which means that the client app user may proxy only as the `uid=admin` account. Next, the server confirms that `uid=admin` is in the list of proxyable users and then evaluates the `ds-auth-is-proxyable-*` attributes present in the `uid=admin` entry. These attributes determine the list of restricted users that either are allowed, prohibited, or required to proxy as the `uid=admin` entry. In this case, the `uid=admin` entry has the `ds-auth-is-proxyable` attribute with a value of "required", which indicates that the entry can only be accessed by means of proxied authorization. The `uid=admin` entry also has the `ds-auth-is-proxyable-by` attribute with a value of `uid=clientApp`, which indicates it can only be requested by the `uid=clientApp` entry. Once both sets of attributes have been confirmed, the `uid=clientApp` can bind to the server as the authenticated user. From this point, the Data Store performs ACI evaluation on the branch to determine if the requested user has access rights to the branch. If the branch is accessible by the `uid=clientApp` entry, and then the search request is processed.

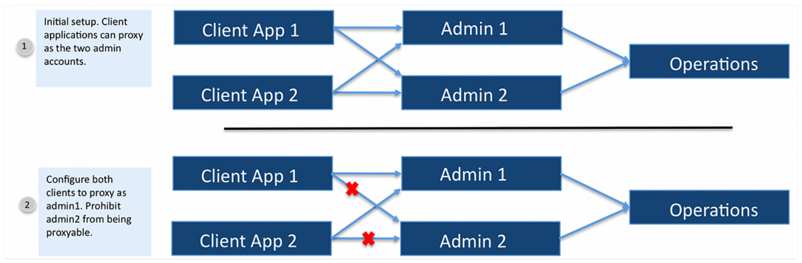

1
Initial setup. Client applications can proxy as the two admin accounts.
Client App 1
Client App 2
Admin 1
Admin 2
Operations
2
Configure both clients to proxy as admin1. Prohibit admin2 from being proxyable.
Client App 1
Client App 2
Admin 1
Admin 2
Operations

Figure 9: Proxying Operational Attributes Examples

About the ds-auth-may-proxy-as-* Operational Attributes

The Data Store first evaluates the list of potential users that can be proxied for the authenticated user based on the presence of the `ds-auth-may-*` operational attributes in the entry. These operational attributes are multi-valued and are evaluated together if all are present in an entry:

- **ds-auth-may-proxy-as**. Specifies the user DNs that the associated user is allowed to proxy as. For instance, based on the previous example, you could specify in the `uid=clientApp` entry that it can proxy operations as `uid=admin` and `uid=agent1`.

  ```
  dn: uid=clientApp,ou=Applications,dc=example,dc=com
  objectClass: top
  ...
  ds-privilege-name: proxied-auth
  ds-auth-may-proxy-as: uid=admin,dc=example,dc=com
  ds-auth-may-proxy-as: uid=agent1,ou=admins,dc=example,dc=com
  ```

- **ds-auth-may-proxy-as-group**. Specifies the group DNs and its group members that the associated user is allowed to proxy as. For instance, you could specify that the potential users that the `uid=clientApp` entry can proxy as are those members who are present in the group `cn=Agents,ou=Groups,dc=example,dc=com`. This attribute is multi-valued, so that more than one group can be specified. Nested static and dynamic groups are also supported.

  ```
  dn: uid=clientApp,ou=Applications,dc=example,dc=com
  objectClass: top
  ...
  ds-privilege-name: proxied-auth
  ds-auth-may-proxy-as-group: cn=Agents,ou=Groups,dc=example,dc=com
  ```

- **ds-auth-may-proxy-as-url**. Specifies the DNs that are returned based on the criteria defined in an LDAP URL that the associated user is allowed to proxy as. For instance, the attribute specifies that the client can proxy as those entries that match the criteria in the LDAP URL. This attribute is multi-valued, so that more than one LDAP URL can be specified.

  ```
  dn: uid=clientApp,ou=Applications,dc=example,dc=com
  objectClass: top
  ...
  ds-privilege-name: proxied-auth
  ds-auth-may-proxy-as-url: ldap:///ou=People,dc=example,dc=com??sub?(l=austin)
  ```

About the ds-auth-is-proxyable-* Operational Attributes

After the Data Store has evaluated the list of users that the authenticated user can proxy as, the server checks to see if the requested authorized user is in the list. If the requested authorized user is present in the list, then the server continues processing the proxable attributes in the entry. If the requested authorized user is not present in the list, the bind will fail.

The operational attributes on the proxying entry are as follows:

- **ds-auth-is-proxyable**. Specifies whether the entry is proxyable or not. Possible values are: "allowed" (operation may be proxied as this user), "prohibited" (operations may not be proxied as this user), "required" (indicates that the account will not be allowed to authenticate directly but may only be accessed by some form of proxied authorization).

- **ds-auth-is-proxyable-as**. Specifies any users allowed to use this entry as a target of proxied authorization.
- **ds-auth-is-proxyable-as-group**. Specifies any groups allowed to use this entry as a target of proxied authorization. Nested static and dynamic groups are also supported.
- **ds-auth-is-proxyable-as-url**. Specifies the LDAP URLs that are used to determine any users that are allowed to use this entry as a target of proxied authorization.

Restricting Proxied Authorization for Specific Users

To illustrate how the proxied authorization operational attributes work, it is best to set up a simple example where two LDAP clients, `uid=clientApp1` and `uid=clientApp2` can freely proxy two administrator accounts, `uid=admin1` and `uid=admin2`. We will add the `ds-auth-may-proxy-as-*` and the `ds-auth-is-proxyable-*` attributes to these entries to restrict how each account can use proxied authorization. For example, the two client applications will continue to proxy the `uid=admin1` account but the `uid=admin2` account will no longer be able to be used as a proxied entry.

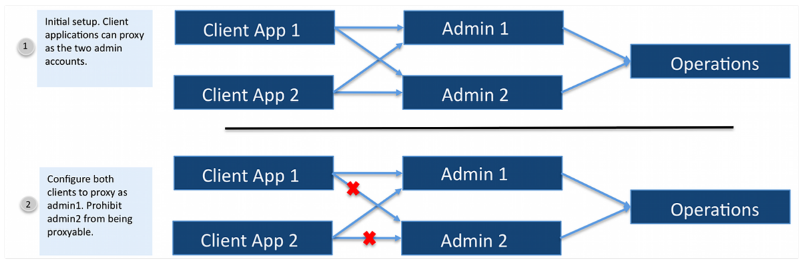

1
Initial setup. Client applications can proxy as the two admin accounts.
Client App 1
Client App 2
Admin 1
Admin 2
Operations
2
Configure both clients to proxy as admin1. Prohibit admin2 from being proxyable.
Client App 1
Client App 2
Admin 1
Admin 2
Operations

Figure 10: Proxy Users Example Scenario

To Restrict Proxied Authorization for Specific Users

1. For this example, set up two user entries, `uid=clientApp1` and `uid=clientApp2`, which will be proxying the `uid=admin1` and `uid=admin2` accounts to access the `ou=People,dc=example,dc=com` subtree. Both entries have the `proxied-auth` privilege assigned to it. Open a text editor and create an LDIF file. Add the file using the `ldapmodify` tool. Note that "..." indicates that other attributes present in the entry are not included in the example for readability purposes.

```
dn: uid=clientApp1,ou=Applications,dc=example,dc=com
objectClass: top
...
ds-privilege-name: proxied-auth

dn: uid=clientApp2,ou=Applications,dc=example,dc=com
objectClass: top
...
ds-privilege-name: proxied-auth
```

2. Next, assign the ACI for each client application to the subtree, `ou=People,dc=example,dc=com`. Note that the ACIs should be on one line of text. The example displays the ACIs over multiple lines for readability.

```
dn: ou=People,dc=example,dc=com
aci: (version 3.0; acl "People Proxy Access"; allow(proxy)
       userdn="ldap:///uid=clientApp1,ou=Applications,dc=example,dc=com";)
aci: (version 3.0; acl "People Proxy Access"; allow(proxy)
       userdn="ldap:///uid=clientApp2,ou=Applications,dc=example,dc=com";)
```

3. Run a search for each entry. In this example, assume that there are two admin accounts: `admin1` and `admin2` that have full access rights to user attributes. You should be able to proxy as the `uid=admin1` and `uid=admin2` entries to access the subtree for both clients.

```
$ bin/ldapsearch --port 1389 \
  --bindDN "uid=clientApp1,ou=Applications,dc=example,dc=com" \
  --bindPassword password \
  --proxyAs "dn:uid=admin1,dc=example,dc=com" \
  --baseDN ou=People,dc=example,dc=com \
  "(objectclass=*)"

$ bin/ldapsearch --port 1389 \
  --bindDN "uid=clientApp2,ou=Applications,dc=example,dc=com" \
  --bindPassword password \
  --proxyAs "dn:uid=admin2,dc=example,dc=com" \
  --baseDN ou=People,dc=example,dc=com \
  "(objectclass=*)"
```

4. Next, limit the proxied authorization capabilities for each client application. Update the `uid=clientApp1` entry to add the `ds-auth-may-proxy-as` attribute. In this example, the `ds-auth-may-proxy-as` attribute specifies that `uid=clientApp1` can proxy as the `uid=admin1` entry. Open a text editor, create the following LDIF file, save it, and add it using `ldapmodify`. Note that `ds-auth-may-proxy-as` is multi-valued:

```
dn: uid=clientApp1,ou=Applications,dc=example,dc=com
changetype: modify
add: ds-auth-may-proxy-as
ds-auth-may-proxy-as: uid=admin1,dc=example,dc=com
```

5. Repeat the previous step for the `uid=clientApp2` entry, except specify the `ds-auth-may-proxy-as-url`. The client entry may proxy as any DN that matches the LDAP URL.

```
dn: uid=clientApp2,ou=Applications,dc=example,dc=com
changetype: modify
add: ds-auth-may-proxy-as-url
ds-auth-may-proxy-as-url: ldap:///dc=example,dc=com??sub?(uid=admin*)
```

6. Next, we want to create a group of client applications that has `uid=clientApp1` and `uid=clientApp2` as its `uniquemembers` to illustrate the use of the `ds-auth-proxyable-by-group` attribute. In this example, set up a static group using the `groupOfUniqueNames` object class.

```
dn: ou=Groups,dc=example,dc=com
objectClass: top
objectClass: organizationalunit
ou: groups

dn: cn=Client Applications,ou=Groups,dc=example,dc=com
objectClass: top
objectClass: groupOfUniqueNames
cn: Client Applications
ou: groups
uniquemember: uid=clientApp1,ou=Applications,dc=example,dc=com
uniquemember: uid=clientApp2,ou=Applications,dc=example,dc=com
```

7. Update the `uid=admin1` entry to provide the DN that it may be proxied as. Add the `ds-auth-is-proxyable` and the `ds-auth-is-proxyable-by` attributes. For instance, we make the `uid=admin1` a required proxyable entry, which means that it can only be accessed by some form of proxied authorization. Then, specify each DN that can proxy as `uid=admin1` using

the `ds-auth-is-proxyable-by`. Open a text editor, create the following LDIF file, save it, and add it using `ldapmodify`. Note that the example includes all three types of `ds-auth-is-proxable-by-*` attributes as an illustration, but, in an actual deployment, only one type of attribute is necessary if they all target the same entries.

```
dn: uid=admin1,dc=example,dc=com
changetype: modify
add: ds-auth-is-proxyable
ds-auth-is-proxyable: required
-
add: ds-auth-is-proxyable-by
ds-auth-is-proxyable-by: ou=clientApp1,ou=Applications,dc=example,dc=com
ds-auth-is-proxyable-by: ou=clientApp2,ou=Applications,dc=example,dc=com
-
add: ds-auth-is-proxyable-by-group
ds-auth-is-proxyable-by-group: cn=Client Applications,ou=Groups,dc=example,dc=com
-
add: ds-auth-is-proxyable-by-url
ds-auth-is-proxyable-by-url: ldap:///ou=Applications,dc=example,dc=com??sub?
(uid=clientApp*)
```

8. Next, prohibit proxying for the `uid=admin2` entry by setting the `ds-auth-is-proxyable` to prohibited. Open a text editor, create the following LDIF file, save it, and add it using `ldapmodify`.

```
dn: uid=admin2,dc=example,dc=com
changetype: modify
add: ds-auth-is-proxyable
ds-auth-is-proxyable: prohibited
```

9. Run a search using the proxied account. For example, run a search first with `uid=clientApp1` or `uid=clientApp2` that proxies as `uid=admin1` to return a successful operation. However, if you run a search for `uid=clientApp1` that proxies as `uid=admin2`, as seen below, you will see an "authorization denied" message due to `uid=admin2` not matching the list of potential entries that can be proxied. The `ds-auth-may-proxy-as-*` attributes specify that the client can only proxy as `uid=admin1`:

```
$ bin/ldapsearch --port 1389 \
  --bindDN "uid=clientApp1,ou=Applications,dc=example,dc=com" \
  --bindPassword password \
  --proxyAs "dn:uid=admin2,dc=example,dc=com" \
  --baseDN ou=People,dc=example,dc=com \
  "(objectclass=*)"
```

```
One of the operational attributes (ds-auth-may-proxy-as,
ds-auth-may-proxy-as-group, ds-auth-may-proxy-as-url) in user entry
'uid=clientApp1,ou=Applications,dc=example,dc=com' does not allow
that user to be proxied as user 'uid=admin2,dc=example,dc=com'

Result Code:  123 (Authorization Denied)

Diagnostic Message:  One of the operational attributes (ds-auth-may-proxy-as,
ds-auth-may-proxy-as-group, ds-auth-may-proxy-as-url) in user entry
'uid=clientApp1,ou=Applications,dc=example,dc=com' does not allow that
user to be proxied as user 'uid=admin2,dc=example,dc=com'
```

10. Run another search using `uid=clientApp2`, which attempts to proxy as `uid=admin2`. You will see an "authorization denied" message due to the presence of the `ds-auth-is-proxyable:prohibited` operational attribute, which states that `uid=admin2` is not available for proxied authorization.

```
$ bin/ldapsearch --port 1389 \
  --bindDN "uid=clientApp2,ou=Applications,dc=example,dc=com" \
  --bindPassword password \
  --proxyAs "dn:uid=admin2,dc=example,dc=com" \
  --baseDN ou=People,dc=example,dc=com \
  "(objectclass=*)"
```

```
The 'ds-auth-is-proxyable' operational attribute
in user entry 'uid=admin2,dc=example,dc=com' indicates that
user may not be accessed via proxied authorization

Result Code:  123 (Authorization Denied)

Diagnostic Message: The 'ds-auth-is-proxyable' operational
attribute in user entry 'uid=admin2,dc=example,dc=com' indicates
that user may not be accessed via proxied authorization
```

Chapter 18 Managing the Schema

This chapter presents a basic summary of the supported schema components on the UnboundID Data Store and procedures to extend the schema with new element definitions. The chapter presents the following topics:

Topics:

About the Schema

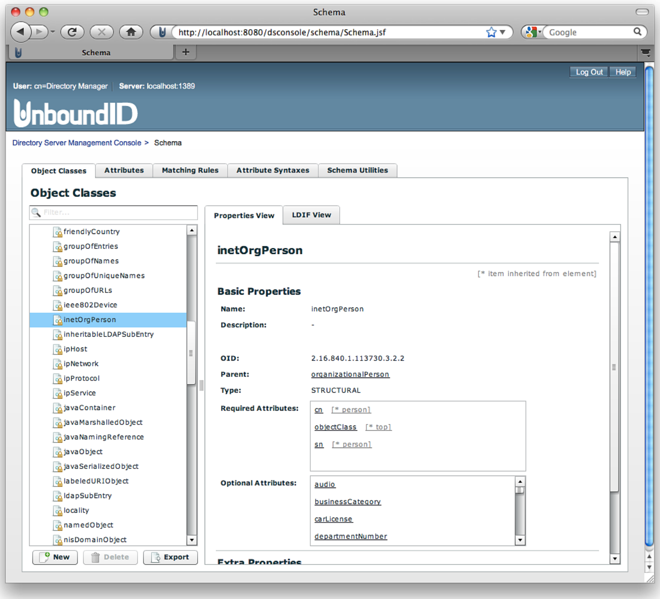
A schema is the set of data store rules that define the structures, contents, and constraints of a Directory Information Tree (DIT). The schema guarantees that any new data entries or modifications meet and conform to these predetermined set of definitions. It also reduces redundant data definitions and provides a uniform method for clients or applications to access its Data Store objects.

The UnboundID Data Store ships with a default set of read-only schema files that define the core properties for the Data Store. The Management Console provides a Schema Editor that administrators can use to view existing schema definitions and add new custom schema elements to their DIT. Any attempt to alter a schema element defined in a read-only file or add a new schema element to a read-only file will result in an "Unwilling to Perform" result. All custom schema definitions are stored in user-defined files, for example, `99-user.ldif`, which are marked as read-only through the server configuration.

About the Schema Editor

The Management Console provides a user-friendly graphical editor with tabs to manage any existing schema component related to your DIT: object classes, attributes, matching rules, attribute syntaxes, and schema utilities. The **Object Classes** and **Attribute** tabs allow you to view your existing definitions as well as add, modify, or remove custom schema elements. Read-only schema elements, such as those in the Standard folder, appear with a tiny "lock" symbol next to them. Read-write schema elements, such as those in the Custom folder, appear without a "lock" symbol.

The **Matching Rules** and **Attribute Syntaxes** tabs are read-only and provide a comprehensive listing of all of the elements necessary to define new schema elements. The **Schema Utilities** tab provides a schema validator that allows you to load a schema file or perform a cut-and-paste operation on the schema definition to verify that it meets the proper schema and ASN.1 formatting rules. The **Utilities** tab also supports schema file imports by first checking for proper syntax compliance and generating any error message if the definitions do not meet specification.



Object Classes

inetOrgPerson

[* item inherited from element]

Basic Properties

Name: inetOrgPerson
Description: -
OID: 2.16.840.1.113730.3.2.2
Parent: organizationalPerson
Type: STRUCTURAL
Required Attributes: cn [* person], objectClass [* top], sn [* person]
Optional Attributes: audio, businessCategory, carLicense, departmentNumber

Figure 11: Example Schema Editor Screen

The Schema Editor provides two views for each definition: **Properties View** and **LDIF View**. The **Properties View** breaks down the schema definition by its properties and shows any inheritance relationships among the attributes. The **LDIF View** shows the equivalent schema definition in ASN.1 format, which includes the proper text spacing required for each schema element. Buttons to create, delete, or export any schema definitions are available under the left pane. Editable schema definitions will have an **Edit** button in the top right corner of a specific schema element window.

To use the Management Console, you must have the console installed on your system. See *Installing the Management Console*. To use the schema editor, you must have the proper privileges to view and modify the schema. See *Managing Root User Accounts* for more information on privileges.

Default Data Store Schema Files

The UnboundID Data Store stores its schema as a set of LDIF files for a Data Store instance in the `<server-root>/config/schema` directory. The Data Store reads the schema files in alphanumeric order at startup, so that the `00-core.ldif` file is read first, then `01-pwpolicy.ldif`, and then the rest of the files. Custom schema files should be named so that they are loaded in last. For example, custom schema elements could be saved in a file labelled `99-user.ldif`, which loads after the default schema files are read at startup.

The Data Store then uses the schema definitions to determine any violations that may occur during add, modify, or import requests. Clients applications check the schema (i.e., matching rule definitions) to determine the assertion value algorithm used in comparison or search operations.

The default set of schema files are present at installation and should not be modified. Modifying the default schema files could result in an inoperable server.

The schema files have the following descriptions:

Table 34: Default Schema Files

Schema Files	Description
00-core.ldif	Governs the Data Store's core functions.
01-pwpolicy.ldif	Governs password policies.
02-config.ldif	Governs the Data Store's configuration.
03-changelog.ldif	Governs the Data Store's change log.
03-rfc2713.ldif	Governs Java objects.
03-rfc2714.ldif	Governs Common Object Request Broker Architecture (CORBA) object references.
03-rfc2739.ldif	Governs calendar attributes for vCard.
03-rfc2926.ldif	Governs Server Location Protocol (SLP) mappings to and from LDAP schemas.
03-rfc2985.ldif	Governs PKCS #9 public-key cryptography.
03-rfc3112.ldif	Governs LDAP authentication passwords.
03-rfc3712.ldif	Governs printer services.
03-uddiv3.ldif	Governs web services registries of SOA components.
04-rfc2307bis.ldif	Governs mapping entities from TCP/IP and UNIX into X.500 entries.

Extending the Data Store Schema

The UnboundID Data Store stores its schema as LDIF files in the `<server-root>/config/schema` directory. At startup, the Data Store reads the schema files once in alphanumeric order starting with `00-core.ldif` and ending with any custom schema definition files, such as `99-user.ldif` if present.

You can extend the schema to include additional customizations necessary for your Data Store data using one of the following methods:

- **Using the Schema Editor**. This method is the easiest and quickest way to set up a schema definition and have it validated for the correct ASN.1 formatting. The Editor lets you define your schema properties, load your custom file, or perform a cut-and-paste operation on a new schema element. If any errors exist in the file, the Schema Editor generates an error message if the schema definitions do not pass compliance.

- **Using a Custom Schema File**. You can create a custom schema file with your new definitions using a text editor, save it as `99-user.ldif`, and then import the file using the Schema Editor or the `ldapmodify` tool. You must name the custom LDIF file with a high two-digit number prefix, so that the Data Store will read the file AFTER the core schema files are read at startup. For example, you can name the file, `99-myschema.ldif`, etc. See the next section, *General Tips on Extending the Schema* to see the requirements for naming each file.

- **Using the Command Line**. If you have a small number of additions, you can extend the schema over LDAP and from the command line using the `ldapmodify` tool. The Data Store writes the new schema changes to a file `99-user.ldif` in the `<server-root>/config/schema` directory. However, this method can be cumbersome as schema definitions require strict adherence to text spacing and white space characters.

General Tips on Extending the Schema

You should consider the following points when extending the schema:

- Never modify the default schema files as doing so could damage the Data Store's processing capabilities.
- Define all attributes first before they can be used in an object class. If you are using the Schema Editor to add new schema elements, then you can use the Quick Add Attributes option when defining new objectclasses.
- Define the parent object class first before creating object classes that inherit from the parent.
- The schema file naming syntax requires that custom schema files must begin with exactly two digits followed by a non-digit character, followed by a zero or more characters and ending with ".ldif". Note that the two digits do not need to be followed by a dash ("-"). Any files that do not meet this criteria will be ignored and either a NOTICE or SEVERE_WARNING message will be logged.

  Any file in the `<server-root>/config/schema` directory with a name that starts with "." or with a name that ends with a tilde ('~'), ".swp", or ".tmp" will generate a NOTICE message indicating that temporary files will be ignored. Any other file that does not meet the naming criteria will generate a SEVERE_WARNING message indicating that it will be ignored.
- Define custom attributes and object classes in one file. Typically, this file will be the `99-user.ldif`. You can specify a different file name to which the Data Store writes using the X-SCHEMA-FILE element and the file name in the definition. For example:

  ```
  add: attributeTypes attributeTypes: ( 1.3.6.1.4.1.32473.3.1.9.1
    NAME 'contractorStatus'
    EQUALITY booleanMatch
    SYNTAX 1.3.6.1.4.1.1466.115.121.1.7
    SINGLE-VALUE
    USAGE userApplications
    X-ORIGIN 'Data Store Example'
    X-SCHEMA-FILE '99-custom.ldif' )
  ```
- Pay special attention to the white space characters in the schema definitions, where WSP means zero or more space characters, and SP means one or more space characters. The LDIF specification states that LDIF parsers should ignore exactly one space at the beginning of each continuation line, since continuation lines must begin with a space character. Thus, if you define a new schema definition with each keyword on a separate continuation line, you should add two spaces before an element keyword to be safe. For example, the following attribute definition has two spaces before the keywords: NAME, SUP, and X-ORIGIN.

  ```
  attributeTypes: ( 2.5.4.32 NAME 'owner' SUP distinguishedName X-ORIGIN 'RFC 4519' )
  ```
- In a replicated topology, any new schema additions will be replicated to other replication servers to their respective Schema backend. The additions will be written to the file specified by the X-SCHEMA-FILE extension or written to `99-user.ldif` if no file is specified.

Managing Attribute Types

An attribute type determines the important properties related to an attribute, such as specifying the matching and syntax rules used in value comparisons. An attribute description consists of an attribute type and a set of zero or more options. Options are short, case-insensitive text strings that differentiate between attribute descriptions. For example, the LDAPv3 specification defines only one type of option, the tagging option, which can be used to tag language options, such as `cn;lang-de;lang-sp` or binary data, such as `userCertificate;binary`. You can also extend the schema by adding your own attribute definitions.

Attributes have the following properties:

- Attributes can be user attributes that hold information for client applications, or operational attributes that are used for administrative or server-related purposes. You can specify the purpose of the attribute by the `USAGE` element.
- Attributes are multi-valued by default. Multi-valued means that attributes can contain more than one value within an entry. Include the `SINGLE-VALUE` element if the attribute should contain at most one value within an entry.
- Attributes can inherit properties from a parent attribute as long as they both have the same USAGE, and the child attribute has the same `SYNTAX` or its `SYNTAX` allows values which are a subset of the values allowed by the `SYNTAX` of the parent attribute. For example, the surname (`sn`) attribute is a child of the name attribute.

Attribute Type Definitions

New attribute types do not require server code extensions if the provided matching rules and attribute syntaxes are used in the definitions. Administrators can create new attributes using the Schema Editor, which stores the definition in a file in the `<server-root>/config/schema` directory. See *Extending the Data Store Schema* for more information.

The formal specification for attribute types is provided in RFC 4512, section 4.1.2 as follows:

```
AttributeTypeDescription = "(" wsp; Left parentheses followed by a white space
numericoid                         ; Required numeric object identifier
[ sp "NAME" sp qdescrs ]           ; Short name descriptor as alias for the OID
[ sp "DESC" sp qdstring ]          ; Optional descriptive string
[ sp "OBSOLETE" ]                  ; Determines if the element is active
[ sp "SUP" sp oid ]                ; Specifies the supertype
[ sp "EQUALITY" sp oid ]           ; Specifies the equality matching rule
[ sp "ORDERING" sp oid ]           ; Specifies ordering matching rule
[ sp "SUBSTR" sp oid ]             ; Specifies substrings matching rule
[ sp "SYNTAX" sp oidlen ]          ; Numeric attribute syntax with minimum upper bound
                                   ;  length expressed in {num}
[ sp "SINGLE-VALUE" ]              ; Specifies if the attribute is single valued in
                                   ;  the entry
[ sp "COLLECTIVE" ]                ; Specifies if it is a collective attribute
[ sp "NO-USER-MODIFICATION" ]      ; Not modifiable by external clients
[ sp "USAGE" sp usage ]            ; Application usage
extensions wsp ")"                 ; Extensions followed by a white space and ")"

usage = "userApplications" /       ; Stores user data
  "directoryOperation" /           ; Stores internal server data
  "distributedOperation" /         ; Stores operational data that must be synchronized
                                   ; across servers
  "dSAOperation"                   ; Stores operational data specific to a server and
```

```
                                  ; should not be synchronized across servers
```

The following extensions are specific to the UnboundID Data Store and are not defined in RFC 4512:

```
extensions = /
"X-ORIGIN" /              ; Specifies where the attribute type is defined
"X-SCHEMA-FILE" /         ; Specifies which schema file contains the definition
"X-APPROX" /              ; Specifies the approximate matching rule
"X-ALLOWED-VALUE" /       ; Explicitly specifies the set of allowed values
"X-VALUE-REGEX" /         ; Specifies the set of regular expressions to compare against
                          ;  attribute values to determine acceptance
"X-MIN-VALUE-LENGTH" /    ; Specifies the minimum character length for attribute values
"X-MAX-VALUE-LENGTH" /    ; Specifies the maximum character length for attribute values
"X-MIN-INT-VALUE" /       ; Specifies the minimum integer value for the attribute
"X-MAX-INT-VALUE" /       ; Specifies the maximum integer value for the attribute
"X-MIN-VALUE-COUNT" /     ; Specifies the minimum number of allowable values for the
                          ;  attribute
"X-MAX-VALUE-COUNT" /     ; Specifies the maximum number of allowable values for the
                          ;  attribute
"X-READ-ONLY"             ; True or False. Specifies if the file that contains the
                          ;  schema element is marked as read-only in the server
                          ;  configuration.
```

Basic Properties of Attributes

The Basic Properties section displays the standard elements in schema definition.

Table 35: Basic Properties of Attributes

Attributes	Description
Name	Specifies the globally unique name.
Description	Specifies an optional definition that describes the attribute and its contents. The analogous LDIF equivalent is "DESC".
OID	Specifies the object identifier assigned to the schema definition. You can obtain a specific OID for your company that allows you to define your own object classes and attributes from IANA or ANSI.
Syntax	Specifies the attribute syntax used. For example, the `userPassword` attribute uses the User Password Syntax whereas the `authPassword` attribute uses the Authentication Password Syntax.
Parent	Specifies the schema definition's parent or supertype if any. The analogous LDIF equivalent is "SUP".
Multivalued	Specifies if the attribute can appear more than once in its containing object class.
Required By Class	Specifies any object classes that require the attribute.
Allowed By Class	Specifies any object classes that can optionally use the attribute.
Value Restrictions	Specifies any restriction on the value of the attribute.

The Extra Properties section provides additional auxiliary information associated with the attribute.

Table 36: Basic Properties of Attributes

Attributes	Description
Aliases	Specifies any shortform alias names, if any. In theory, you could have any number of shortform names as long as they are all unique. The analogous LDIF equivalent appears as the secondary element with the NAME element. For example, NAME ('sn' 'surname').

Attributes	Description
Origin	Specifies the origin of the schema definition. Typically, it could refer to a specific RFC or company.
Stored in File	Specifies the schema file that stores the definition in the `<server-root>/config/schema` folder.
Usage	Specifies the intended use of the attribute. Choices are the following: ➢ userApplications ➢ directoryOperation ➢ distributedOperation ➢ dSAOperation
User-Modifiable	Specifies if the attribute can be modified by an authorized user.
Obsolete	Specifies if the schema definition is obsolete or not.
Matching Rules	Specifies the associated matching rules for the attribute.

Viewing Attributes

The Schema Editor displays all of the attribute types on your data store instance. It shows the basic properties that are required elements plus the extra properties that are allowed within the attribute definition.

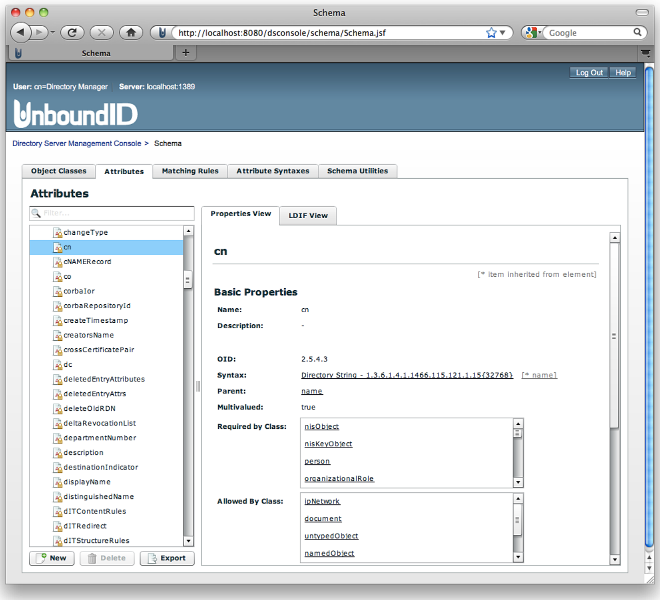
To View Attribute Types Using the Schema Editor

1. Start the Management Console. Check that the Data Store instance associated with the console is also running.

2. On the main menu, click **Schema**.

3. On the **Schema Editor**, click the **Attributes** tab, and then click the `Standard` folder to view the attribute definitions. The `Custom` folder holds user-defined schema elements if any.

4. Click a specific attribute to view its definition. In this example, click the `sn` attribute. In the **Required by Class** and **Allowed By Class** fields, you can click on the objectclass to view it.



Attributes

cn

[* item inherited from element]

Basic Properties

Name: cn

Description: -

OID: 2.5.4.3

Syntax: Directory String - 1.3.6.1.4.1.1466.115.121.1.15{32768} [* name]

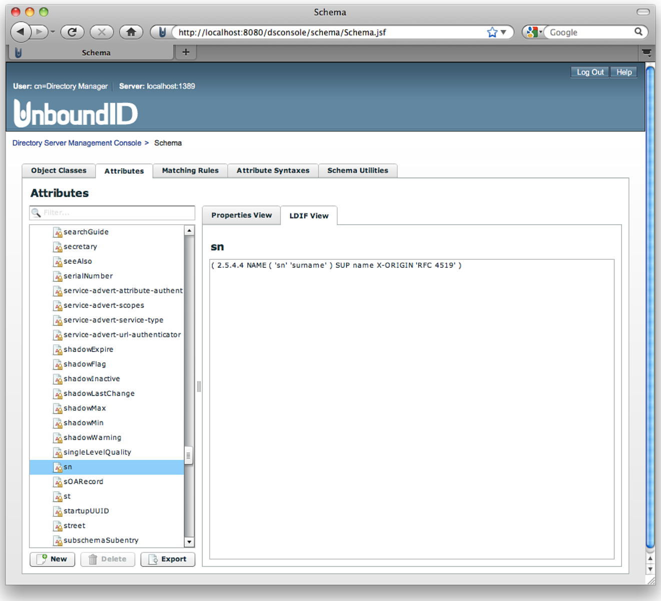
Parent: name

Multivalued: true

Required by Class: nisObject, nisKeyObject, person, organizationalRole

Allowed By Class: ipNetwork, document, untypedObject, namedObject

5. Click the **LDIF View** tab to see the equivalent attribute definition in ASN.1 format.



Attributes

sn

```
( 2.5.4.4 NAME ( 'sn' 'surname' ) SUP name X-ORIGIN 'RFC 4519' )
```

To View Attribute Types over LDAP

- Use `ldapsearch` to view a multi-valued operational attribute `attributeTypes`, which publishes the definitions on the Data Store. The attribute is stored in the subschema subentry.

```
$ bin/ldapsearch --baseDN cn=schema --searchScope base \
  "(objectclass=*)" attributeTypes
```

To View a Specific Attribute Type over LDAP

- Use `ldapsearch` with the `--dontWrap` option and use the `grep` command to search for a specific attribute.

```
$ bin/ldapsearch --baseDN cn=schema \
  --searchScope base --dontWrap "(objectclass=*)" \
  attributeTypes | grep 'personalTitle'
```

Creating a New Attribute Using the Schema Editor

The Management Console’s Schema Editor provides the easiest and quickest way to add a new definition to your existing schema. The Schema Editor allows you to create a new attribute by its properties, load a schema file into the Data Store, perform a copy-and-paste operation on a definition, or define the new element from an existing attribute.

The following example shows how you can create a new attribute:

- **contractorStatus**. Defines an attribute that determines if the employee is a contractor (TRUE) or not (FALSE). The attribute is a single-valued element that uses the `booleanMatch` matching rule and the Boolean LDAP syntax. Because the Data Store accepts alphanumeric OIDs, the Schema Editor uses `<Name>-OID`. The attribute is also `user-modifiable` and set for `userApplications`.

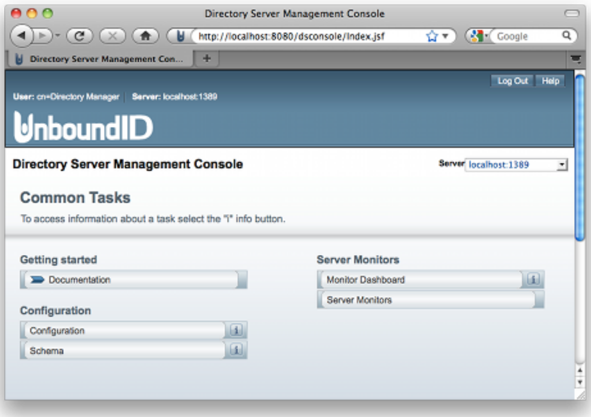
The example only adds an attribute to your server's schema. You must add a new object class or modify an existing object class definition, so that it references this new attribute to expose it to client applications.

To extend the schema over LDAP, the user must have the `update-schema` privilege. Root users, such as `cn=Directory Manager`, have the privilege assigned by default.

To Create a New Attribute Using the Schema Editor

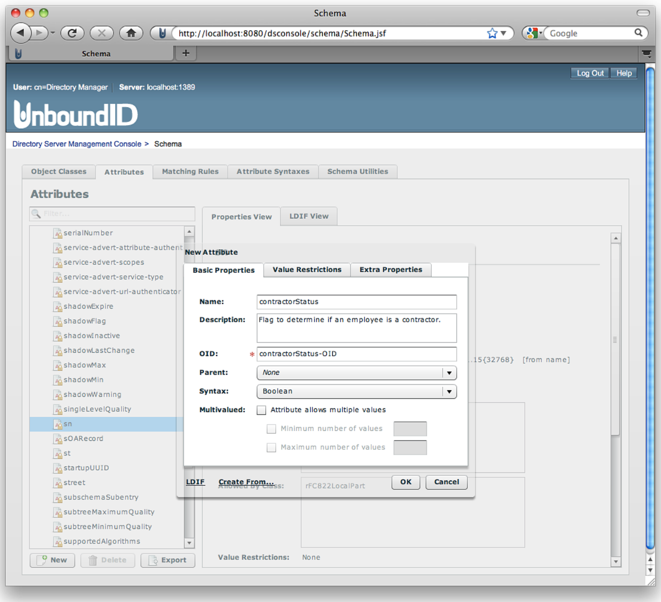
1. Start the Management Console. Check the data store instance associated with the console is also running.

2. On the main menu, click **Schema** under Configuration. And then, click the **Attributes** tab on the Schema Editor.


Directory Server Management Console
http://localhost:8080/dsconsole/index.jsf
Log Out
Help
User: cn=Directory Manager
Server: localhost:1389
UnboundID
Directory Server Management Console
Server localhost:1389
Common Tasks
To access information about a task select the "i" info button.
Getting started
Documentation
Configuration
Configuration
Schema
Server Monitors
Monitor Dashboard
Server Monitors

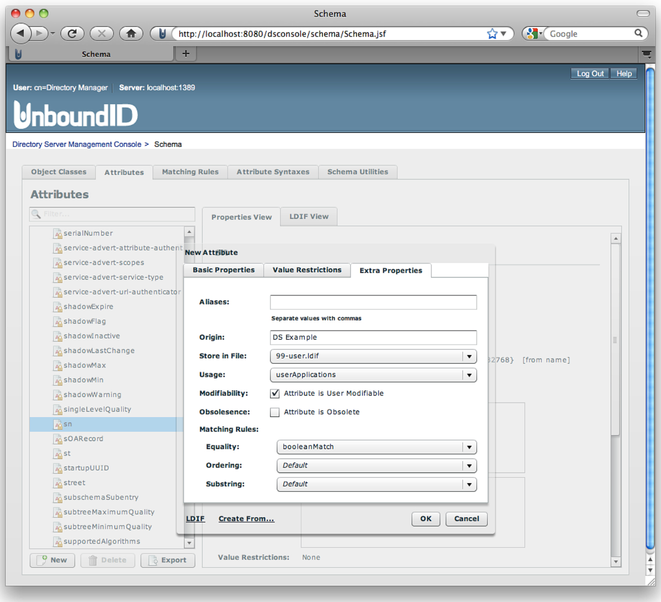
3. Click the **New** button below the list of attributes. The **Properties** dialog opens, where you can enter the individual properties.

4. Enter the properties for the new attribute. Because the Data Store allows alphanumeric OIDs, the OID property automatically fills with the `<name>-OID` format when you enter a `Name` property.



Name: contractorStatus
Description: Flag to determine if an employee is a contractor.
OID: contractorStatus-OID
Parent: None
Syntax: Boolean
Multivalued: [ ] Attribute allows multiple values
[ ] Minimum number of values
[ ] Maximum number of values

5. Click `Extra Properties` to define additional information for the new attribute, and then click **OK** to create the attribute. In this example, enter the Origin (’`DS Example`’), select **userApplications**, and select **Attribute** is user modifiable.



New Attribute

Basic Properties | Value Restrictions | Extra Properties

Aliases:
Separate values with commas

Origin: DS Example

Store in File: 99-user.ldif

Usage: userApplications

Modifiability: ✓ Attribute is User Modifiable

Obsolescence: Attribute is Obsolete

Matching Rules:

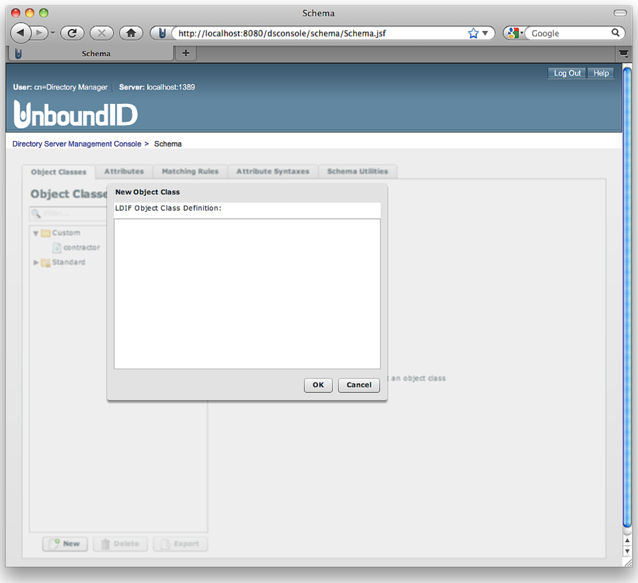
Equality: booleanMatch

Ordering: Default

Substring: Default

LDIF | Create From... | OK | Cancel

6. If you selected the LDIF option, enter the new attribute definition in the dialog window, and then click **OK**. You can type in the attribute definition or perform a cut-and-paste operation on an attribute. Pay special attention to the text spacings.

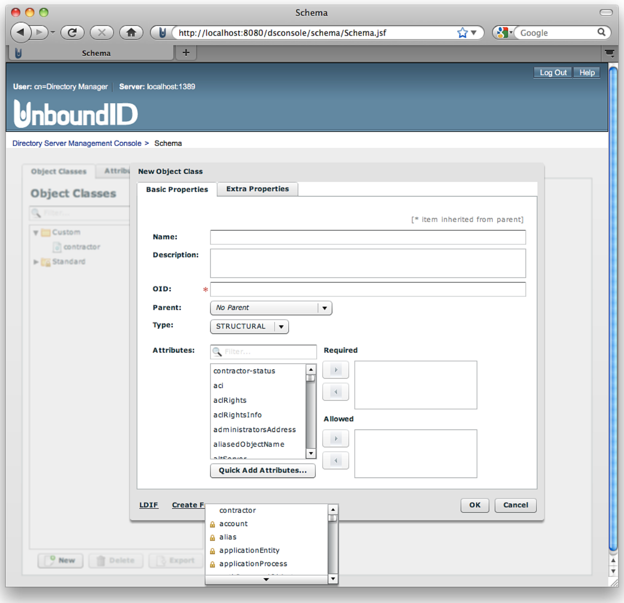


New Object Class

LDIF Object Class Definition:

OK | Cancel

7. If you selected `Create From`, you can create a new attribute definition from an existing attribute, which serves as a template. Modify any properties to fit your new attribute.



Creating a New Attribute over LDAP

The following section shows how you can add the schema element from the previous section over LDAP. You can create your own schema file or type the schema from the command line. In either case, you must pay special attention to text spacing and ASN.1 formatting.

To Add an New Attribute to the Schema over LDAP

1. Create an LDIF file with the new attribute definition using a text editor. Save the file as `myschema.ldif`.

```
dn: cn=schema
changetype: modify
add: attributeTypes
attributeTypes: ( contractorStatus-OID NAME 'contractorStatus'
  EQUALITY booleanMatch
  SYNTAX 1.3.6.1.4.1.1466.115.121.1.7
  SINGLE-VALUE
  USAGE userApplications
  X-ALLOWED-VALUES ’Y’ ’N’ ’y’ ’n’
  X-ORIGIN 'Data Store Example' )
```

2. Use `ldapmodify` to add the attribute.

```
$ bin/ldapmodify --filename myschema.ldif
```

3. Verify the addition by displaying the attribute using `ldapsearch`.

```
$ bin/ldapsearch --baseDN cn=schema --searchScope base \
  --dontwrap "(objectclass=*)" attributeTypes | grep 'contractorStatus'
```

4. You can view the custom schema file at `<server-root>/config/schema/99-user.ldif`. You should see the following:

```
dn: cn=schema
objectClass: top
objectClass: ldapSubentry
objectClass: subschema
cn: schema
attributeTypes: ( contractorStatus-OID
  NAME 'contractorStatus'
  EQUALITY booleanMatch
  SYNTAX 1.3.6.1.4.1.1466.115.121.1.7
  SINGLE-VALUE
  USAGE userApplications
  X-ORIGIN 'UnboundID Data Store Example' )
```

To Add Constraints to Attribute Types

- The Data Store provides attribute type extensions that constrain the values for the associated attribute using the `DirectoryString` attribute syntax. The following schema definition includes two `attributeType` definitions for `myAttr1` and `myAttr2`. The first definition constrains the values for the attribute `myAttr1` to ’foo’, ’bar’, ’baz’. The second definition constrains the minimum allowable length for `myAttr2` to 1 and the maximum allowable length to 5.

```
attributeTypes: (1.2.3.4
  NAME ’myAttr1’
  SYNTAX 1.3.6.1.4.1.1466.115.121.1.15
  X-ALLOWED-VALUES ( ’foo’ ’bar’ ’baz’ ))
attributeTypes: ( 1.2.3.5
  NAME ’myAttr2’
  SYNTAX 1.3.6.1.4.1.1466.115.121.1.15
  X-MIN-VALUE-LENGTH ’1’
  X-MAX-VALUE-LENGTH ’5’ )
```

Managing Object Classes

Object classes are sets of related information objects that form entries in a Directory Information Tree (DIT). The Data Store uses the schema to define these entries, to specify the position of the entries in a DIT, and to control the operation of the server. You can also extend the schema by adding your own schema definitions.

Object classes have the following general properties:

- Object classes must have a globally unique name or identifier.
- Object classes specify the required and allowed attributes in an entry.
- Object classes can inherit the properties and the set of allowed attributes from its parent object classes, which may also be part of a hierarchical chain derived from the top abstract object class.
- Object classes that are defined in the UnboundID Data Store can be searched using the `objectClasses` operational attribute. The Data Store also has a special entry called the subschema subentry, which provides information about the available schema elements on the server.

Object Classes Types

Based on RFC 4512, object classes can be a combination of three different types:

- **Abstract object classes** are used as the base object class, from which structural or auxiliary classes inherit its properties. This inheritance is a one-way relationship as abstract object classes cannot be derived from structural or auxiliary classes. The most common abstract object class is `top`, which defines the highest level object class in a hierarchical chain of object classes.
- **Structural object classes** define the basic attributes in an entry and define where an entry can be placed in a DIT. All entries in a DIT belong to one structural object class. Structural object classes can inherit properties from other structural object classes and from abstract object classes to form a chain of inherited classes. For example, the `inetOrgPerson` structural object class inherits properties from the `organizationalPerson` structural class, which inherits from another object class, person.
- **Auxiliary object classes** are used together with structural object classes to define additional sets of attributes required in an entry. The auxiliary object class cannot form an entry alone but must be present with a structural object class. Auxiliary object classes cannot derive from structural object classes or vice-versa. They can inherit properties from other auxiliary classes and from abstract classes.

Object Class Definition

New object classes can be specified with existing schema components and do not require additional server code extensions for their implementation. Administrators can create new object classes using the Schema Editor, which manages schema in the `<server-root>/config/schema` directory. See *Extending the Data Store Schema* for more information.

The object class definition is defined in RFC 4512, section 4.1.1, as follows::

```
ObjectClassDescription = "(" wsp; Left parenthesis followed by a white space
numericoid                        ; Required numeric object identifier
[ sp "NAME" sp qdescrs ]          ; Short name descriptor as alias for the OID
[ sp "DESC" sp qdstring ]         ; Optional descriptive string
[ sp "OBSOLETE" ]                 ; Determines if the element is inactive
[ sp "SUP" sp oid ]               ; Specifies the direct superior object class
[ sp kind ]                       ; abstract, structural (default), auxiliary
[ sp "MUST" sp oids ]             ; Required attribute types
[ sp "MAY" sp oids ]              ; Allowed attribute type
extensions wsp ")"                ; Extensions followed by a white space and ")"

usage = "userApplications" /      ; Stores user data
  "directoryOperation" /          ; Stores internal server data
  "distributedOperation" /        ; Stores operational data that must be synchronized
                                  ;   across servers
  "dSAOperation"                  ; Stores operational data specific to a server and
                                  ;   should not be synchronized across servers
```

The following extensions are specific to the UnboundID Data Store and are not defined in RFC 4512:

```
extensions = /
"X-ORIGIN" /             ; Specifies where the object class is defined
"X-SCHEMA-FILE" /        ; Specifies which schema file contains the definition
"X-READ-ONLY"            ; True or False. Specifies if the file that contains
                         ;   the schema element is marked as read-only
```

```
                              ;   in the server configuration.
```

Note: Although RFC 4512 allows multiple superior object classes, the UnboundID Data Store allows at most one superior object class, which is defined by the SUP element in the definition.

Basic Object Class Properties

The Basic Properties section displays the standard elements in schema definition.

Table 37: Basic Properties of Attributes

Attributes	Description
Name	Specifies the globally unique name.
Description	Specifies an optional definition that describes the object class and its contents. The analogous LDIF equivalent is "DESC".
OID	Specifies the object identifier assigned to the schema definition. You can obtain a specific OID for your company that allows you to define your own object classes and attributes from IANA or ANSI.
Parent	Specifies the schema definition's hierarchical parent or superior object class if any. An object class can have one parent. The analogous LDIF equivalent
Type	Specifies the type of schema definition: abstract, structural, or auxiliary. The analogous LDIF equivalent is "ABSTRACT", "STRUCTURAL", or "AUX
Required Attributes	Specifies any required attributes with the object class. The Schema Editor also marks any inherited attributes from another object class. You can double-click an attribute value to take you to the Properties View for that particular attribute. The analogous LDIF equivalent is "MUST".
Optional Attributes	Specifies any optional attributes that could be used with the object class. The Schema Editor also marks any inherited attributes from another object class. You can double-click an attribute value to take you to the Properties View for that particular attribute. The analogous LDIF equivalent is "MAY".

The Extra Properties section provides additional auxiliary information associated with the object class.

Table 38: Basic Properties of Attributes

Attributes	Description
Aliases	Specifies any shortform alias names, if any. In theory, you could have any number of shortform names as long as they are all unique. The analogous LDIF equivalent appears as the secondary element with the NAME element although most object classes do not have aliases.
Origin	Specifies the origin of the schema definition. Typically, it could refer to a specific RFC or company.
Obsolete	Specifies if the schema definition is obsolete or not.
Stored in File	Specifies the schema file that stores the definition in the `<server-root>/config/schema` folder.

Viewing Object Classes

You can view the object classes on your Data Store by using the Schema Editor on the Management Console, over LDAP using the `ldapsearch` tool, or some third party tool. The Schema Editor displays all of the object classes on your data store instance. It shows the basic properties that are required elements and the extra properties that are allowed within the object class.

To View Object Classes over LDAP

- Use `ldapsearch` tool to view a multi-valued operational attribute, `objectClasses`, which publishes the object class definitions on the Data Store. The attribute is stored in the subschema subentry.

```
$ bin/ldapsearch --baseDN cn=schema --searchScope base \
--dontWrap "(objectclass=*)" objectClasses
```

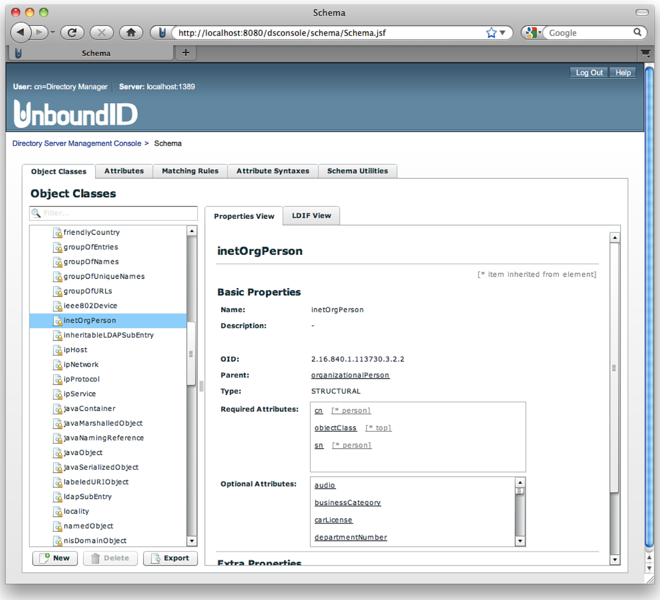
```
dn: cn=schema
objectClasses: ( 2.5.6.0 NAME 'top' ABSTRACT MUST objectClass X-ORIGIN 'RFC 4512' )
objectClasses: ( 2.5.6.1 NAME 'alias' SUP top STRUCTURAL MUST aliasedObjectName
  X-ORIGIN 'RFC 4512' )
objectClasses: ( 2.5.6.2 NAME 'country' SUP top STRUCTURAL MUST c
  MAY ( searchGuide $ description ) X-ORIGIN 'RFC 4519' )
...(more output)...
```

To View Object Classes Using the Schema Editor

1. Start the Management Console. Check that the data store instance associated with the console is also running.

2. Under **Object Classes**, click the **Standard** folder, which opens the folder to display the object classes on the Data Store. The **Custom** folder holds user-defined schema elements if any.

3. Click a specific object class to view its properties. In this example, click the `inetOrgPerson` objectclass. The Schema Editor opens in the **Properties View** and shows the Basic and Extra properties associated with the object class. If you click one of the attributes in the **Required Attributes** or **Optional Attributes** section, you will be taken to the **Attributes** tab, which displays the properties for that specific attribute. The "lock" symbol specifies that the objectclass cannot be modified or deleted unless that restriction is changed on the system.



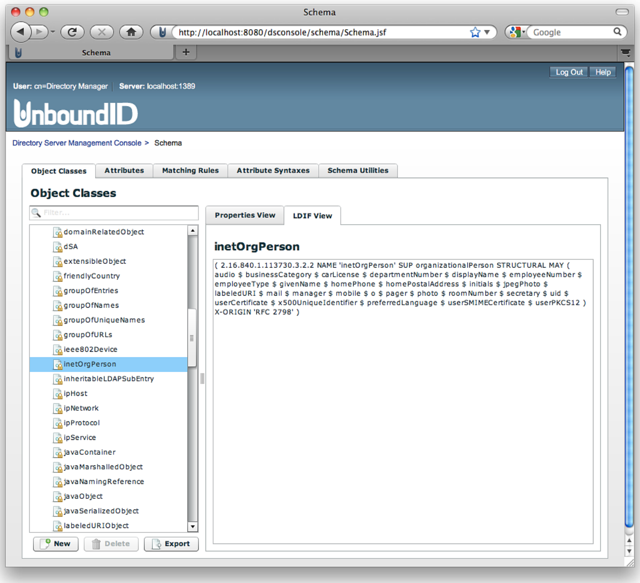
inetOrgPerson

[* item inherited from element]

Basic Properties

Name:	inetOrgPerson
Description:	-
OID:	2.16.840.1.113730.3.2.2
Parent:	organizationalPerson
Type:	STRUCTURAL
Required Attributes:	cn [* person] objectClass [* top] sn [* person]
Optional Attributes:	audio businessCategory carLicense departmentNumber

4. Click the **LDIF View** tab to view the equivalent objectclass definition in its ASN.1 format.



inetOrgPerson

```
( 2.16.840.1.113730.3.2.2 NAME 'inetOrgPerson' SUP organizationalPerson STRUCTURAL MAY (
audio $ businessCategory $ carLicense $ departmentNumber $ displayName $ employeeNumber $
employeeType $ givenName $ homePhone $ homePostalAddress $ initials $ jpegPhoto $
labeledURI $ mail $ manager $ mobile $ o $ pager $ photo $ roomNumber $ secretary $ uid $
userCertificate $ x500UniqueIdentifier $ preferredLanguage $ userSMIMECertificate $ userPKCS12 )
X-ORIGIN 'RFC 2798' )
```

Managing an Object Class over LDAP

The following section shows how you can manage an object class schema element over LDAP by adding a new attribute element to an existing object class. You can create your own schema file or type the schema from the command line. In either case, you must pay special attention to text spacing and ASN.1 formatting. The following example procedure adds an attribute, `contractorAddress`, to the custom schema file, then adds it to the `contractor` objectclass.

To Manage an Object Class over LDAP

1. Assume that you have defined the `contractorAddress` attribute, create an LDIF file called `contractorAddress-attr.ldif` with the following content:

```
dn: cn=schema
changetype: modify

add: attributeTypes attributeTypes: ( contractor-OID NAME 'contractorAddress'
  SYNTAX 1.3.6.1.4.1.1466.115.121.1.15
  SINGLE-VALUE
  USAGE userApplications
  X-ORIGIN 'user defined'
  X-SCHEMA-FILE ’98-custom-schema.ldif’ )
  X-ORIGINS ’user defined’
  X-SCHEMA-FILE ’98-custom-schema.ldif’ )
```

2. Add the attribute using `ldapmodify`.

```
$ bin/ldapmodify --filename contractorAddress-attr.ldif
```

3. Next, create an LDIF file to modify the contractor objectclass to allow this attribute. When doing this, you are just re-adding the updated `objectClass` and the Data Store will handle the proper replacement of the existing object class with the new one. Create a file called `contractor-oc.ldif`. Make sure that the lines are not wrapped, the `objectClasses` line should be one continuous line.

```
dn:cn=schema
changetype: modify
add: objectClasses
objectClasses: ( contractor-OID NAME ’contractor’
  DESC ’Contractor status information
  SUP top
  AUXILIARY MAY ( contractorStatus $ contractorAgency $ contractorAddress )
  X-ORIGIN ’Data Store Example’
  X-SCHEMA-FILE ’98-custom-schema.ldif’ )
```

4. Update the `objectClass` using `ldapmodify` as follows:

```
$ bin/ldapmodify --filename contractor-oc.ldif
```

5. These schema changes will be replicated to all servers in the replication topology. Verify the change by looking at the `config/schema/98-custom-schema.ldif` file on the other servers in the replication topology to ensure that the changes are present.

6. If you need to add an index for this attribute, you can do so by using the `dsconfig` command-line utility. You will need to do this on each server in your topology unless you have server configuration groups set up. See *Configuring Server Groups* for more information.

```
$ bin/dsconfig create-local-db-index --backend-name userRoot \
  --index-name contractorAddress --set index-type:equality
```

7. Rebuild the index online. This will not affect other indexes or entries since there is no currently existing data for this attribute on any entry.

```
$ bin/rebuild-index --baseDN dc=example,dc=com --index contractorAddress
```

Creating a New Object Class Using the Schema Editor

The procedures to create a new object class are similar to that of creating a new attribute with slight differences in the dialog windows. You should ensure that any attributes that are part of the new object class are defined prior to defining the object class.

The following example adds an auxiliary object class called `contractor` that allows two attributes, `contractorStatus` and `contractorAgency`. In a previous section, we defined the `contractorStatus` attribute. In this section, we will use the Schema Editor's **QuickAdd** function to create the `contractorAgency` attribute, while creating the `contractor` objectclass.

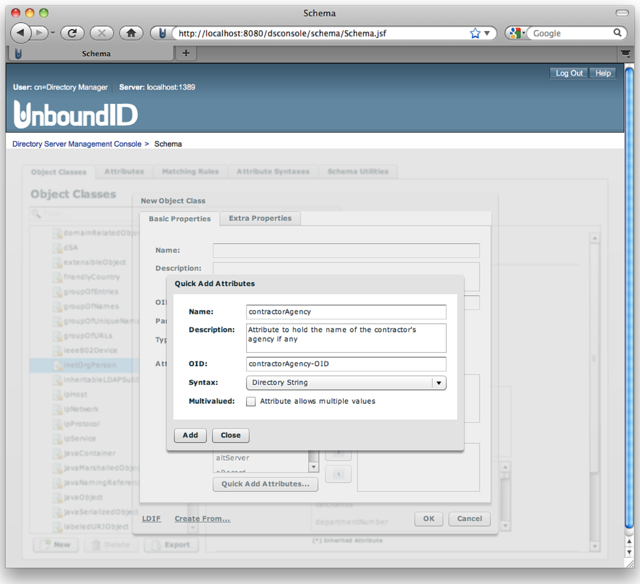
To Create a New Object Class Using the Schema Editor

1. Start the Management Console. Check that the Data Store instance associated with the console is running.

2. On the main menu, click **Schema**.

3. On the **Schema Editor**, click the **Object Classes** tab, and then click **New** located in the bottom left of the window.

4. On the **New Object Class** dialog, click **Quick Add Attributes** to add the `contractorAgency` attribute. The attribute uses the Directory String syntax and will be a single-valued element. When completed, click **Close**.


Quick Add Attributes

Name: contractorAgency

Description: Attribute to hold the name of the contractor's agency if any

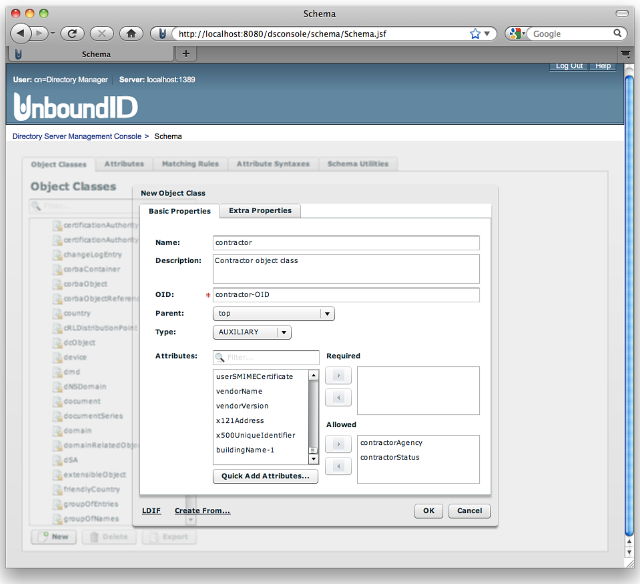
OID: contractorAgency-OID

Syntax: Directory String

Multivalued: [ ] Attribute allows multiple values

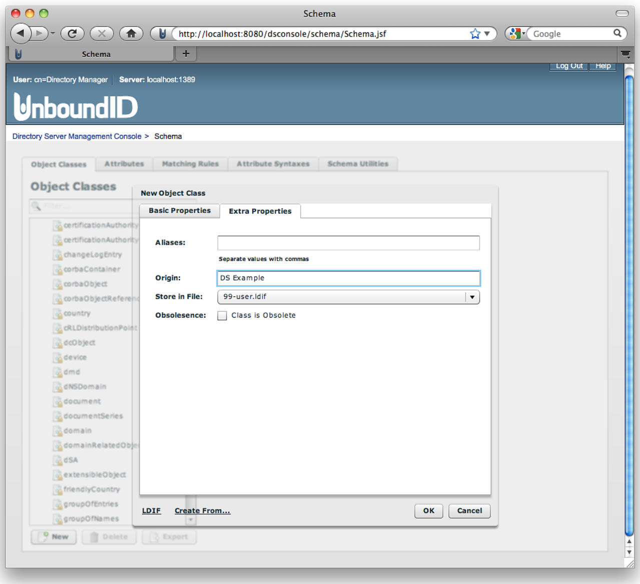
5. Enter the properties for the new objectclass. In the **Attributes** box, you can filter the types of attributes required for the new object class. Click the right arrow to move it into the

Required or the **Allowed** box. All custom attributes appear at the bottom of the list in the **Attributes** box.



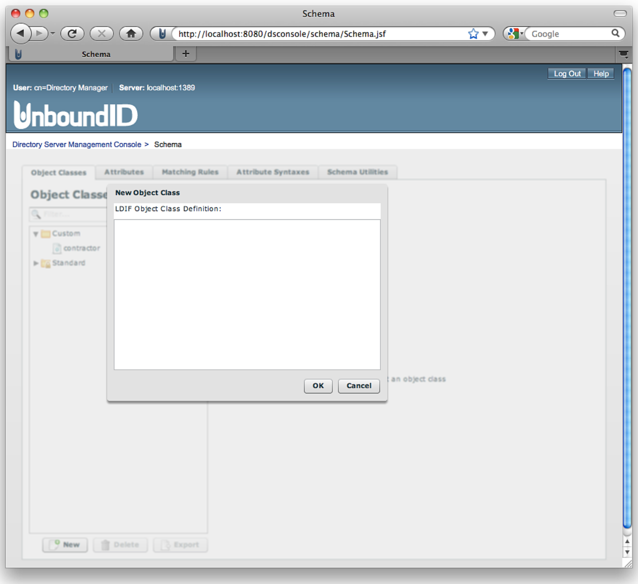
Name: contractor
Description: Contractor object class
OID: * contractor-OID
Parent: top
Type: AUXILIARY
Attributes: userSMIMECertificate, vendorName, vendorVersion, x121Address, x500UniqueIdentifier, buildingName-1
Required:
Allowed: contractorAgency, contractorStatus

6. Click **Extra Properties** tab to add the auxiliary information for the object class, and then click **OK** when finished.

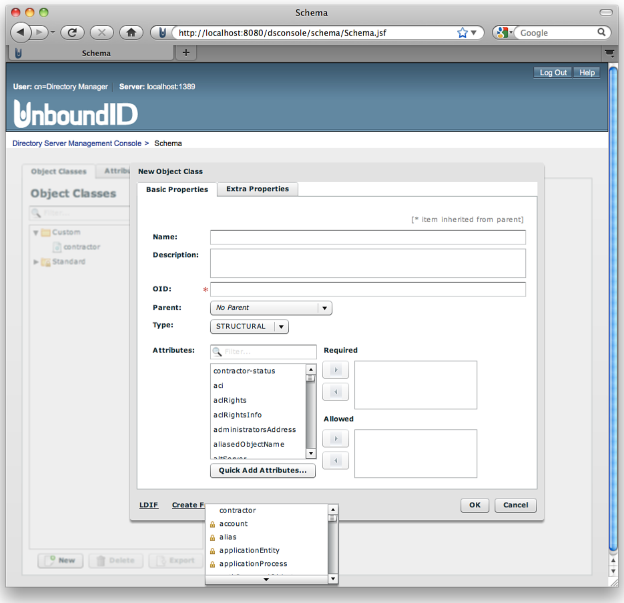


Aliases:
Separate values with commas
Origin: DS Example
Store in File: 99-user.ldif
Obsolescence: ☐ Class is Obsolete

7. If you clicked the **LDIF** link on the **New Object Class** dialog, you can perform a cut-and-paste operation on the object class definition, and then click **OK** when done.



8. If you clicked the **Create From** link, you can create a new object class from an existing object class definition using it as a template.



Extending the Schema Using a Custom Schema File

You can add new attributes and object classes to your Data Store schema by creating a custom schema file. You can import the file using the Schema Editor, over LDAP using the `ldapmodify` tool, or from the command line. Make sure to define the attributes first, then define the object classes.

To Extend the Schema Using a Custom Schema File

1. Create an LDIF file with the new attribute extensions using a text editor.

```
dn: cn=schema
objectClass: top
objectClass: ldapSubentry
objectClass: subschema
attributeTypes: ( contractorStatus-OID NAME 'contractorStatus'
  EQUALITY booleanMatch
  SYNTAX 1.3.6.1.4.1.1466.115.121.1.7
  SINGLE-VALUE
  USAGE userApplications
  X-ORIGIN 'Data Store Example' )
attributeTypes: ( contractorAgency-OID NAME 'contractorAgency'
  EQUALITY caseIgnoreMatch
  SUBSTR caseIgnoreSubstringsMatch
  SYNTAX 1.3.6.1.4.1.1466.115.121.1.44{256}
  SINGLE-VALUE
  USAGE userApplications
  X-ORIGIN 'UnboundID Data Store Example' )
```

2. In the same LDIF file, add a new object class definition after the attribute types. In this example, we create an auxiliary object class, `contractor`, that alone cannot be used as an entry. The object class will be used to add supplemental information to the `inetOrgPerson` structural object class. The attributes are all optional for the new object class.

```
objectClasses: ( contractor-OID
  NAME 'contractor'
  DESC 'Contractor status information'
  SUP top
  AUXILIARY
  MAY ( contractorStatus $ contractorAgency )
  X-ORIGIN 'UnboundID Data Store Example' )
```

3. Save the file as `99-auxobjclass.ldif` and place it in the `<server-root>/config/schema` directory.

4. At this stage, the schema extensions are not loaded into the Data Store yet. You have four options to load them:

   - Create a task that loads the new extensions into the schema. We create a task labelled with the ID "add-schema-99-auxobjclass" and add it using `ldapmodify`. You do not need to restart the server when using this method.

   ```
   dn: ds-task-id=add-schema-99-auxobjclass,cn=Scheduled Tasks,cn=tasks
   objectClass: top
   objectClass: ds-task
   objectClass: ds-task-add-schema-file
   ds-task-id: add-schema-99-auxobjclass
   ds-task-class-name: com.unboundid.directory.server.tasks.AddSchemaFileTask
   ds-task-schema-file-name: 99-auxobjclass.ldif
   ```

   - Import the schema file using the Schema Editor. You do not need to restart the server when using this method. See *Using the Schema Editor Utilities*.
   - Add the schema file using `ldapmodify`. You do not need to restart the server when using this method. See *Creating a New Attribute over LDAP* to find a similar example.
   - Restart the Data Store. The schema file is read at startup.

5. Use `ldapmodify` to make use of the new object class and one of its attributes in an existing entry.

```
$ bin/ldapmodify
dn: uid=user.9,ou=People,dc=example,dc=com
changetype: modify
add: objectclass
objectclass: contractor
-
add: contractorStatus
contractorStatus: TRUE
```

6. Verify the addition by displaying the attribute using `ldapsearch`.

```
$ bin/ldapsearch --baseDN dc=example,dc=com "(uid=user.9)" contractorStatus
```

```
dn: uid=user.9,ou=People,dc=example,dc=com
contractorStatus: TRUE
```

Managing Matching Rules

Matching rules determine how clients and servers compare attribute values during LDAP requests or operations. They are also used in evaluating search filter elements including distinguished names and attributes. Matching rules are defined for each attribute based on EQUALITY (e.g., two attributes are equal based on case, exact match, etc.), SUBSTR (e.g., assertion value is a substring of an attribute), and ORDERING (e.g., greater than or equal, less than or equal, etc.) properties.

Note: The UnboundID Data Store supports an `APPROXIMATE` matching rule that compares similar attributes based on fuzzy logic. Thus, attributes that are similar or "sound-like" each other are matched. For example, "petersen" would match "peterson".

Matching Rule Definition

New matching rules require additional server code extensions to be implemented on the UnboundID Data Store. If you need new matching rules, contact your authorized support provider for assistance.

The formal specification for attribute types is provided in RFC 4512, section 4.1.3 as follows:

```
MatchingRuleDescription = "(" wsp    ; Left parentheses followed by a white space
numericoid                           ; Required numeric object identifier identifying
                                     ;   this matching rule
[ sp "NAME" sp qdescrs               ; Short name descriptor
[ sp "DESC" sp qdstring              ; Description
[ sp "OBSOLETE" ]                    ; Specifies if the rule is inactive
sp "SYNTAX" sp numericoid            ; Assertion syntax
extensions wsp ")"                   ; Extensions followed by a white space and ")"
```

Default Matching Rules

The UnboundID Data Store provides a large set of matching rules, which support a variety of applications. The default matching rules available for the Data Store are listed in the table below for each matching rule type: Equality, Substring, Ordering, and Approximate matches.

Table 39: Default Matching Rules

Matching Rule/OID	Attribute Syntax/OID	Description
uuidMatch/ 1.3.6.1.1.16.2	UUID/ 1.3.6.1.1.16.1	Compares an asserted UUID with a stored UUID attribute value for equality. RFC 4530.
uuidOrderingMatch/ 1.3.6.1.1.16.3	UUID/ 1.3.6.1.1.16.1	Compares the collation order of an asserted UUID with a stored UUID attribute value for ordering RFC 4530.
caseExactIA5Match/ 1.3.6.1.4.1.1466.109.114.1	IA5 String/ 1.3.6.1.4.1.1466.115.121.1.26	Compares an asserted value with an attribute value of International Alphabet 5 syntax. RFC 4517.
caseIgnoreIA5Match/ 1.3.6.1.4.1.1466.109.114.2	IA5 String/ 1.3.6.1.4.1.1466.115.121.1.26	Compares an asserted value with an attribute value of International Alphabet 5 syntax. Case, leading, and trailing spaces are ignored. Multiple spaces are treated as a single space. RFC 4517.
caseIgnoreIA5SubstringsMatch/ 1.3.6.1.4.1.1466.109.114.3	Substring Assertion/ 1.3.6.1.4.1.1466.115.121.1.58	Compares an asserted substring with an attribute value of IA5 string syntax. Case, leading, and trailing spaces are ignored. Multiple spaces are treated as a single space. RFC 4517.
authPasswordExactMatch/ 1.3.6.1.4.1.4203.1.2.2	Authentication Password Syntax/ 1.3.6.1.4.1.4203.1.1.2	Authentication password exact matching rule.
authPasswordMatch/ 1.3.6.1.4.1.4203.1.2.3	Authentication Password Syntax/ 1.3.6.1.4.1.4203.1.1.2	Authentication password matching rule.
ds-mr-double-metaphone-approx/ 1.3.6.1.4.1.30221.1.4.1	Directory String/ 1.3.6.1.4.1.1466.115.121.1.15	Syntax based on the phonetic Double Metaphone algorithm for approximate matching.
ds-mr-user-password-exact/ 1.3.6.1.4.1.30221.1.4.2	User Password Syntax/ 1.3.6.1.4.1.30221.1.3.1	User password exact matching rule.
ds-mr-user-password-equality/ 1.3.6.1.4.1.30221.1.4.3	User Password Syntax/ 1.3.6.1.4.1.30221.1.3.1	User password equality matching rule.
historicalCsnOrderingMatch/ 1.3.6.1.4.1.30221.1.4.4	1.3.6.1.4.1.30221.1.3.5	Compares the collation order of a historical change sequence number with a historical CSN attribute value.
caseExactIA5SubstringsMatch/ 1.3.6.1.4.1.30221.1.4.902	Substring Assertion/ 1.3.6.1.4.1.1466.115.121.1.58	Compares an asserted substring with an attribute value of IA5 string syntax. RFC 4517.
compactTimestampMatch/ 1.3.6.1.4.1.30221.2.4.1	Compact Timestamp/ 1.3.6.1.4.1.30221.2.3.1	Compact Timestamp matching rule.
compactTimestampOrderingMatch/ 1.3.6.1.4.1.30221.2.4.2	Compact Timestamp/ 1.3.6.1.4.1.30221.2.3.1	Compares the collation order of a compact timestamp number with an attribute value of Compact Timestamp syntax.

Matching Rule/OID	Attribute Syntax/OID	Description
objectIdentifierMatch/ 2.5.13.0	OID/ 1.3.6.1.4.1.1466.115.121.1.38	Compares an asserted value with an attribute value of OID syntax. RFC 4517.
distinguishedNameMatch/ 2.5.13.1	DN/ 1.3.6.1.4.1.1466.115.121.1.12	Compares an asserted value with an attribute value of DN syntax. Spaces around commas and semicolons are ignored. Spaces around plus and equal signs around RDN components are ignored. RFC 4517.
caseIgnoreMatch/ 2.5.13.2	Directory String/ 1.3.6.1.4.1.1466.115.121.1.15	Compares an asserted value with an attribute value. Case, leading, and trailing spaces are ignored. Multiple spaces are treated as a single space. RFC 4517.
caseIgnoreOrderingMatch/ 2.5.13.3	Directory String/ 1.3.6.1.4.1.1466.115.121.1.15	Compares the collation order of the asserted string with an attribute value of Directory String syntax. Case, leading, and trailing spaces are ignored. Multiple spaces are treated as a single space. RFC 4517
caseIgnoreSubstringsMatch/ 2.5.13.4	Substring Assertion/ 1.3.6.1.4.1.1466.115.121.1.58	Compares an asserted substring value with an attribute value of Directory String syntax. Case, leading, and trailing spaces are ignored. Multiple spaces are treated as a single space. RFC 4517
caseExactMatch/ 2.5.13.5	Directory String/ 1.3.6.1.4.1.1466.115.121.1.15	Compares an asserted value with an attribute value of Directory String syntax. RFC 4517.
caseExactOrderingMatch/ 2.5.13.6	Directory String 1.3.6.1.4.1.1466.115.121.1.15	Compares the collation order of the asserted string with an attribute value of Directory String syntax. RFC 3698
caseExactSubstringsMatch/ 2.5.13.7	Substring Assertion/ 1.3.6.1.4.1.1466.115.121.1.58	Compares an asserted substring with an attribute value of Directory String syntax. RFC 3698
numericStringMatch/ 2.5.13.8	Numeric String/ 1.3.6.1.4.1.1466.115.121.1.36	Compares an asserted value with an attribute value of Numeric String syntax. Spaces are ignored when performing these comparisons. RFC 4517.
numericStringOrderingMatch/ 2.5.13.9	Numeric String/ 1.3.6.1.4.1.1466.115.121.1.36	Compares the collation order of the asserted string with an attribute value of Numeric String syntax. Spaces are ignored when performing these comparisons. RFC 4517.

Matching Rule/OID	Attribute Syntax/OID	Description
numericStringSubstringsMatch/ 2.5.13.10	Substring Assertion/ 1.3.6.1.4.1.1466.115.121.1.58	Compares an asserted substring with an attribute value of Numeric String syntax. Spaces are ignored when performing these comparisons. RFC 4517.
caseIgnoreListMatch/ 2.5.13.11	Postal Address/ 1.3.6.1.4.1.1466.115.121.1.41	Compares an asserted value with an attribute value which is a sequence of Directory Strings. Case, leading, and trailing spaces are ignored. Multiple spaces are treated as a single space. RFC 4517.
caseIgnoreListSubstringsMatch/ 2.5.13.12	Substring Assertion/ 1.3.6.1.4.1.1466.115.121.1.58	Compares the asserted substring with an attribute value, which is a sequence of Directory Strings. Case, leading, and trailing spaces are ignored. Multiple spaces are treated as a single space. RFC 3698.
booleanMatch/ 2.5.13.13	Boolean/ 1.3.6.1.4.1.1466.115.121.1.7	Compares an asserted boolean value with an attribute value of BOOLEAN syntax. Returns true if the values are both TRUE or both FALSE. RFC 3698.
integerMatch/ 2.5.13.14	Integer/ 1.3.6.1.4.1.1466.115.121.1.27	Compares an asserted value with an attribute value of INTEGER syntax. RFC 4517.
integerOrderingMatch/ 2.5.13.15	Integer/ 1.3.6.1.4.1.1466.115.121.1.27	Compares the collation order of the asserted integer with an attribute value of Integer syntax. Returns true if the attribute value is less than the asserted value. RFC 3698.
bitStringMatch/ 2.5.13.16	Bit String/ 1.3.6.1.4.1.1466.115.121.1.6	Compares an asserted Bit String value with an attribute value of Bit String syntax. RFC 4517.
octetStringMatch/ 2.5.13.17	Octet String/ 1.3.6.1.4.1.1466.115.121.1.40	Compares an asserted value with an attribute value of octet string syntax using a byte-for-byte comparison. RFC 4517.
octetStringOrderingMatch/ 2.5.13.18	Octet String/ 1.3.6.1.4.1.1466.115.121.1.40	Compares the collation order of the asserted octet string with an attribute value of Octet String syntax. Zero precedes a one bit. Shorter strings precede longer strings. RFC 3698.
octetStringSubstringsMatch/ 2.5.13.19	Substring Assertion/ 1.3.6.1.4.1.1466.115.121.1.58	Compares an asserted substring with an attribute value of octet string syntax using a byte-for-byte comparison. RFC 4517.

Matching Rule/OID	Attribute Syntax/OID	Description
telephoneNumberMatch/ 2.5.13.20	Telephone Number/ 1.3.6.1.4.1.1466.115.121.1.50	Compares an asserted value with an attribute value of Telephone Number syntax. RFC 4517.
telephoneNumberSubstringsMatch/ 2.5.13.21	Substring Assertion/ 1.3.6.1.4.1.1466.115.121.1.58	Compares an asserted value with the substrings of an attribute value of Telephone Number String syntax. RFC 4517.
presentationAddressMatch/ 2.5.13.22	Presentation Address/ 1.3.6.1.4.1.1466.115.121.1.43	Compares an asserted value with an attribute value of Presentation Address syntax. RFC 4517.
uniqueMemberMatch/ 2.5.13.23	Name and Optional UID/ 1.3.6.1.4.1.1466.115.121.1.34	Compares an asserted value with an attribute value of Unique Member syntax. RFC 4517.
protocolInformationMatch/ 2.5.13.24	Protocol Information/ 1.3.6.1.4.1.1466.115.121.1.42	Compares an asserted value with an attribute value of Protocol Information syntax. RFC 4517.
generalizedTimeMatch/ 2.5.13.27	Generalized Time/ 1.3.6.1.4.1.1466.115.121.1.24	Compares an asserted value with an attribute value of Generalized Time syntax. RFC 4517.
generalizedTimeOrderingMatch/ 2.5.13.28	Generalized Time 1.3.6.1.4.1.1466.115.121.1.24	Compares the collation order of the asserted string with an attribute value of Generalized Time String syntax and case is ignored. RFC 4517.
integerFirstComponentMatch/ 2.5.13.29	Integer/ 1.3.6.1.4.1.1466.115.121.1.27	Equality matching rules for subschema attributes between an Integer syntax and the value syntax. RFC 4517.
objectIdentifierFirstComponentMatch/ 2.5.13.30	OID/ 1.3.6.1.4.1.1466.115.121.1.38	Equality matching rules for subschema attributes between an OID syntax and the value syntax. RFC 4517.
directoryStringFirstComponentMatch/ 2.5.13.31	Directory String/ 1.3.6.1.4.1.1466.115.121.1.15	Compares an asserted Directory String value with an attribute value of type SEQUENCE whose first component is mandatory and of type Directory String. Returns true if the attribute value has a first component whose value matches the asserted Directory String using the rules of caseIgnoreMatch. RFC 3698.
wordMatch/ 2.5.13.32	Directory String/ 1.3.6.1.4.1.1466.115.121.1.15	Compares an asserted word with any word in the attribute value for equality RFC 3698.
keywordMatch/ 2.5.13.33	Directory String/ 1.3.6.1.4.1.1466.115.121.1.15	Compares an asserted value with any keyword in the attribute value for equality. RFC 3698.

Basic Matching Rule Properties

The Properties section displays the standard elements in a matching rule schema definition.

Table 40: Basic Properties of Matching Rules

Attributes	Description
Name	Specifies the descriptive and unique name of the element.
Description	Specifies an optional definition that describes the matching rule. The analogous LDIF equivalent is "DESC".
OID	Specifies the globally unique object identifier assigned to the schema definition. You can obtain a specific OID for your company that allows you to define your own object classes and attributes from IANA or ANSI.
Type	Specifies the type of type of matching rule: Equality, Ordering, Substring, or Approximate.
Syntax	Specifies the matching rule syntax.
Used by Attributes	Specifies any attributes that use the corresponding matching rule.

Viewing Matching Rules

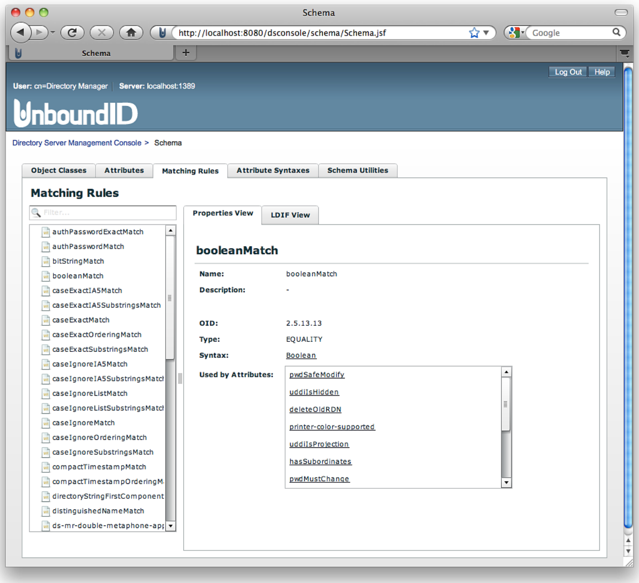
You can view the matching rules on your Data Store by using the Schema Editor on the Management Console, over LDAP using the `ldapsearch` tool, or some third party tool.

The Schema Editor displays all of the matching rules on your Data Store instance. It shows the basic properties that are allowed within the matching rule.

To View Matching Rules Using the Schema Editor

1. Start the **Management Console**, and then click Schema on the main menu. Check that the data store instance associated with the console is also running.

2. On the Schema Editor, click the **Matching Rules** tab. You can also click the **LDIF View** tab to see the ASN.1 equivalent format.



booleanMatch

Name: booleanMatch
Description: -

OID: 2.5.13.13
Type: EQUALITY
Syntax: Boolean
Used by Attributes: pwdSafeModify, uddiIsHidden, deleteOldRDN, printer-color-supported, uddiIsProjection, hasSubordinates, pwdMustChange

To View Matching Rules Over LDAP

- Use `ldapsearch` to view a multi-valued operational attribute, `matchingRules`, which publishes the definitions on the Data Store. The attribute is stored in the subschema subentry.

```
$ bin/ldapsearch --baseDN cn=schema --searchScope base \
  "(objectclass=*)" matchingRules
```

Managing Attribute Syntaxes

The attribute type definition has a `SYNTAX` element, or attribute syntax, that specifies how the data values for the attribute are represented. The syntax can be used to define a large range of data types necessary for client applications. An attribute syntax uses the Abstract Syntax Notation One (ASN.1) format for its definitions.

Attribute Syntax Definition

New attribute syntaxes require additional code to be implemented on the UnboundID Data Store. If you need new syntax definitions, contact your authorized support provider for assistance.

The formal specification for attribute types is provided in RFC 4512, section 4.1.5 as follows:

```
SyntaxDescription = "(" wsp
numericoid               ; Object identifier
[ sp "DESC" sp qdstring ] ; Description
extensions wsp ")"       ; Extensions followed by a white space and ")"
```

Default Attribute Syntaxes

The UnboundID Data Store supports a large set of Attribute Syntax rules for applications. The default Attribute Syntax rules available for the data store are listed in the table below.

Table 41: Default Attribute Syntaxes

LDAP Syntax	OID	Description
UUID	1.3.6.1.1.16.1	128-bit (16 octets) Universally Unique Identifier (UUID) used for Uniform Resource Names as defined in RFC 4122. For example, a4028c1a-f36e-11da-ba1a-04112154bd1e.
Attribute Type Description	1.3.6.1.4.1.1466.115.121.1.3	Syntax for the AttributeTypeDescription rule based on RFC 4517.
Binary	1.3.6.1.4.1.1466.115.121.1.5	Strings based on Basic Encoding Rules (BER) or Distinguished Encoding rules (DER). For example, an X.509 digital certificate or LDAP messages are BER encoded.
Bit String	1.3.6.1.4.1.1466.115.121.1.6	Sequence of binary digits based on RFC 4517. For example, '0010111'B.
Boolean	1.3.6.1.4.1.1466.115.121.1.7	TRUE or FALSE.
Certificate	1.3.6.1.4.1.1466.115.121.1.8	BER/DER-encoded octet strings based on an X.509 public key certificate as defined in RFC 4523.
Certificate List	1.3.6.1.4.1.1466.115.121.1.9	BER/DER-encoded octet string based on an X.509 certificate revocation list as defined in RFC 4523.
Certificate Pair	1.3.6.1.4.1.1466.115.121.1.10	BER/DER-encoded octet string based on an X.509 public key certificate pair as defined in RFC 4523.
Country String	1.3.6.1.4.1.1466.115.121.1.11	Two character country code specified in ISO 3166. For example, US, CA, etc.
DN	1.3.6.1.4.1.1466.115.121.1.12	Distinguished name of an entry as defined in RFC4514.
Delivery Method	1.3.6.1.4.1.1466.115.121.1.14	Sequence of services in preference order by which an entity receives messages as defined in RFC4517. For example, videotext $ telephone.
Directory String	1.3.6.1.4.1.1466.115.121.1.15	String of one or more characters from the Universal Character Set (UCS) using UCS Transformation Format 8 (UTF-8) encoding of the string.
DIT Content Rule Description	1.3.6.1.4.1.1466.115.121.1.16	DITContentRuleDescription as defined in RFC4517.
DIT Structure Rule Description	1.3.6.1.4.1.1466.115.121.1.17	DITStructureRuleDesciption as defined in RFC4517.
Enhanced Guide	1.3.6.1.4.1.1466.115.121.1.21	Combination of attribute types and filter operators to be used to construct search filters as defined in RFC4517. For example, person#(sn $EQ)#oneLevel.
Facsimile Telephone Number	1.3.6.1.4.1.1466.115.121.1.22	Fax telephone number on the public switched telephone network as defined in RFC4517.

LDAP Syntax	OID	Description
Fax	1.3.6.1.4.1.1466.115.121.1.23	Image generated using Group 3 fax process as defined in RFC4517.
Generalized Time	1.3.6.1.4.1.1466.115.121.1.24	String representing data and time as defined in RFC4517. YYYYMMDDHHMMSS[.|,fraction][(+|-HHMM)|Z] For example, 201103061032, 201103061032-0500, or 201103061032Z ("Z" indicates Coordinated Universal Time).
Guide	1.3.6.1.4.1.1466.115.121.1.25	Attribute types and filter operators as defined in RFC4517.
IA5 String	1.3.6.1.4.1.1466.115.121.1.26	String of zero or more characters from the International Alphabet 5 (IA5) character set as defined in RFC4517.
Integer	1.3.6.1.4.1.1466.115.121.1.27	String representations of integer values. For example, the character string "1234" represents the number 1234 as defined in RFC4517.
JPEG	1.3.6.1.4.1.1466.115.121.1.28	Image in JPEG File Interchange Format (JFIF) as defined in RFC4517.
Matching Rule Description	1.3.6.1.4.1.1466.115.121.1.30	MatchingRuleDescription as defined in RFC4512.
Matching Rule Use Description	1.3.6.1.4.1.1466.115.121.1.31	Attribute types to which a matching rule is applied in an extensibleMatch search filter (RFC4511).
Name and Optional UID	1.3.6.1.4.1.1466.115.121.1.34	Distinguished name and an optional unique identifier that differentiates identical DNs as defined in RFC4517. For example, uid=jsmith,ou=People,dc=example,dc=com#'0111'B
Name Form Description	1.3.6.1.4.1.1466.115.121.1.35	NameFormDescription as defined in RFC4512.
Numeric String	1.3.6.1.4.1.1466.115.121.1.36	Sequence of one or more numerals and spaces as defined in RFC4517. For example, 14 848 929 102.
Object Class Description	1.3.6.1.4.1.1466.115.121.1.37	ObjectClassDescription as defined in RFC 4512.
OID	1.3.6.1.4.1.1466.115.121.1.38	Object identifier as defined in RFC 4512.
Other Mailbox	1.3.6.1.4.1.1466.115.121.1.39	Specifies an electronic mailbox as defined in RFC 4517. For example, otherMailbox = google $ user@gmail.com
Octet String	1.3.6.1.4.1.1466.115.121.1.40	Sequence of zero or more octets (8-bit bytes) as defined in RFC4517.
Postal Address	1.3.6.1.4.1.1466.115.121.1.41	Strings of characters that form a multi-line address in a physical mail system. Each component is separated by a "$". For example, 1234 Main St.$Austin, TX 78744$USA.
Protocol Information	1.3.6.1.4.1.1466.115.121.1.42	Undefined.
Presentation Address	1.3.6.1.4.1.1466.115.121.1.43	String encoded OSI presentation address as defined in RFC 1278. For example, TELEX +00728722+RFC-1006+03+10.0.0.6
Printable String	1.3.6.1.4.1.1466.115.121.1.44	String of one or more printable ASCII alphabetic, numeric, and punctuation characters as defined in RFC 4517.

LDAP Syntax	OID	Description
RFC3672 Subtree Specification	1.3.6.1.4.1.1466.115.121.1.45	Syntax based on subtree specification as defined as RFC 3672.
Supported Algorithm	1.3.6.1.4.1.1466.115.121.1.49	Octet string based on the LDAP-encoding for a supported algorithm value that results from the BER encoding of a SupportedAlgorithm ASN.1 value.
Telephone Number	1.3.6.1.4.1.1466.115.121.1.50	String of printable international telephone number representations in E.123 format as defined in RFC 4517. For example, +1 512 904 5525.
Teletex Terminal Identifier	1.3.6.1.4.1.1466.115.121.1.51	Identifier and telex terminal as defined in RFC 4517.
Telex Number	1.3.6.1.4.1.1466.115.121.1.52	String representing the telex number, country code, and answerback code as defined in RFC 4517. For example, 812374, ch, ehhg.
UTC Time	1.3.6.1.4.1.1466.115.121.1.53	Character string representing the data and time in UTC Time format as defined as RFC 4517: YYMMDDHHMM[SS][(+|-HHMM)|Z], where Z is the coordinated universal time. For example, 0903051035Z, 0903051035-0500.
LDAP Syntax Description	1.3.6.1.4.1.1466.115.121.1.54	SyntaxDescription as defined in RFC4512.
Substring Assertion	1.3.6.1.4.1.1466.115.121.1.58	Syntax for assertion values in an extensible match as defined in RFC 4517.
Authentication Password Syntax	1.3.6.1.4.1.4203.1.1.2	Encoded password storage syntax as defined in RFC 3112. For example, the syntax specifies the storage scheme in brackets as follows: <storage-scheme>$<auth component>$<auth value> For example: SSHA$xdEZWRqgyJk= $egDEFDXvdeeEnXUEIDPnd39dkpe=
User Password Syntax	1.3.6.1.4.1.30221.1.3.1	Encoded password storage syntax as defined in RFC 2307. For example, the syntax specifies the storage scheme in brackets as follows: {SSHA}XaljOF0ii3fOwCrU1klgBpWFayqSYs +5W1pMnw==
Relative Subtree Specification	1.3.6.1.4.1.30221.1.3.2	Similar to the RFC 3672 subtree specification except it uses an LDAP search filter as the specification filter.
Absolute Subtree Specification	1.3.6.1.4.1.30221.1.3.3	Syntax for a subset of entries in a subtree based on RFC 3672.
Sun-defined Access Control Information	1.3.6.1.4.1.30221.1.3.4	Syntax for access control instructions used in Sun Directory Servers.
Compact Timestamp	1.3.6.1.4.1.30221.2.3.1	Syntax based on compact timestamp ISO 8601 format. For example, 20110306T102532.

Basic Attribute Syntax Properties

The Properties section displays the standard elements in an attribute syntax.

Table 42: Basic Properties of Attribute Syntaxes

Attributes	Description
Name	Specifies the descriptive and unique name of the element.
Description	Indicates an optional definition that describes the attribute syntax. The analogous LDIF equivalent is "DESC".
OID	Specifies the globally unique object identifier assigned to the schema definition.
Used by Attributes	Indicates any attributes that use the corresponding attribute syntax.

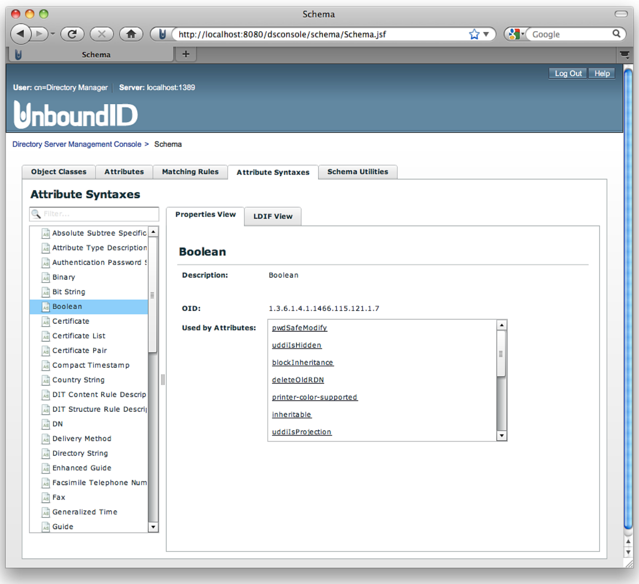
Viewing Attribute Syntaxes

You can view the attribute syntaxes on your Data Store by using the Schema Editor on the Management Console, over LDAP using the `ldapsearch` tool, or some third party tool.

The Schema Editor displays all of the attribute syntaxes on your Data Store instance. It shows the properties that are allowed within the attribute syntax.

To View Attribute Syntaxes Using the Schema Editor

1. Start the Management Console. Check that the data store instance associated with the console is also running.
2. On the main menu, click **Schema**.
3. On the Schema Editor, click the **Attribute Syntaxes** tab. You can also click the **LDIF View** tab to see the ASN.1 equivalent format.



Boolean

Description: Boolean

OID: 1.3.6.1.4.1.1466.115.121.1.7

Used by Attributes: pwdSafeModify, uddiIsHidden, blockInheritance, deleteOldRDN, printer-color-supported, inheritable, uddiIsProjection

To View Attribute Syntaxes Over LDAP

- Use `ldapsearch` to view the Data Store's published list of attribute syntaxes using the multi-valued operational attribute, `ldapSyntaxes`, which publishes the definitions on the Data Store. The attribute is stored in the subschema subentry.

  ```
  $ bin/ldapsearch --baseDN cn=schema \
    --searchScope base "(objectclass=*)" ldapSyntaxes
  ```

Using the Schema Editor Utilities

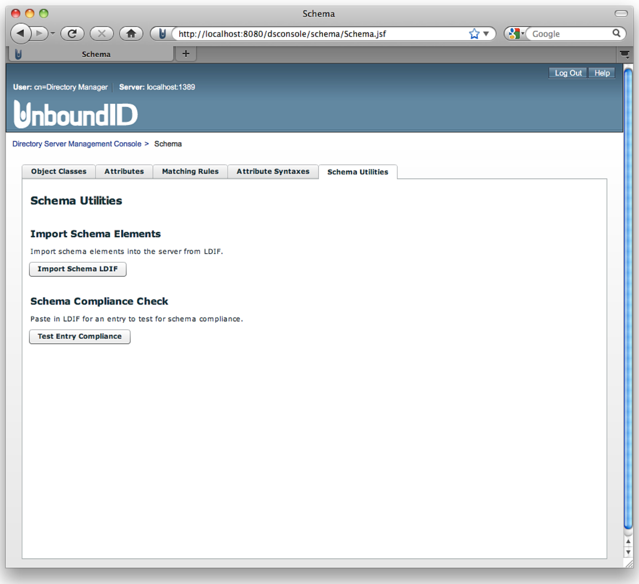
The Schema Editor provides a **Utilities** tab that allows you to import new schema elements from a file and to check schema compliance for new elements. If you are importing a schema file, the system automatically checks for compliance prior to the import. If your definition does not meet schema compliance, the system will display an error message. However, it is good practice to first check if your file is compliant with your schema prior to importing it.

To Check Schema Compliance Using the Schema Editor

1. Start the Management Console. Check that the data store instance associated with the console is also running.

2. On the main menu, click **Schema**.

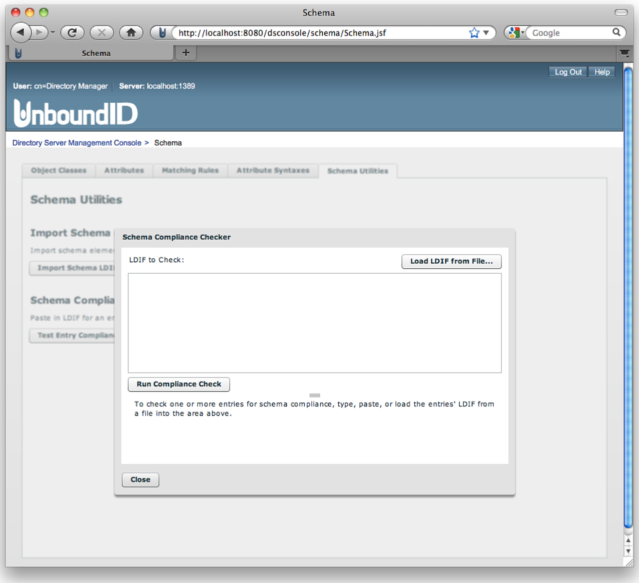
3. On the Schema Editor, click the **Schema Utilities** tab, then click **Test Entry Compliance**.



Import schema elements into the server from LDIF.

Paste in LDIF for an entry to test for schema compliance.

4. Click **Load LDIF from File** to read in an LDIF file, or copy-and-paste your new schema definition, and then click **Run Compliance Check**. If there is a problem, an error will be generated.



To check one or more entries for schema compliance, type, paste, or load the entries' LDIF from a file into the area above.

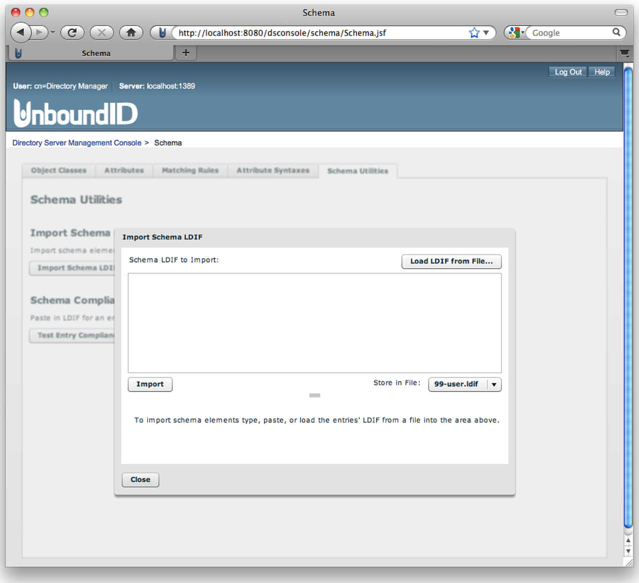
To Import a New Schema File Using the Schema Editor

1. Start the Management Console. Check that the Data Store instance associated with the console is also running.

2. On the main menu, click **Schema**. Then, on the Schema Editor, click the **Schema Utilities** tab.

3. Click on Import Schema LDIF.

4. Click **Load LDIF from File** to upload an LDIF file, or copy-and-paste your new schema definition in the dialog window, and then click **Import**. If there is a problem, an error will be generated. By default, you can load the file to `99-user.ldif`, but you can specify a new file by clicking the arrow and then clicking **New**.



Schema Utilities

To import schema elements type, paste, or load the entries' LDIF from a file into the area above.

Modifying a Schema Definition

The Data Store only allows schema definitions that are read-write to be edited. In general, those schema definitions in the **Custom** folder of the Schema Editor can be modified.

To Modify a Schema Definition

1. Start the Management Console. Check that the Data Store instance associated with the console is running.
2. On the main menu, click **Schema**.
3. On the Schema Editor, click the **Object Classes** tab, and then click the **Custom** folder.
4. Select the object class that you want to modify, and then click the **Edit** button. The Edit dialog box appears.
5. Make your changes, and then click **OK**.

Deleting a Schema Definition

The Data Store only allows schema definitions that are read-write to be deleted. In general, those schema definitions in the **Custom** folder of the Schema Editor can be removed from the system. You should make sure that the schema element is not currently in use.

To Delete a Schema Definition

1. Start the Management Console. Check that the Data Store instance associated with the console is also running.
2. On the main menu, click **Schema**.
3. On the **Schema Editor**, click the **Object Classes** tab, and then click the **Custom** folder.
4. Select the object class that you want to remove, and then click the **Delete** button.
5. On the **Confirmation** dialog, click **Yes** if you are sure that you want to delete the schema element.

Schema Checking

The UnboundID Data Store provides full support for parsing all schema elements and provides access to all of its components. By default, the Data Store enables schema checking for all operations, especially when importing data to the server or when modifying entries using the `ldapmodify` tool. Any schema violations will generate an error message to standard output.

To View the Schema Checking Properties

- Use `dsconfig` to view the schema checking property.

```
$ bin/dsconfig get-global-configuration-prop \
  --property check-schema
```

To Disable Schema Checking

Although not recommended, you can use the `dsconfig` tool to disable the schema checking. This feature only applies to public backends. Schema checking is enforced on private backends, such as changes to the Configuration, Schema, Task, and others. An admin action alert will be generated when attempting to disable schema checking using `dsconfig` interactive or non-interactive mode. The alert provides alternatives to disabling schema checking.

Run the `dsconfig` command and specify the `set-global-configuration-prop` subcommand to disable the `check-schema` property.

```
$ bin/dsconfig --no-prompt set-global-configuration-prop \
  --set check-schema:false
```

The system generates an admin action alert providing alternate options to disabling schema checking. Press **Enter** to continue the process or following one of the suggested tasks:

```
One or more configuration property changes require administrative action or
confirmation/notification.

Those properties include:
  *   check-schema: Schema checking should only be disabled as a last resort
      since disabling schema checking harms performance and can lead to
      unexpected behavior in the server as well as the applications that
      access it. There are less severe options for addressing schema issues:


  1.  Update the data to conform to the server schema.

  2.  Modify the server schema to conform to the data. Contact support before
      modifying the server's default schema.

  3.  Change the single-structural-objectclass-behavior property to allow
      entries to have no structural object class or multiple structural object
      classes.

  4.  Change the invalid-attribute-syntax-behavior property to allow attribute
      values to violate their attribute syntax.

  5.  Change the allow-zero-length-values property of the Directory String
      Attribute Syntax configuration to allow attributes with this syntax to
      have a zero length value.

Continue?  Choose 'no' to return to the previous step (yes / no) [yes]:
```

Managing Matching Rule Uses

Matching Rule Use definitions map certain attribute types with a matching rule definition for extensible match filters. Extensible match filters allows clients to search using DN components, for example, (`ou:dn:=engineering`) or using an OID number, for example, (`cn:1.2.3.4:=Sam Carter`). The matching rule use attribute publishes those attribute types and matching rule combinations, which can be used in extensible match assertions.

Typically, you define a matching rule use that is not normally specified in the attribute type definition. You can create new matching rule uses from the existing schema definitions by adding a custom schema file in the `<server-root>/config/schema` directory.

Matching Rule Use Definitions

Matching Rule Use can be specified with existing schema components and do not require additional code for its implementation.

The formal specification for attribute types is provided in RFC 4512, section 4.1.4 as follows:

```
MatchingRuleUseDescription = "(" wsp
numericoid                 ; Object identifier
[ sp "NAME" sp qdescrs ]    ; Short name descriptor
[ sp "DESC" sp qdstring ]   ; Description
[ sp "OBSOLETE" ]          ; Specifies if the rule use is inactive
sp "APPLIES" sp oid         ; Attribute types
extensions wsp ")"          ; Extensions followed by a white space and ")"
```

The following extensions are specific to the UnboundID Data Store and are not defined in RFC 4512:

```
extensions = /
"X-SCHEMA-FILE" /         ; Specifies which schema file contains the definition
"X-READ-ONLY"             ; True or False. Specifies if the file that contains
                          ;   the schema element is marked as read-only in the
                          ;   server configuration.
```

To View Matching Rule Uses

A matching rule use lists the attribute types that are suitable for use with an `extensibleMatch` search filter.

- Use `ldapsearch` to view the Data Store's published list of matching rule uses using the multi-valued operational attribute, `matchingRuleUse`, which publishes the definitions on the Data Store if any. The attribute is stored in the subschema subentry.

```
$ bin/ldapsearch --baseDN cn=schema --searchScope base \
  "(objectclass=*)" matchingRuleUse
```

Managing DIT Content Rules

DIT Content Rules provide a way to precisely define what attributes may be present in an entry, based on its structural object class, without specifically creating a new object class definition. The DIT content rules can define the mandatory and optional attributes that entries contain, the set of auxiliary object classes that entries may be part of, and any optional attributes from the structural and auxiliary object classes that are prohibited from being present in the entries.

DIT Content Rule Definitions

DIT Content Rules can be specified with existing schema components and do not require additional code for its implementation. On the UnboundID Data Store, only one DIT Content Rule may be defined for an entry in the structural object class.

The formal specification for attribute types is provided in RFC 4512, section 4.1.6 as follows:

```
DITContentRuleDescription = "(" wsp
numericoid                  ; Object identifier of the structural object class the rule
 applies to
[ sp "NAME" sp qdescrs ]    ; Short name descriptor
[ sp "DESC" sp qdstring ]   ; Description
[ sp "OBSOLETE" ]           ; Specifies if the rule is inactive
[ sp "AUX" sp oids ]        ; List of allowed auxiliary object classes
[ sp "MUST" sp oids ]       ; List of required attributes
[ sp "MAY" sp oids ]        ; List of allowed attributes in the entry
[ sp "NOT" sp oids ]        ; List of prohibited attributes in the entry
extensions wsp ")"          ; Extensions followed by a white space and ")"
```

The following extensions are specific to the UnboundID Data Store and are not defined in RFC 4512:

```
extensions = /
"X-ORIGIN" /             ; Specifies where the attribute type is defined
"X-SCHEMA-FILE" /        ; Specifies which schema file contains the definition
"X-READ-ONLY"            ; True or False. Specifies if the file that contains
                         ;   the schema element is marked as read-only in
                         ;   the server configuration.
```

To View DIT Content Rules

- Use `ldapsearch` to view a multi-valued operational attribute `dITContentRules`, which publishes the definitions on the Data Store if any. The attribute is stored in the subschema subentry.

```
$ bin/ldapsearch --baseDN cn=schema --searchScope base \
  "(objectclass=*)" dITContentRules
```

Managing Name Forms

Name Forms define how entries can be named based on their structural object class. Specifically, name forms specify the structural object class to be named, as well as the mutually-exclusive set of required and allowed attributes to form the Relative Distinguished Names (RDNs) of the entries. Each structural object class may be associated with at most one name form definition.

Name Form Definitions

Name Forms can be specified with existing schema components and do not require additional code for its implementation.

The formal specification for attribute types is provided in RFC 4512, section 4.1.7.2 as follows:

```
NameFormDescription = "(" wsp
numericoid                 ; object identifier
[ sp "NAME" sp qdescrs ]   ; short name descriptor
[ sp "DESC" sp qdstring ]  ; description
[ sp "OBSOLETE" ]          ; not active
sp "OC" sp oid             ; structural object class
sp "MUST" SP oids          ; attribute types
[ sp "MAY" sp oids ]       ; attribute types
extensions wsp ")"         ; extensions followed by a white space and ")"
```

The following extensions are specific to the UnboundID Data Store and are not defined in RFC 4512:

```
extensions = /
"X-ORIGIN" /            ; Specifies where the attribute type is defined
"X-SCHEMA-FILE" /       ; Specifies which schema file contains the definition
"X-READ-ONLY"           ; True or False. Specifies if the file that contains
                        ;   the schema element is marked as read-only in
                        ;   the server configuration.
```

To View Name Forms

- Use `ldapsearch` to view a multi-valued operational attribute `nameForms`, which publishes the definitions on the Data Store. The attribute is stored in the subschema subentry.

```
$ bin/ldapsearch --baseDN cn=schema --searchScope base "(objectclass=*)" nameForms
```

Managing DIT Structure Rules

DIT Structure Rules define which entries may be superior or subordinate to other entries in the DIT. Together with name forms, DIT Structure Rules determine how RDNs are added together to make up distinguished names (DNs). Because DITs do not have a global standard and are specific to a company's implementation, each DIT structure rule associates a name form with an object class and specifies each structure rule with an integer rule identifier, instead of an OID number. The identifier defines its relationship, either superior or subordinate, to another object class. If no superior rules are specified, then the DIT structure rule applies to the root of the subtree.

DIT Structure Rule Definition

DIT Structure Rules can be specified with existing schema components and do not require additional code for its implementation.

The formal specification for attribute types is provided in RFC 4512, section 4.1.7.1 as follows:

```
DITStructureRuleDescription = "(" wsp
ruleid                       ; object identifier
[ sp "NAME" sp qdescrs ]     ; short name descriptor
[ sp "DESC" sp qdstring ]    ; description
[ sp "OBSOLETE" ]            ; specifies if the rule is inactive
sp "FORM" sp oid             ; OID or name form with which the rule is associated
[ sp "SUP" ruleids ]         ; Superior rule IDs
extensions wsp ")"           ; extensions followed by a white space and ")"
```

The following extensions are specific to the UnboundID Data Store and are not defined in RFC 4512:

```
extensions = /
"X-ORIGIN" /              ; Specifies where the rule is defined
"X-SCHEMA-FILE" /         ; Specifies which schema file contains the definition
"X-READ-ONLY"             ; True or False. Specifies if the file that contains
                          ;   the schema element is marked as read-only in
                          ;   the server configuration.
```

To View DIT Structure Rules

- Use `ldapsearch` to view a multi-valued operational attribute `dITStructureRules`, which publishes the definitions on the Data Store. The attribute is stored in the subschema subentry.

  ```
  $ bin/ldapsearch --baseDN cn=schema --searchScope base \
    "(objectclass=*)" dITStructureRules
  ```

Managing JSON Attribute Values

The UnboundID Data Store supports a JSON object attribute syntax, which can be used for attribute types whose values are JSON objects. The syntax requires that each value of this type is a valid JSON object. The following is an example schema definition:

```
dn: cn=schema
objectClass: top
objectClass: ldapSubentry
objectClass: subschema
cn: schema
attributeTypes: ( jsonAttr1-OID NAME 'jsonAttr1' DESC 'test json attribute support'
 EQUALITY jsonObjectExactMatch SYNTAX 1.3.6.1.4.1.30221.2.3.4 USAGE userApplications )
objectClasses: ( jsonObjectClass-OID NAME 'jsonObjectClass' AUXILIARY MAY jsonAttr1 )
```

Note: The EQUALITY matching rule should always be specified as `jsonObjectExactMatch` in the schema definition. Using the `jsonObjectFilterExtensibleMatch` is not valid in this case.

Two matching rules are provided to filter the JSON object syntax: `jsonObjectExactMatch` and `jsonObjectFilterExtensibleMatch`.

The `jsonObjectExactMatch` equality matching rule is used in evaluating equality filters in search operations, and for matching performed against JSON object attributes for add, compare, and modify operations. It determines whether two values are logically-equivalent JSON objects. The field names used in both objects must match exactly (although fields may appear in different orders). The values of each field must have the same data types. String values are case-insensitive. The order of elements in arrays is considered significant. Substring or approximate matching is not supported.

The `jsonObjectFilterExtensibleMatch` matching rule can perform more powerful matching against JSON objects. The assertion values for these extensible matching filters should be JSON objects that express the constraints for the matching. These JSON object filters are described in detail in the Javadoc documentation for the UnboundID LDAP SDK for Java. Although the LDAP SDK can facilitate searches with this matching rule, these searches can be issued through any LDAP client API that supports extensible matching.

The following are example searches using the `jsonObjectFilterExtensibleMatch` rule with available filter types.

Equals field filter type:

```
$ bin/ldapsearch -p 1389 -b dc=example,dc=com  -D "cn=Directory Manager" -w password
 '(jsonAttr1:jsonObjectFilterExtensibleMatch:={ "filterType" : "equals", "field" :
 ["stuff", "onetype", "name"], "value" : "John Doe" })'
```

Contains field filter type:

```
$ bin/ldapsearch -p 1389 -b dc=example,dc=com  -D "cn=Directory Manager" -w password
 '(jsonAttr1:jsonObjectFilterExtensibleMatch:={ "filterType" : "containsField",
 "field" : "age", "expectedType" : "number" })'
```

Greater than field filter type:

```
$ bin/ldapsearch -p 1389 -b dc=example,dc=com  -D "cn=Directory Manager" -w password
 '(jsonAttr1:jsonObjectFilterExtensibleMatch:={ "filterType" : "greaterThan", "field" :
 "age", "value" : 26, "allowEquals" : true})'
```

Indexing is supported only for the `jsonObjectExactMatch` matching rule. If possible, non-baseObject searches that use the `jsonObjectFilterExtensibleMatch` matching rule should be wrapped in an LDAP `AND` filter that also contains one or more indexed components so that the search can be processed efficiently.

Configuring JSON Attribute Constraints

The UnboundID Data Store can define a number of constraints for the fields included in JSON objects stored in values of a specified attribute type. Constraints that can be placed on a JSON field include:

- Requiring values of the field to have a specified data type.
- Indicating whether the field is required or optional.
- Indicating whether the field can have multiple values in an array. If a field is permitted to have array values, restrictions can also be placed on the number of elements that can be present in the array.
- Indicating whether the field can have a value that is the null primitive as an alternative to values of the indicated data type.
- Restricting values of string fields to a predefined set of values, that match a given regular expression, or a specified length.
- Restricting values of numeric fields with upper and lower bounds.

Any existing data that doesn't match newly-defined JSON constraints can still be decoded and managed by the server. Only new entries are subject to the new constraints. Attempts to alter existing entries with non-compliant JSON objects may require fixing those objects to make them conform to the new constraints.

The two global configuration properties that define schema constraints for JSON objects are `create-json-attribute-constraints` and `create-json-field-constraints` in `dsconfig`. In `dsconfig` interactive under advanced settings, the menu options are JSON Attribute Constraints and JSON Field Constraints. Configuration properties for each include:

- **attribute-type**. The name or object identifier of the attribute type with which the definition is associated. This attribute type must have the JSON object syntax. This property will be the naming attribute for the configuration entry.
- **allow-unnamed-fields**. A boolean value that indicates whether JSON objects, used as the values of attributes of the associated type, can include fields that are not referenced in the `attribute-value-constraints` object. If this is `false`, JSON objects will only be permitted to have the defined fields. If this is `true` (which is the default behavior), JSON objects are permitted to have fields that are not referenced, and no constraints are imposed on those fields.

Unless a schema definition is configured with `allow-unnamed-fields` set to `false`, it is only necessary to include information about fields whose values should be indexed or tokenized. However, it may be desirable to define other fields that are expected in order to ensure that clients will not be permitted to store invalid values. See the *Working with JSON Indexes* for information about indexing JSON attributes.

As with standard LDAP schema, JSON schema constraints are enforced for any changes made after the constraints are defined. If there are already JSON values in the data before a JSON schema is defined for that attribute type (or before changes are made), values that already exist may violate those constraints. JSON schema constraints will also be enforced for data provided in an LDIF import, so that entries containing JSON objects that violate these constraints will be rejected.

Table 43: JSON Field Constraints

Property	Description
`field`	Specifies the path to the target field as a string, with periods to separate levels of hierarchy. If any field name in the hierarchy itself includes a period, that period should be escaped with a backslash.
`value-type`	Specifies the expected data type for the target field. Values can include: • `any`. The target field can have any value. • `boolean`. The target field must have a value of true or false. • `integer`. The target field must have a number that can be exactly represented as an integer. • `null`. The target field must have a value of null. • `number`. The target field must have a value that represents a valid JSON number • `object`. The target field must have a value that represents a valid JSON object. The `allowed-fields` array may contain additional elements that define constraints for the fields that may be present in the object. • `string`. The target field must have a value that represents a valid JSON string.
`is-required`	Specifies whether the target field is required to be present. If it is present, its value must be either `true` or `false`. If it is absent, a default of `false` is assumed.
`is-array`	Indicates whether the target field can be an array. If the value can be an array, all of the elements of the array must be of the type specified in the `value-type` field. It can be present with a value that is one of the single strings listed below. If it is absent, a value of `prohibited` is assumed. Values include: • `required`. The target field must be an array with zero or more values of the specified type, and must not be a single value of the specified type. • `optional`. The target field may be an array with zero or more values of the specified type, or it may be a single value of the specified type. • `prohibited`. The target field must not be an array and may only be a single value of the specified type.
`allow-null-value`	Specifies whether the target field can have a value of `null` as an alternative to the specified `value-type`. If present, its value must be either `true` or `false`. If it is absent, a default of `false` is assumed. This has no effect if the value-type is `null`.
`allow-empty-object`	If the value of the target field is a JSON object (or an array of JSON objects), specifies whether empty objects are permitted. If present, the value must be either `true` (the object may have zero or more fields) or `false` (the object may have one or more fields). If it is absent, a default of `false` is assumed.
`index-values`	Specifies whether values of the target field should be indexed in backends. If present, the value must be either `true` (the field should be indexed) or `false` (the field should not be indexed). If it is absent, a default of `false` is assumed. If `true`, the `value-type` must be `boolean`, `integer`, `null`, or `string`.
`index-entry-limit`	Specifies the maximum number of entries in which a particular value may appear before the entry ID list for that value is no longer maintained. If present, the value must be an integer greater than or equal to one. If it is absent, the server will use the default index entry limit for the associated backend. This is only applicable if `index-values` is `true`.

Property	Description
`prime-index`	Specifies whether backends should prime the contents of the JSON index database into memory when they are opened. This is ignored if the backend's `prime-all-indexes` property has a value of `true`.
`cache-mode`	Specifies the cache mode to use for the contents of the JSON index database. If the value is not specified, the backend's default cache mode will be used. If a cache mode of `cache-keys-only` is configured, priming will only load the internal nodes into memory for the index. If `no-caching` is configured, no priming is performed for the index.
`tokenize-values`	Specifies whether values of the target field should be tokenized in backends. If present, the value is either `true` (field values should be tokenized) or `false`. If it is absent, a value of `false` is assumed. If `true`, the `value-type` must be `string`.
`allowed-values`	Specifies an explicit set of values that the target field is permitted to have. If present, the value must be an array of strings. Any attempt to use a value not in this array for the associated field is rejected. This can only be used with a `value-type` of `string`. If not present, any value can be used as long as it satisfies all other defined constraints.
`allowed-value-regular-expression`	Specifies a regular expression that the target field will be required to match. If present, the value must be a single string or an array of strings representing valid regular expressions (which may require escaping to represent in JSON). Any attempt to use a value that does not match one of the provided regular expressions will be rejected. This can only be used with a `value-type` of `string`. If not present, values are not required to match any regular expression.
`minimum-numeric-value`	Specifies the lower bound for values of the target field. If present, the value must be a single number (it can be an integer). Any attempt to use a value that is less than this number is rejected. This can only be used with a `value-type` of `integer` or `number`. If not present, no minimum numeric value applies.
`maximum-numeric-value`	Specifies the upper bound for values of the target field. If present, the value must be a single number (it can be an integer). Any attempt to use a value that is more than this number is rejected. This can only be used with a `value-type` of `integer` or `number`. If not present, no maximum numeric value applies.
`minimum-value-length`	Specifies the minimum number of characters allowed for values of the target field. If present, the value must be an integer. Any attempt to use a value with fewer characters than this number is rejected. This can only be used with a `value-type` of `string`. If not present, no minimum length applies.
`maximum-value-length`	Specifies the maximum number of characters allowed for values of the target field. If present, the value must be an integer. Any attempt to use a value with more characters than this number is rejected. This can only be used with a `value-type` of `string`. If not present, no maximum length applies.
`minimum-value-count`	Specifies the minimum number of elements that must be present in an array. If present, the value must be an integer. Any attempt to use an array with fewer elements is rejected. This can only be used with an `is-array` value of `required` or `optional`. If not present, no minimum array value count applies.
`maximum-value-count`	Specifies the maximum number of elements that must be present in an array. If present, the value must be an integer. Any attempt to use an array with more elements is rejected. This can only be used with an `is-array` value of `required` or `optional`. If not present, no maximum array value count applies.

Note: When writing JSON objects in a local DB backend, field names and JSON primitive values of `null`, `true`, and `false` are always tokenized. Integers are either tokenized or compacted using their two's complement representation (other numbers are stored using string representations). Array and object sizes are compacted, and their contents are compacted based on their data types. String values are tokenized that match a recognizable format, including:

- Dates and times in common generalized time and ISO 8601 formats.
- UUIDs in which the alphabetic characters are either all uppercase or all lowercase.

- Strings of at least 12 bytes that are a valid base64 encoding.
- Strings of at least 6 bytes that are a valid hexadecimal encoding, in which the alphabetic characters are either all uppercase or all lowercase.

To Add Constraints to JSON Attributes

- Use the `dsconfig` tool (interactive or command line) to create and configure JSON attribute constraints. The following is a sample command:

```
$ bin/dsconfig create-json-attribute-constraints \
  --attribute-type appjson \
  --set enabled:true \
  --set allow-unnamed-fields:false
```

```
$ bin/dsconfig create-json-field-constraints \
  --attribute-type appjson \
  --json-field email.verified \
  --set value-type:boolean \
  --set is-required:true \
  --set index-values:true \
  --set tokenize-values:false \
  --set allow-null-value:true
```

```
$ bin/dsconfig create-json-field-constraints \
  --attribute-type appjson \
  --json-field email.type \
  --set value-type:string \
  --set is-required:true \
  --set index-values:true \
  --set tokenize-values:true \
  --set allowed-value:home \
  --set allowed-value:other \
  --set allowed-value:work \
  --set allow-null-value:false \
  --set minimum-value-length:1
```

```
$ bin/dsconfig create-json-field-constraints \
  --attribute-type appjson \
  --json-field email.value \
  --set value-type:string \
  --set is-required:true \
  --set index-values:true \
  --set tokenize-values:true \
  --set prime-index:true \
  --set allow-null-value:true \
  --set maximum-value-length:256 \
  --set minimum-value-length:1 \
  --set allowed-value-regular-expression:[-_\+\.\w\d]+@\w+\.\w{2,5}
```

Chapter 19 Managing Password Policies

The UnboundID Data Store provides a flexible password policy system to assign, manage, or remove password policies for root and non-root users. The password policy contains configurable properties for password expiration, failed login attempts, account lockout and other aspects of password and account maintenance on the Data Store. The Data Store also provides a global configuration option and a per-user privilege feature that disables parts of the password policy evaluation for production environments that do not require a password policy.

This chapter presents the following topics:

Topics:

Viewing Password Policies

Password policies enforce a set of rules that ensure that access to data is not compromised through negligent password practices. The UnboundID Data Store provides mechanisms to create and maintain password policies that determine whether passwords should expire, whether users are allowed to modify their own passwords, or whether too many failed authentication attempts should result in an account lockout. Many other options are available to fully configure a password policy for your UnboundID Platform system.

The Data Store provides three out-of-the-box password policies that can be applied to your entries or as templates for configuring customized policies. The Default Password Policy is automatically applied to all users although it is possible to use an alternate password policy on a per-user basis. The Root Password Policy is enforced for the default root user, which uses a stronger password storage scheme (salted 512-bit SHA-2 rather than the salted 160-bit SHA-1 scheme used for normal users) and also requires that a root user provide his or her current password to select a new password.

The Secure Password Policy provides a more secure option than the default policy that makes use of a number of features, including password expiration, account lockout, last login time and last login IP address tracking, password history, and a number of password validators.

Caution:

Using the Secure Password policy as-is may notably increase write load in the server by requiring updates to password policy state attributes in user entries and/or requiring users to change passwords more frequently. In environments in which write throughput is a concern (including environments spread across multiple data centers requiring replication over a WAN), it may be useful to consider whether the policy should be updated to reduce the number of entry updates that may be required.

To View Password Policies

- You can view the list of password policies configured on the Data Store using the `dsconfig` tool, in either interactive or non-interactive mode, or the web administration console. The following example demonstrates the process for obtaining a list of defined password policies in non-interactive mode:

```
$ bin/dsconfig list-password-policies
```

```
Password Policy      : Type : password-attribute : default-password-storage-scheme
------------------------:---------:--------------------:------------------------------
Default Password Policy : generic : userpassword    : Salted SHA-1
Root Password Policy : generic : userpassword    : Salted SHA-512
Secure Password Policy  : generic : userpassword       : CRYPT
```

To View a Specific Password Policy

- Use `dsconfig` or the web administration console to view a specific password policy. In this example, view the Default Password Policy that applies to all uses for which no specific policy has been configured.

```
$ bin/dsconfig get-password-policy-prop \
  --policy-name "Default Password Policy"
```

```
Property                                  : Value(s)
------------------------------------------:-------------------------
description                               : -
password-attribute                        : userpassword
default-password-storage-scheme           : Salted SHA-1
deprecated-password-storage-scheme        : -
password-validator                        : -
account-status-notification-handler       : -
allow-user-password-changes               : true
password-change-requires-current-password : false
force-change-on-add                       : false
force-change-on-reset                     : false
password-generator                        : Random Password Generator
require-secure-authentication             : false
require-secure-password-changes           : false
min-password-age                          : 0s
max-password-age                          : 0s
max-password-reset-age                    : 0s
password-expiration-warning-interval      : 5d
expire-passwords-without-warning          : false
allow-expired-password-changes            : false
grace-login-count                         : 0s
lockout-failure-count                     : 0s
lockout-duration                          : 0s
lockout-failure-expiration-interval       : 0s
require-change-by-time                    : -
last-login-time-attribute                 : ds-pwp-last-login-time
last-login-time-format                    : -
previous-last-login-time-format           : -
idle-lockout-interval                     : 0s
password-history-count                    : 0s
password-history-duration                 : 0s
```

About the Password Policy Properties

The Data Store provides a number of configurable properties that can be used to control password policy behavior.

Note: To view a description of each of the password policy properties, see the *UnboundID Data Store Configuration Reference* that is bundled with the UnboundID Data Store.

Some of the most notable properties include:

- **allow-user-password-changes**. Specifies whether users can change their own passwords. If a user attempts to change his/her own password, then the server will consult this property for the user’s password policy, and will also ensure that the access control handler allows the user to modify the configured password attribute.

- **default-password-storage-scheme**. Specifies the names of the password storage schemes that are used to encode clear-text passwords for this password policy.
- **enable-debug**. When enabled, is used to debug password policy interaction. This property should be used in addition to the server's debug framework with a relevant debug target.
- **force-change-on-add**. Specifies whether users are required to change their passwords upon first authenticating to the Data Store after their account has been created.
- **force-change-on-reset**. Specifies whether users are required to change their passwords after they have been reset by an administrator. An administrator is a user who has the `password-reset` privilege and the appropriate access control instruction to allow modification of other users' passwords.
- **idle-lockout-interval**. Specifies the maximum length of time that an account may remain idle (the associated user does not authenticate to the server) before that user is locked out. For accounts that do not have a last login time value, the password changed time or the account creation time will be used. If that information is not available, then the user will not be allowed to authenticate. It is strongly recommended that the server be allowed to run for a period of time with last login time tracking enabled (i.e., values for both `last-login-time-attribute` and `last-login-time-format` properties) to ensure that users have a last login time before enabling idle account lockout.
- **lockout-duration**. Specifies the length of time that an account is locked after too many authentication failures. The value of this attribute is an integer followed by a unit of seconds, minutes, hours, days, or weeks. A value of 0 seconds indicates that the account must remain locked until an administrator resets the password.
- **lockout-failure-count**. Specifies the maximum number of times that a user may be allowed to attempt to bind with the wrong password before that user's account becomes locked either temporarily (in which case the account will automatically be unlocked after a configurable length of time) or permanently (in which case an administrator must reset the user's password before the account may be used again). For example, if the value is set to 3, then the user is locked out on the fourth failed attempt.
- **max-password-age**. Specifies the maximum length of time that a user can continue to use the same password before he or she is required to choose a new password. The value can be expressed in seconds (s), minutes (m), hours (h), days (d), or weeks (w). A minimum length of time can also be specified before the user is allowed to change the password.
- **password-change-requires-current-password**. Specifies whether users must include their current password when changing their password. This applies for both password changes made with the password modify extended operation as well as simple modify operations targeting the password attribute. In the latter case, if the current password is required then the password modification must remove the current value and add the desired new value (providing both the current and new passwords in the clear rather than using encoded representations).
- **password-expiration-warning-interval**. Specifies the length of time before a user's password expires that he or she receives notification about the upcoming expiration (either through the password policy or password expiring response controls). The value can be expressed in seconds (s), minutes (m), hours (h), days (d), or weeks (w).

- **password-retirement-behavior**. Specifies the behavior of a password that is allowed a retirement period before becoming invalid. This setting may be used by application service accounts that require a transition period while updating passwords. This is disabled by default.
- **password-validator**. Specifies the names of the password validators that are used with the associated password storage scheme. The password validators are invoked when a user attempts to provide a new password, to determine whether the new password is acceptable.
- **require-secure-authentication**. Indicates whether users with the associated password policy are required to authenticate in a secure manner. This might mean either using a secure communication channel between the client and the server, or using a SASL mechanism that does not expose the credentials.
- **require-secure-password-changes**. Indicates whether users with the associated password policy are required to change their password in a secure manner that does not expose the credentials.

Modifying an Existing Password Policy

You can modify an existing password policy to suit your company's requirements.

To Modify an Existing Password Policy

- Use `dsconfig` (in interactive or non-interactive mode) or the web administration console to modify the configuration for any defined password policy. The following example sets some of the properties presented in the previous section for the default password policy using `dsconfig` in non-interactive mode:

```
$ bin/dsconfig set-password-policy-prop \
  --policy-name "Default Password Policy" \
  --set "max-password-age:90 days" \
  --set "password-expiration-warning-interval:14 days" \
  --set "lockout-failure-count:3" \
  --set "password-history-count:6"
```

Creating a New Password Policy

You can create any number of password policies in the Data Store using either the `dsconfig` tool (in interactive or non-interactive mode) or the web administration console.

To Create a New Password Policy

- Use `dsconfig` (in interactive or non-interactive mode) or the web administration console to create a new pasword policy. The following example demonstrates the process for creating a new policy using `dsconfig` in non-interactive mode.

```
$ bin/dsconfig create-password-policy \
  --policy-name "Demo Password Policy" \
  --set "password-attribute:userpassword" \
  --set "default-password-storage-scheme:Salted SHA-1" \
  --set "force-change-on-add:true" \
  --set "force-change-on-reset:true" \
  --set "password-expiration-warning-interval:2 weeks" \
  --set "max-password-age:90 days" \
  --set "lockout-duration:24 hours" \
  --set "lockout-failure-count:3" \
  --set "password-change-requires-current-password:true"
```

To Assign a Password Policy to an Individual Account

To indicate that a user should be subject to a particular password policy (rather than automatically inheriting the default policy), include the `ds-pwp-password-policy-dn` operational attribute in that user's entry with a value equal to the DN of the desired password policy for that user. This attribute can be explicitly included in a user's entry, or it can be generated by a virtual attribute, which makes it easy to apply a custom password policy to a set of users based on a flexible set of criteria.

1. Create a file (`assign.ldif`) with the following contents:

```
dn: uid=user.1,ou=People,dc=example,dc=com
changetype: modify
add: ds-pwp-password-policy-dn
ds-pwp-password-policy-dn: cn=Demo Password Policy,cn=Password Policies,cn=config
```

2. Use `ldapmodify` to apply the modification to the user's entry.

```
$ bin/ldapmodify --filename assign.ldif
```

To Assign a Password Policy Using a Virtual Attribute

It is possible to automatically assign a custom password policy for a set of users using a virtual attribute. The virtual attribute can be configured so that it can use a range of criteria for selecting the entries for which the virtual attribute should appear.

1. Create an LDIF file, which may be used to add a group to the server.

```
dn: ou=Groups,dc=example,dc=com
objectClass: organizationalunit
objectClass: top
ou: Groups

dn: cn=Engineering Managers,ou=groups,dc=example,dc=com
objectClass: groupOfUniqueNames
objectClass: top
cn: Engineering Managers
uniqueMember: uid=user.0,ou=People,dc=example,dc=com ou: groups
```

2. Use `ldapmodify` to add the entries to the server.

```
$ bin/ldapmodify --defaultAdd --filename groups.ldif
```

3. Use `dsconfig` to create a virtual attribute that will add the `ds-pwp-pasword-policy-dn` attribute with a value of `cn=Demo Password Policy,cn=Password Policies,cn=config` to the entries for all users that are members of the `cn=Engineering Managers,ou=Groups,dc=example,dc=com` group.

```
$ bin/dsconfig create-virtual-attribute \
  --name "Eng Mgrs Password Policy" \
  --type user-defined \
  --set "description:Eng Mgrs Grp PWPolicy" \
  --set enabled:true \
  --set attribute-type:ds-pwp-password-policy-dn \
  --set "value:cn=Demo Password Policy,cn=Password Policies,cn=config" \
  --set "group-dn:cn=Engineering Managers,ou=Groups,dc=example,dc=com
```

4. Use `ldapsearch` to verify that a user in the group contains the assigned password policy DN.

```
$ bin/ldapsearch --baseDN dc=example,dc=com "(uid=user.0)" \
ds-pwp-password-policy-dn
```

```
dn: uid=user.0,ou=People,dc=example,dc=com
ds-pwp-password-policy-dn: cn=Demo Password Policy,cn=Password Policies,cn=config
```

Deleting a Password Policy

You can delete a password policy using either the `dsconfig` tool (in interactive or non-interactive mode) or the web administration console.

To Delete a Password Policy

Custom password policies may be removed using either the `dsconfig` tool (in interactive or non-interactive mode) or the web administration console).

- Run the `dsconfig` command with the `delete-password-policy` subcommand to remove a password policy.

```
$ bin/dsconfig delete-password-policy \
  --policy-name "Demo Password Policy"
```

Modifying a User’s Password

There are two primary ways to change user passwords in the Data Store:

- Perform a modify operation which replaces the value of the password attribute (often `userPassword`). Note that in some configurations, when a user attempts to change his or her own password it may be necessary to perform the modification by removing the password value and adding the desired new value to demonstrate that the user knows the current password value.
- Use the password modify extended operation to change the password. Note that if a user is changing his or her own password, it may be necessary to provide the current password value. The server will allow a new password to be provided (assuming that the new password is acceptable to all configured password validators), or it may automatically generate a new password for the user.

Note that regardless of the mechanism used to change the password, all password values should be provided in clear text rather than pre-encoded, and the user will be required to have sufficient access control rights to update the password attribute in the target user's entry. Further, when one user attempts to change the password for another user, then the requester will be required to have the `password-reset` privilege.

Validating a Password

The requirements that the server will impose for a password change can be displayed to users. The get password quality requirements extended operation can be used to retrieve information about the requirements, which can then be sent to an end user before an attempted password change. These requirements can also be used to enable client-side validation, so that any password problems can be identified before it is sent to the server. The password validation details request control can be included in an add or modify request, or a password modify extended request, to identify which validation requirements were not met by the password provided in the request.

Password validators can be configured with user-friendly messages that describe the password requirements, and the messages that should be returned if a proposed password does not satisfy those requirements. The server will generate these messages if they are not provided in the configuration.

Password validator properties include `validator-requirement-description` and `validator-failure` message. The following is a simple password validator configuration that requires passwords to contain a minimum of five characters, and lists custom validator messages:

```
$ dsconfig create-password-validator \
  --validator-name "Minimum 5 Characters Password Validator" \
  --type length-based --set enabled:true \
  --set "validator-requirement-description:The password must contain
         at least 5 characters." \
  --set "validator-failure-message:The password did not contain
         at least 5 characters." \
  --set min-password-length:5
```

After the password validator is created, it should be assigned to a Password Policy to take affect:

```
$ dsconfig set-password-policy-prop \
  --policy-name "Default Password Policy" \
  --set "password-validator:Minimum 5 Characters Password Validator"
```

Retiring a Password

An account password can be retired and rotated out of service, instead of immediately invalidated. This enables a new password to be assigned to an account while keeping the original password valid for a period of time to enable a transition. This is useful for application service accounts that require uninterrupted authentication with the server.

This behavior is disabled by default, but can be enabled in the password policy configuration by setting the `password-retirement-behavior` and `maximum-retired-password-age` properties.

To manually retire an account password or purge a password that has been retired, use the `ldapmodify` and `ldappasswordmodify` commands with options `-- retireCurrentPassword` and `--purgeCurrentPassword`. To use these commands on an account, the password policy that governs the account must have the `password-retirement-behavior` enabled.

To Change a User’s Password using the Modify Operation

- Use `ldapmodify` to change a user’s password by replacing the `userPassword` attribute.

```
$ bin/ldapmodify
dn: uid=user.0,ou=People,dc=example,dc=com
changetype: modify
replace: userPassword
userPassword: newpw
```

To Change a User’s Password using the Password Modify Extended Operation

- Use `ldappasswordmodify` to request that the Password Modify extended operation be used to modify a user’s password.

```
$ bin/ldappasswordmodify --authzID dn:uid=jdoe,ou=People,dc=example,dc=com \
  --newPassword newpw
```

To Use an Automatically-Generated Password

- Use `ldappasswordmodify` to automatically generate a new password for a user.

```
$ bin/ldappasswordmodify --authzID "u:user.1"
```

```
The LDAP password modify operation was successful
Generated Password: fbi27oqy
```

Managing User Accounts

The Data Store provides a user management utility, the `manage-account` tool, that provides a means to quickly view and manipulate a number of password and account policy properties for a user.

Note: A disabled account status (for example, `account-is-disabled: true`) is different from an *account lockout* due to password policy. Unlocking a user account requires a *password reset* by an administrator. A disabled account requires the administrator to enable the account; password resets are not involved.

To Return the Password Policy State Information

- Use `manage-account` to get information about the account’s password policy.

```
$ bin/manage-account get-all \
  --targetDN uid=user.1,ou=People,dc=example,dc=com
```

```
Password Policy DN: cn=Demo Password Policy,cn=Password Policies,cn=config
Account Is Disabled: false
Account Expiration Time:
Seconds Until Account Expiration:
Password Changed Time: 19700101000000.000Z
Password Expiration Warned Time:
Seconds Until Password Expiration: 1209600
Seconds Until Password Expiration Warning: 0
Authentication Failure Times:
Seconds Until Authentication Failure Unlock:
Remaining Authentication Failure Count: 3
Last Login Time:
Seconds Until Idle Account Lockout:
Password Is Reset: false
Seconds Until Password Reset Lockout:
Grace Login Use Times:
Remaining Grace Login Count: 0
Password Changed by Required Time:
Seconds Until Required Change Time:
Password History:
```

To Determine Whether an Account is Disabled

- Use `manage-account` to determine whether a user's account has been disabled.

```
$ bin/manage-account get-account-is-disabled \
  --targetDN uid=user.1,ou=People,dc=example,dc=com
```

```
Account Is Disabled: true
```

To Disable an Account

- Use `manage-account` to disable a user's account.

```
$ bin/manage-account set-account-is-disabled \
  --operationValue true --targetDN uid=user.1,ou=People,dc=example,dc=com
```

```
Account Is Disabled: true
```

To Enable a Disabled Account

- Use `manage-account` to enable a user's account.

```
$ bin/manage-account clear-account-is-disabled \
  --targetDN uid=user.1,ou=People,dc=example,dc=com
```

```
Account Is Disabled: false
```

To Assign the Manage-Account Access Privileges to Non-Root Users

Non-root users (e.g., `uid=admin`) with admin right privileges require access control permission to interact with certain password policy operational attributes when using the `manage-account` tool.

For example, the presence of the `ds-pwp-account-disabled` operational attribute in an entry determines that the entry is disabled. If the non-root admin user does not have the access privilege to read or interact with the `ds-pwp-account-disabled` operational attribute, the `manage-account` tool may report that the account is active. An account is considered active if the `ds-pwp-account-disabled` operational attribute does not exist in the entry or if the admin user does not have permission to see it.

Use the following procedure to give access rights to the non-root admin user.

1. Create a non-root user admin account, such as `uid=admin,dc=example,dc=com`. Grant the `password-reset` privilege to the account. See step 1 and 6 in the Configuring Administrators section for more information.

2. Run the `manage-account` tool to view the account status for an account.

```
$ bin/manage-account get-all \
  --targetDN uid=user.0,ou=People,dc=example,dc=com
```

```
Password Policy DN:  cn=Default Password Policy,cn=Password Policies,cn=config
Account Is Disabled:  false
Account Expiration Time:
Seconds Until Account Expiration:
Password Changed Time:  19700101000000.000Z
Password Expiration Warned Time:
Seconds Until Password Expiration:
Seconds Until Password Expiration Warning:
Authentication Failure Times:
Seconds Until Authentication Failure Unlock:
Remaining Authentication Failure Count:
Last Login Time:
Seconds Until Idle Account Lockout:
Password Is Reset:  false
Seconds Until Password Reset Lockout:
Grace Login Use Times:
Remaining Grace Login Count:  0
Password Changed by Required Time:
Seconds Until Required Change Time:
Password History:
```

3. Grant access control privileges to the admin account. Here you have two options: give full access rights to all user attributes and specify the `ds-pwp-account-disabled` operational attribute.

```
aci: (targetattr="*||ds-pwp-account-disabled")
  (version 3.0; acl "Allow user to access all user attributes and the
   ds-pwp-account-disabled operational attribute";
   allow (all) userdn="ldap:///uid=admin,dc=example,dc=com";)
```

   or give full access to all user and operational attributes:

```
aci: (targetattr="*||+")
  (version 3.0; acl "Allow user to access all user and operational
   attributes";
   allow (all) userdn="ldap:///uid=admin,dc=example,dc=com";)
```

4. Optional. The Data Store comes with a default set of global ACIs that include access privileges to the password policy extended operation, which is automatically available to all authenticated users. If your UnboundID Platform system limits access to these Global ACIs, you can grant the password policy extended operation to all authenticated users (`userdn="ldap:///all";`) or to an admin user as follows:

```
aci: (extop="1.3.6.1.4.1.30221.1.6.1")
  (version 3.0; acl "Allow the password policy extended operation";
  allow (read) userdn="ldap:///uid=admin,dc=example,dc=com";)
```

5. Run the `manage-account` tool to disable an account. The following command sets the `account-is-disabled` property to true for the `uid=user.0,dc=example,dc=com`.

   ```
   $ bin/manage-account set-account-is-disabled \
     --targetDN uid=user.0,ou=People,dc=example,dc=com \
     --operationValue true
   ```

   ```
   Account Is Disabled:  true
   ```

6. Run the `ldapsearch` tool to view the presence of the `ds-pwp-account-disabled` operational attribute in the entry.

   ```
   $ bin/ldapsearch --baseDN dc=example,dc=com "(uid=user.0)" "+"
   ```

   ```
   dn: uid=user.0,ou=People,dc=example,dc=com
   ds-pwp-account-disabled: true
   ```

Disabling Password Policy Evaluation

The Data Store provides a global configuration property (`disable-password-policy-evaluation`) that can be used to disable most password policy evaluation processing. This provides a convenience for those production environments that do not require password policy support. If the `disable-password-policy` property is set to true, passwords will still be encoded and evaluated, but only account expiration and account disabling will be in effect. All other password policy properties, such as password expiration, lockout, and force change on add or reset, are ignored.

The server also supports the use of a `bypass-pw-policy` privilege, which can be used to skip password policy evaluation for operations on a per-user basis. If a user has this privilege, then they will be allowed to perform operations on user entries that would normally be rejected by the password policy associated with the target entry. Note that this privilege will not have any effect for bind operations.

To Globally Disable Password Policy Evaluation

- Use `dsconfig` to set the `disable-password-policy-evaluation` property globally for the Data Store.

  ```
  $ bin/dsconfig --no-prompt set-global-configuration-prop \
    --set "disable-password-policy-evaluation:false"
  ```

To Exempt a User from Password Policy Evaluation

- Use `ldapmodify` to add the `bypass-pw-policy` privilege to a user entry.

  ```
  $ bin/ldapmodify
  dn: uid=user.1,ou=People,dc=example,dc=com
  changetype: modify
  add: ds-privilege-name
  ds-privilege-name: bypass-pw-policy
  ```

Managing Password Validators

A password validator is a password policy component that is used to determine if a new password is acceptable. A password policy can be configured with any number of password validators. If a password policy is configured with multiple password validators, then all of them must consider a proposed new password acceptable before it will be allowed.

Password Validators

The UnboundID Data Store offers a number of types of password validators, including those listed in the following table. It is also possible to use the UnboundID Server SDK to create custom password validators with whatever constraints are necessary for your environment.

Table 44: Password Validators

Password Validators	Description
Attribute Value	Ensures that the proposed password does not match the value of another attribute in the user's entry. The validator can be configured to look in all attributes or in a subset of attributes. It can perform forward and reverse mapping, and it can also reject values which are substrings of another attribute.
Character Set	Ensures that the proposed password contains a sufficient number of characters from one or more user-defined character sets. For example, the validator can ensure that passwords must have at least one lowercase letter, one uppercase letter, one digit, and one symbol.
Commonly-Used Passwords Dictionary	Ensures that the proposed password is not one of 10,000 commonly used passwords. These are words that are common for attackers to use when trying to access user accounts. The Commonly-Used Passwords validator is invoked by the Secure Password Policy by default. The word list is located in `<server-root>/config/commonly-used-passwords.txt`, and can be used to create a custom validator, but should not be modified.
Dictionary	Ensures that the proposed password is not present in a specified dictionary file, optionally also testing the password with all characters in reverse order. A large dictionary file is provided with the server, but the administrator can supply an alternate dictionary. In this case, then the dictionary must be a plain-text file with one word per line.
Haystack Password Validator	Ensures that the proposed password is secure based on a combination of its length and the types of characters that it contains. For example, a longer password containing only lowercase letters may be stronger than a shorter password containing a mix of uppercase and lowercase letters, numbers, and symbols. This is based on the Gibson Research Corporation Password Haystacks concept.
Length-Based Password Validator	Ensures that the number of characters in the proposed new password is within an acceptable range. Both a maximum and minimum number of characters may be specified.
Regular Expression Validator	Ensures that a proposed password either matches or does not match a given regular expression.
Repeated Characters	Ensures that a proposed password does not contain a substring in which the same character is repeated more than a specified number of times (for example,

Password Validators	Description
	"aaaaa" or "aaabbb"). The validator can be configured to operated in a case-sensitive or case-insensitive manner, and you can also define custom sets of equivalent characters (for example, you could define all digits as equivalent, so the proposed password could not contain more than a specified number of consecutive digits.
Similarity-Based Password Validator	Ensures that the proposed new password is not too similar to the current password, using the Levenstein Distance algorithm, which calculates the number of characters that need to be inserted, removed, or replaced to transform one string into another. Note that for this password validator to be effective, it is necessary to have access to the user's current password. Therefore, if this password validator is to be enabled, the `password-change-requires-current-password` attribute in the password policy configuration must also be set to true.
Unique Characters	Ensures that the proposed password contains at least a specified minimum number of unique characters, optionally using case-insensitive validation.

Configuring Password Validators

You can use the `dsconfig` configuration tool or web administration console to configure or modify any password validators. Once you have defined your password validators, you can add them to an existing password policy. The following example procedures show the dsconfig non-interactive commands necessary to carry out such tasks. If you use `dsconfig` in interactive command-line mode, you can access the Password Validator menu in the Basic Objects menu. For more details on the password validator properties, see the *UnboundID Data Store Configuration Reference*.

To View the List of Defined Password Validators

- Use `dsconfig` to view the set of password validators defined in the Data Store.

```
$ bin/dsconfig --no-prompt list-password-validators
```

To Configure the Attribute Value Password Validator

1. Use `dsconfig` to edit the existing default configuration for the Attribute Value Password Validator. For example, the following change configures the validator to only examine a specified set of attributes..

```
$ bin/dsconfig set-password-validator-prop \
  --validator-name "Attribute Value" \
  --set match-attribute:cn \
  --set match-attribute:sn \
  --set match-attribute:telephonenumber \
  --set match-attribute:uid
```

2. Update an existing password policy to use the Attribute Value Password Validator.

```
$ bin/dsconfig set-password-policy-prop \
  --policy-name "Default Password Policy" \
  --set "password-validator:Attribute Value"
```

3. Test the Attribute Value Password Validator by submitting a password that is identical to one of the configured attributes (`cn`, `sn`, `telephonenumber`, `uid`).

```
$ bin/ldappasswordmodify --authzID "uid=user.0,ou=People,dc=example,dc=com" \
  --newPassword user.0
```

```
The LDAP password modify operation failed with result code 53
Error Message: The provided new password failed the validation checks defined in the
server: The provided password was found in another attribute in the user entry
```

To Configure the Character Set Password Validator

1. Use `dsconfig` to edit the existing default configuration. In this example, we change the requirement for special characters making them optional in a password, and add a requirement that at least two digits must be included in the password. Thus, in this example, all newly created passwords must have at least one lowercase letter, one uppercase letter, two digits, and optionally any special characters listed.

```
$ bin/dsconfig set-password-validator-prop \
  --validator-name "Character Set" \
  --remove character-set:1:0123456789 \
  --remove "character-set:1:~\!@#\$\%^&*()-_=+[]{}\|;:,.<>/?" \
  --add character-set:2:0123456789 \
  --add "character-set:0:~\!@#\$\%^&*()-_=+[]{}\|;:,.<>/?" \
  --set allow-unclassified-characters:false
```

2. Update an existing password policy to use the Character Set Password Validator.

```
$ bin/dsconfig set-password-policy-prop \
  --policy-name "Default Password Policy" \
  --set "password-validator:Character Set"
```

3. Test the Character Set Password Validator by submitting a password that meets the requirements (one lowercase letter, one uppercase letter, two digits). The following example should reject the given password because it does not pass the Character Set Password Validator.

```
$ bin/ldappasswordmodify \
  --authzID "uid=user.0,ou=People,dc=example,dc=com" --newPassword abab1
```

To Configure the Length-Based Password Validator

1. Use `dsconfig` to edit the existing default configuration. In this example, we set the required minimum number of characters in a password to five.

```
$ bin/dsconfig create-password-validator \
  --validator-name "Length-Based Password Validator" \
  --set max-password-length:5 --set min-password-length:5
```

2. Update an existing password policy to use the Length-Based Password Validator.

```
$ bin/dsconfig set-password-policy-prop \
  --policy-name "Default Password Policy" \
  --set "password-validator:Length-Based Password Policy"
```

3. Test the Length-Based Password Validator by submitting a password that has fewer than the minimum number of required characters.

```
$ bin/ldappasswordmodify \
  --authzID "uid=user.0,ou=People,dc=example,dc=com" --newPassword abcd
```

```
The LDAP password modify operation failed with result code 53
Error Message: The provided new password failed the validation checks defined in
the server: The provided password is shorter than the minimum required length of
5 characters
```

To Configure the Regular Expression Password Validator

1. Use `dsconfig` to create a Regular Expression password validator. The following password validator checks that the password contains at least one number, one lowercase letter, and one uppercase letter with no restrictions on password length. If the password matches the regular expression, then it will be accepted. When using the following command, remember to include the LDAP/LDAPS connection parameters (host name and port), bind DN, and bind password.

```
$ bin/dsconfig create-password-validator \
  --validator-name "Regular Expression" \
  --type regular-expression --set enabled:true \
  --set "match-pattern:^\\w*(?=\\w*\\d)(?=\\w*[a-z])(?=\\w*[A-Z])\\w*\$" \
  --set match-behavior:require-match
```

2. Update an existing password policy to use the Regular Expression validator.

```
$ bin/dsconfig set-password-policy-prop \
  --policy-name "Default Password Policy" \
  --set "password-validator:Regular Expression"
```

3. Test the Regular Expression Validator by submitting a password that meets the requirements (contains one number, one lowercase letter, and one uppercase letter), then run it again with a password that does not meet these requirements.

```
$ bin/ldappasswordmodify \
  --authzID "uid=user.0,ou=People,dc=example,dc=com" --newPassword baaA1
```

```
The LDAP password modify operation was successful
```

4. Try another password. The following password should fail, because no uppercase letter is present.

```
$ bin/ldappasswordmodify \
  --authzID "uid=user.0,ou=People,dc=example,dc=com" --newPassword baaa1
```

```
Error Message: The provided new password failed the validation checks
defined in the server: The provided password is not acceptable because it does
not match regular expression pattern '^\w*(?=\w*\d)(?=\w*[a-z])(?=\w*[A-Z])\w*$'
```

To Configure the Repeated Character Password Validator

1. Use `dsconfig` to edit the existing default configuration.

   • In this example, we set the maximum consecutive length of any character to 3. For example, the following validator rejects any passwords, such as "baaaa1" or "4eeeeb", etc.

   ```
   $ bin/dsconfig set-password-validator-prop \
     --validator-name "Repeated Characters" \
   ```

```
  --set max-consecutive-length:3
```

- Or, you can configure the validator to reject any character from a pre-defined character set that appears more than the specified number of times in a row (2). You can also specify more than one character set. For example, the following validator defines two characters sets: [abc] and [123]. It rejects any passwords with more than two consecutive characters from a character set. Thus, "aaa", "bbb", "ccc", "abc", or "123" and so on fails, but "12a3" is okay.

```
$ bin/dsconfig set-password-validator-prop \
  --validator-name "Repeated Characters" \
  --set character-set:123 --set character-set:abc
```

2. Update an existing password policy to use the Repeated Character Password Validator.

```
$ bin/dsconfig --no-prompt set-password-policy-prop \
  --policy-name "Default Password Policy" \
  --set "password-validator:Repeated Characters"
```

3. Test the Repeated Character Validator by submitting a password that has more than the maximum allowable length of consecutive characters.

```
$ bin/ldappasswordmodify \
  --authzID "uid=user.0,ou=People,dc=example,dc=com" \
  --newPassword baaa1
```

```
The LDAP password modify operation failed with result code 53
Error Message: The provided new password failed the validation checks defined
in the server: The provided password contained too many instances of the same
character appearing consecutively. The maximum number of times the same
character may appear consecutively in a password is 2
```

To Configure the Similarity-Based Password Validator

1. Use `dsconfig` to edit the existing default configuration. In this example, we set the minimum number of differences to 2.

```
$ bin/dsconfig set-password-validator-prop \
  --validator-name "Similarity-Based Password Validator" \
  --set min-password-difference:2
```

2. Update an existing password policy to use the Similarity-Based Password Validator. The `password-change-requires-current-password` property must be set to TRUE, so that the password policy will ensure that the user’s current password is available when that user is choosing a new password.

```
$ bin/dsconfig set-password-policy-prop \
  --policy-name "Default Password Policy" \
  --set "password-validator:Similarity-Based Password Validator" \
  --set password-change-requires-current-password:true
```

3. Test the Similarity-Based Password Validator by submitting a password that has fewer than the minimum number of changes (e.g., 2). The `ldappasswordmodify` command requires the `--currentPassword` option when testing the Similarity-Based Password Validator.

```
$ bin/ldappasswordmodify \
  --authzID "uid=user.0,ou=People,dc=example,dc=com" \
  --currentPassword abcde --newPassword abcdd
```

```
The LDAP password modify operation failed with result code 49
```

To Configure the Unique Characters Password Validator

1. Use `dsconfig` to edit the existing default configuration. In this example, we set the minimum number of unique characters that a password is allowed to contain to 3.

```
$ bin/dsconfig set-password-validator-prop \
  --validator-name "Similarity-Based" --set min-unique-characters:3
```

2. Update an existing password policy to use the Unique Characters Password Validator.

```
$ bin/dsconfig set-password-policy-prop \
  --policy-name "Default Password Policy" \
  --set "password-validator:Unique Characters"
```

3. Test the Unique Characters Password Validator by submitting a password that has fewer than the minimum number of unique characters (e.g., 3).

```
$ bin/ldappasswordmodify \
  --authzID "uid=user.0,ou=People,dc=example,dc=com" \
  --newPassword aaaaa
```

```
The LDAP password modify operation failed with result code 53
Error Message: The provided new password failed the validation checks defined
in the server: The provided password does not contain enough unique characters.
The minimum number of unique characters that may appear in a user password is 3
```

Chapter 20 Managing Replication

The UnboundID Data Store provides a robust replication system to ensure high availability and fast failover in production environments. Write requests can be handled by every server in the topology with the replication component performing immediate synchronization with other members. The replicated server environment ensures that LDAP clients can seamlessly fail over to another server instance.

This chapter presents the architectural overview of replication, detailed configuration steps, ways to monitor replication as well as troubleshooting steps:

Topics:

Overview of Replication

Replication is a data synchronization mechanism that ensures that updates made to a database are automatically replayed to other servers. Replication improves data availability when unforeseen or planned outages occur, and improves search performance by allowing client requests to be distributed across multiple servers.

By default, all Data Stores participating in replication are writable, so that LDAP clients can perform updates at any of these Data Store instances. These updates will be propagated to the other servers automatically in the background and applied in the same order as the updates were entered. The replication process flow is designed to immediately propagate changes to the other replicas in the topology with little or no latency.

The following figure demonstrates the basic flow of replication.

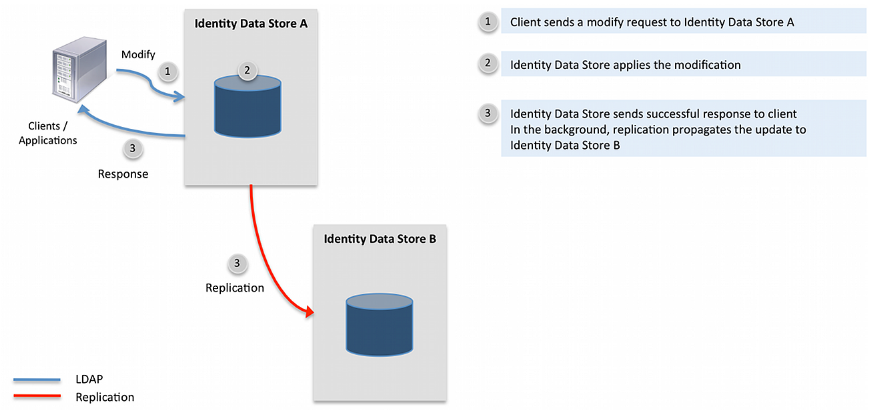

Identity Data Store A
Modify
1
2
Clients / Applications
3
Response
Identity Data Store B
3
Replication
LDAP
Replication
1 Client sends a modify request to Identity Data Store A
2 Identity Data Store applies the modification
3 Identity Data Store sends successful response to client
In the background, replication propagates the update to Identity Data Store B

Figure 12: Replication Process Flow

The benefits of replication can be summarized as follows:

- **High-Availability**. Because the data is fully replicated on all other servers in the topology, replication allows participating servers to process all types of client requests. This mitigates any availability issues when a particular server is down due to a planned maintenance or unplanned outage. For those servers that are temporarily unavailable, they will receive updates when they become available again.
- **Improved Search Performance**. Search requests may be directed to any Data Store participating in replication, which improves search performance over systems that only access single servers. Note, however, that replication does not improve write throughput since updates need to be applied at all servers.
- **WAN Friendly Data Synchronization**. The built-in compression feature in the replication protocol allows efficient propagation of updates over WAN links.

Replication Versus Synchronization

Replication is not a general purpose synchronization facility as it creates replicas with exact copies of the replicated data. Synchronization, on the other hand, can transform data between two different Directory Information Tree (DIT) structures, map attribute types, synchronize subsets of branches and specific object classes. The differences between replication and synchronization are illustrated as follows:

- **Replication cannot Synchronize between Different DIT Structures**. The DN of replicated entries must be the same on all servers. In some situations, it may be desirable to replicate entries with the help of DN mapping that are under different base DNs, but represent the same data, for example `uid=john.doe,ou=people,o=corp` on one server may represent the same user as `uid=john.doe,ou=people,dc=example,dc=com`. This is not supported by replication. Synchronization fully supports this feature.

- **Replication cannot Map Attribute Types or Transform Attribute Values**. In some situations, it may be necessary to map attribute types or transform attribute values when synchronizing data from one server to another. Replication does not support either attribute type mappings or attribute value transformations.

- **Replication does Not Support Fractional Replication**. Replication cannot be configured to replicate a subset of the attribute types from the replicated data set. Synchronization fully supports this feature.

- **Replication does Not Support Sparse Replication**. Replication cannot be configured to replicate entries with a particular object class only. Synchronization fully supports this feature.

- **Replication Requires Full Control of Replicated Data**. When two servers participate in replication, both servers implicitly trust each other using public key cryptography and apply all updates received via replication, which is considered an internal operation. While trust between servers is established between two endpoint servers, synchronization does not require full control of the data. Disparate server system endpoints can be synchronized, such as an UnboundID Data Store and a RDBMS database endpoint with each fully in control of its own data.

If replication does not meet your data synchronization requirements, consider using the UnboundID Data Sync Server, which provides the versatility and robust performance required for most production environments.

Replication Terminology

The following replication terms are used throughout this chapter.

Table 45: Replication Terminology

Term	Description
Assured Replication	For applications that require immediate access to replicated data or require data consistency over response time, administrators can configure *assured replication*, where data is guaranteed to replicate *before* the response is returned to the client.
Change Number	A 64-bit number used to consistently order replication updates across the entire topology. It is composed of 3 fields: the timestamp of the update (measured in milliseconds since 00:00:00 UTC, January 1, 1970), the Replica ID, and the Sequence Number.
Conflict	Client updates made at different replicas affecting the same entry may be found in conflict when the updates are replayed at another replica. The Change Number of each update allows most of these conflicts to be resolved automatically. Certain updates, such as adding an entry with different attribute values at two servers simultaneously, result in conflicts that are flagged for required manual resolution.
Eventual Consistency	When not using assured replication, recent updates from LDAP clients are not immediately present at all servers. Out-of-sync data will be eventually synchronized and will be consistent on all servers. The network latency typically controls how long a given update takes to replicate.
Global Administrator	The administrative user with full rights to manage the replication topology. The user is created at the time of replication enable between two non-replicating servers and thereafter copied to newly enabled servers. The replication command-line utility expects the user name of the Global Administrator (by default, admin). The user is stored in `cn=admin data`.
Historical Data	Historical Data are records of attribute value changes as a result of an LDAP Modify Operation. Historical Data is stored in the `ds-sync-hist` attribute of the target entry. This information allows replication to resolve conflicts from simultaneous LDAP Modify operations automatically.
Location	The collection of servers that may have similar performance characteristics when accessed from this Data Store or reside in the same data center or city. A separate location setting may be defined for each data center, such as Austin, London, Chicago, etc. Location settings are used in the selection of the WAN Gateway server.
Modify Conflict	A conflict between two LDAP Modify operations. Conflicts arising from LDAP Modify operations are automatically resolved.
Naming Conflict	Any conflict other than Modify Conflicts. Naming conflicts typically include an operation that changes the DN of the target entry, creates an entry, or deletes an entry at one Replica.
Replica	The component in the Data Store that handles interaction with a single replication domain, for example, the `dc=example,dc=com` replication domain within the `userRoot` backend.
Replica ID	The unique identifier of a replica that is set automatically in the corresponding Replication Domain configuration entry at each participating server. The replica ID identifies the source of each update in the replication topology.
Replica State	A list of the most recent change numbers of replication updates that have been applied to a replica. There can be at most one change number from each replica in the state. The replica state helps the Replication Server component to determine which updates the Replica has not received yet.
Replication	An automated background process that pushes data store data changes to all other replicas.

Term	Description
Replication Changelog	A backend maintained by each replication server independently that records updates from each replica. This backend is distinct from the LDAP Changelog and the two should not be confused. The main distinction is as follows: • The LDAP Changelog (i.e., the external changelog that clients can access) physically resides at `<server-root>/db/changelog`. • The Replication Changelog Backend (i.e., the changelog that replication servers use) physically resides at `<server-root>/changelogDB` and is not accessible by clients and server extensions.
Replication Domain	The data configured for replication as defined by the base DN. Updates to entries at and below the base DN will be replicated.
Replication Replay	When a replica locally applies the update received via a replication server.
Replication Server	A component within the Data Store process that is responsible for propagating data store data changes to and from replicas. Each Data Store instance participating in replication is also running a replication server.
Replication Server ID	The unique identifier of a replication server set automatically in its configuration object at each server in the replication topology. This identifier is used in the connection management code of the replication servers.
Replication Server State	A list of the most recent change numbers of replication updates that have been processed by a replication server. There can be at most one change number from each replica in the topology. The Replication Server State is used to determine which updates need to be sent to other replication servers. Similarly, the replica can use the Replication Server State to identify the set of updates to send to the replication server.
Sequence Number	A field in the change number that indicates the sequence of the client updates at a particular replica. For every update at the replica, the number is incremented. The initial value of the sequence number is 1. The number is stored as a 32-bit integer, but only positive values are used. The sequence number can roll over.
WAN Gateway	The designated replication server that assumes the WAN Gateway role within a collection of co-located replication servers (i.e., servers that are defined with identical location settings). Replication update messages between servers at different locations are routed through WAN gateways. The WAN Gateway role is assigned automatically by the protocol based on the server's WAN Gateway Priority setting. If the WAN Gateway server is down for any reason, the server with the next highest WAN Gateway Priority will dynamically assume the WAN Gateway role.
WAN Gateway Priority	The configuration setting that determines which replication server assumes the WAN Gateway role. The replication server with the lowest WAN Gateway Priority value in a location assumes the role of the WAN Gateway. The priority values can be set to 0 (never be a gateway), or any value from 1 (highest priority) to 10 (lowest priority).

Replication Architecture

The major elements of replication in the UnboundID Data Store are introduced in this section.

Eventual Consistency

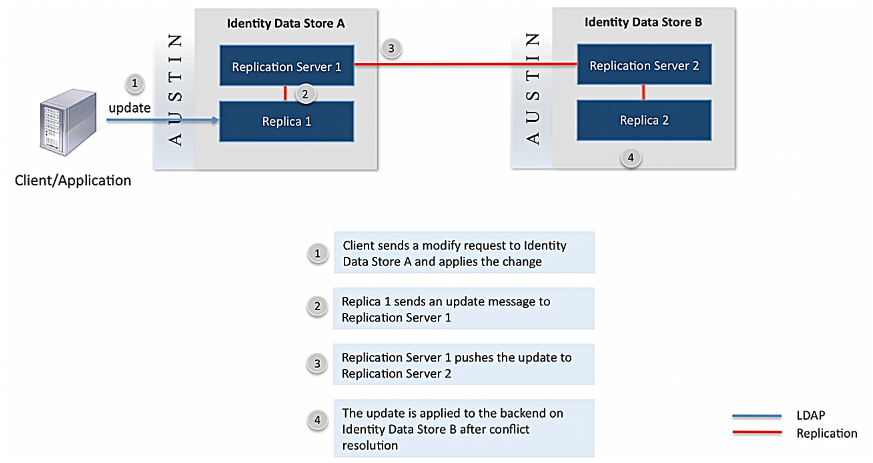
Replication is based on an eventual-consistency model, where updates that are propagated through a connected network of servers will eventually be consistent on all servers over a very short period of time. In a typical update operation, a client application updates an entry or group of entries on the UnboundID Data Store with an ADD, DELETE, MODIFY, or MODIFY DN operation. After processing the operation, the Data Store returns an LDAP response, while concurrently propagating the update to the other servers in the replicated topology. This concurrent processing model allows the client to continue submitting update requests without waiting for a replication completion response from the server. Alternatively, assured replication can be configured for specific write requests that requires local or global consistency, across datacenter locations, before a response is returned to the client. For more information, see *Configuring Assured Replication* on page 434.

To support this processing model, replication never locks the targeted entries at the other Data Store instances before an update can be made locally. This means that the replicated Data Stores may have an inconsistent view of the targeted entry for a very short period of time but will catch up as the propagated changes are applied. The eventual-consistency model also allows clients to complete update operations faster, since clients do not have to wait for replication to propagate the change. The rate of update operations remains the same no matter how many Data Stores participate in replication.

Replicas and Replication Servers

Each Data Store has an embedded replication server that is responsible for transmitting updates to other replication servers. There is a separate component, called a replica, for each replicating base DN, such as `cn=schema, dc=example,dc=com`. Each replica connects to the embedded replication server running within the Data Store JVM process.

When a client application updates an entry on the Data Store, the replica sends an update message to its embedded replication server. The replication server applies the change to the `replicationChangelog` backend repository and then sends an update message to the connected replication server on another data store. The replication server on other data stores then passes the change to the appropriate replica, which in turn applies the change to its backend after performing conflict resolution. This standard setup is seen in the figure below.



1 Client sends a modify request to Identity Data Store A and applies the change

2 Replica 1 sends an update message to Replication Server 1

3 Replication Server 1 pushes the update to Replication Server 2

4 The update is applied to the backend on Identity Data Store B after conflict resolution

Figure 13: Replicas and Replication Servers

Authentication and Authorization

The authentication in the Replication Protocol is based on public key cryptography using client certificate authentication via TLS. The certificate used for authentication is stored in the `ads-truststore` backend of the Data Store. During replication setup, the command-line utility distributes public keys to all data stores to establish trust between the Data Stores and to enable client authentication via TLS.

The authorization model of replication is simple: once authenticated, the remote Data Store is fully authorized to exchange replication messages with the local Data Store. There is no other access control in place.

Logging

The access log messages in the Data Store indicate if the update was received via replication and includes the corresponding change number. This allows the administrator to track which Data Store the update originated from.

Replication Deployment Planning

The following should be considered before deploying in a production environment:

- **Minimizing Replication Conflicts**. Attention should be paid to the origin of client write requests to prevent a conflict. If two different clients attempt to create an entry with the same name, DN, at the same time against different servers, t he possibility exists that both client requests will succeed. In this case, a conflict alert will be sent by the server. However, understand the client traffic pattern beforehand will minimize these occurrences. The Data Store's Assured Replication feature and the UnboundID Proxy Server can both assist in minimizing conflicts.
- **Replication Purge Delay**. Adjust the default one-day replication purge delay, consistently across all servers, to accommodate automatic catchup of changes when a server is offline for an extended period of time. The replication changes database, stored in `<server-root>/changelogDb`, grows larger as the replication purge delay is increased. A minimum value should be defined.

The rest of this section highlights other topics of consideration.

Location

In multi-site deployments, it is strongly recommended to configure the data stores with location information using the `dsconfig create-location` command and `dsconfig set-global-configuration-prop` command. The Data Store cannot determine LAN boundaries automatically, so incorrect location settings can result in undesired WAN communication. By default, replication also compresses all traffic between data stores in different locations.

We recommend setting up the locations prior to enabling replication. The `dsreplication enable` command prompts for location information if you have forgotten to define the property.

User-Defined LDAP

Data Stores participating in replication are required to have a uniform user-defined schema. The `dsreplication` command-line utility sets up replication for the schema backend the first time replication is enabled to ensure that future schema changes are propagated to all data stores.

Disk Space

Replication increases the disk space required for the Data Store. The Replication Changelog backend keeps changes from all data stores for 24 hours by default. After this time period, also known as the purge delay, the backend is trimmed automatically.

In addition, within the `userRoot` and other local DN backends, attribute-level changes are recorded for a short period of time in the `ds-sync-hist` attribute of the entry targeted by an LDAP Modify operation. This attribute is used to resolve all conflicts resulting from LDAP Modify operations automatically.

The disk space impact of replication is highly dependent on the rate and size of changes in the replication topology, and the Replication Changelog purge delay.

Memory

Compared to a standalone data store, replicated data store instances require slightly more memory. All of the items discussed in the Disk Space section have an impact on the amount of memory the Data Store is using. The additional replication overhead is typically less than 5%.

Time Synchronization

Even though replication has a built-in mechanism to compensate for the potential clock skew between hosts, it is generally recommended to keep system clocks in sync within the deployment.

Communication Ports

The replication server component in each data store listens on a TCP/IP port for replication communication (the replication server port). This port, typically 8989, must be accessible from all data stores participating in replication. The server-to-server communication channel is kept alive using a heartbeat, which occurs every 10 seconds. This traffic will prevent firewalls from closing connections prematurely.

The replication command-line utility (`dsreplication`) requires access to all data stores participating in replication. This includes the LDAP or LDAPS port of the data stores.

Keep these communication requirements in mind when configuring firewalls.

Hardware Load Balancers

Replication allows writes to be directed to any data store in the topology. Distributing write operations in a round-robin fashion, however, may introduce conflicts. In particular, distributing a series of LDAP Add, Delete and Modify DN operations targeting the same DN in quick succession can result in conflicts that require manual intervention. The Assured Replication feature can help prevent conflicts created by the same client application.

If possible, consider using server affinity with the load balancer that either associates a client IP address or a client connection with a single data store instance at a time. Also, consider using the UnboundID Proxy Server for load balancing LDAP traffic. The Server Affinity feature in the Proxy Server enables replication-friendly load balancing.

Proxy Server

In addition, to facilitate replication-friendly load balancing, the UnboundID Proxy Server should be considered in every replication deployment. The Proxy Server can automatically adapt to conditions in backend data stores using health checks and route traffic accordingly. For example, traffic can be re-routed from data stores with large backlog of replication updates.

To Display the Server Information for a Replication Deployment

- Run the `dsreplication status` command with the `--displayServerTable` option.

```
$ bin/dsreplication status --displayServerTable
```

```
          --- Replication Status for dc=example,dc=com: ---
Server                          : Location : Priority (1) : Status
--------------------------------:----------:--------------:----------
austin-01.example.com:8989      : US       : 1 (*)        : Available
austin-02.example.com:8989      : US       : 2            : Available
london-01.example.com:8989      : UK       : 5            : Available
london-02.example.com:8989      : UK       : 5 (*)        : Available
sydney-01.example.com:8989      : AU       : 5 (*)        : Available
sydney-02.example.com:8989      : AU       : 5            : Available

[1] WAN Gateway Priority. WAN gateways are marked with a *. To minimize
WAN utilization, the server with the WAN Gateway role is the only server
in a location that exchanges updates with remote locations.

--- Replication Status for dc=example,dc=com: Enabled ---
Server                          : Location : Entries : Conflict Entries : Backlog :
 Recent Change Rate
--------------------------------:----------:---------:------------------:---------:---------------
austin-01.example.com:1389      : US       : 3478174 : 0                : 8       :
 333
austin-02.example.com:1389      : US       : 3478174 : 0                : 5       :
 345
london-01.example.com:1389      : UK       : 3478174 : 0                : 0       :
 349
london-02.example.com:1389      : UK       : 3478174 : 0                : 0       : 5
sydney-01.example.com:1389      : AU       : 3478173 : 0                : 0       :
 350
sydney-02.example.com:1389      : AU       : 3478270 : 0                : 30      :
 332
```

To Display All Status Information for a Replication Deployment

- Run the `dsreplication status` command with the `--showAll` option. You can also use the `--showAll` option together with the `--displayServerTable` option to see the server table information for the replication topology.

Enabling Replication

Enabling replication between multiple Data Stores means that any change within the replicated base DN is automatically propagated to all other Data Stores in the topology. Configuration changes are not replicated. Therefore, each Data Store should be configured according to the deployment design.

Overview

To interface with the replication topology, the Data Store provides a command-line utility, `dsreplication`, that must be used to manage and monitor replication.

Replication setup involves the following basic steps:

- **Set up the servers**. This is the basic installation steps to set up a Data Store instance. See *Setting Up the Data Store in Interactive Mode* for more information.
- **Import or restore data to one server**. After setting up the servers, at least one server should have the target data loaded through `import-ldif` or restore.
- **Enable replication between the servers**. Using the `dsreplication` tool, enable replication for each server to be included in the replication topology. The `dsreplication enable` subcommand should be run *N - 1* times for a topology of *N* servers. See *Command Line Interface* for more information.
- **Initialize data from source server to every server in the topology**. Run the `dsreplication initialize` subcommand for every target server that needs a copy of the data from the source server.
- **Verifying the replication topology**. Administrators can check the replication status after configuring the topology using the `dsreplication` status tool.

Note: The UnboundID Data Store setup utility has a Java-based graphical mode that can also enable replication. This method should be used when quickly configuring replication for evaluation purposes with relatively small data sets. See *Setting Up a Replication Topology for Evaluation Purposes*.

Command Line Interface

Replication topologies are configured and maintained using the `dsreplication` command-line utility, which supports interactive and non-interactive modes. If you are running the server for the first time, we recommend using the `dsreplication` tool in interactive mode.

The `dsreplication` tool has the following format including some important subcommands listed in the section *The dsreplication Command-Line Utility*:

```
dsreplication {subcommand} {connection parameters}
```

The `dsreplication` tool keeps a history of invocations in the `logs/tools/dsreplication.history` file and keeps a log of up to 10 `dsreplication` sessions in the `logs/tools` directory.

What Happens When You Enable Replication

The `dsreplication enable` subcommand is used to set up replication. The `enable` subcommand carries out the following functions:

- If it does not already exist, the global administrator user is created. The global administrator user has all the rights and privileges to update replication-related configuration objects. Most `dsreplication` subcommands require the global administrator.
- The server instances are registered in the `cn=admin data` tree. The registration includes basic host name, port information as well as the public key used during the replication authentication process.

  In case both servers are already participating in replication, the `cn=admin data tree` is merged to retain the server information from existing topologies.
- The embedded replication server is enabled. Servers already in replication will see their replication server configuration updated with the information of the new replication server.
- A replication domain is created for the requested base DNs. In case the first base DN is enabled, the replication domains for two additional base DNs are also enabled: `cn=admin data` and `cn=schema`.
- Initialization for the `cn=admin data` base DN is executed. This will ensure that `cn=admin data` is uniform across the replication topology.
- Initialization for the `cn=schema` base DN is executed. This will ensure that a uniform schema is present in the replication topology.
- Initialization must be performed for the enabled base DNs.

Initialization

Replica initialization transfers of a copy of the backend containing the replication domain to a target server. This should be performed after replication is enabled with the `dsreplication initialize` subcommand. There is no impact on the source server during this process.

- **dsreplication initialize**. The recommended approach for replica initialization. The `dsreplication initialize` subcommand performs the most efficient copy of data needed to initialize one or more replicas on a target server. Any existing data on the target server replica will be lost and the backend containing the base DN will be taken offline on the target server during the initialization.
- **Binary Copy**. The database copy method involves copying database backup files from the source data store to one or more target servers. The Data Store provides tools necessary for backing up and restoring backends. Using `server-root/bin/backup`, create a backup of the backend containing the replicated base DN. The backup files then need to be transferred to the target server(s) and restored individually with `server-root/bin/restore`. There are additional considerations when using database copy as the means to initialize a target replica:
  - If encryption is enabled on the servers, then a database copy must also be performed on the `encryption-settings` backend. Note that, to preserve existing encryption settings, `server-root/bin/restore` will append to the `encryption-settings` database as opposed to replacing it.
  - When using database copy to initialize a server which has been offline longer than the replication purge delay, the database copy of the `replicationChanges`, `schema`, and `adminRoot` backends are required.

Deploying a Basic Replication Topology

This section describes how to set up a two-server replication topology. The example uses the LDAP and replication server ports 1389 and 8989 respectively.

Table 46: Replica Ports

Host Name	LDAP Port	Replication Port
server1.example.com	1389	8989
server2.example.com	1389	8989

To Deploy a Basic Replication Deployment

1. Install the first data store with 2000 sample entries.

```
$ ./setup --cli --acceptLicense --baseDN "dc=example,dc=com" --ldapPort 1389 \ --
rootUserPassword pass --sampleData 10000 --no-prompt
```

2. Install the second data store either on a separate host or the same host as the first, but with a different LDAP port.

```
$ ./setup --cli --acceptLicense --baseDN "dc=example,dc=com" --ldapPort 1389 \ --
rootUserPassword pass --no-prompt
```

3. From the first server, run the `bin/dsreplication` command in interactive mode to configure a replication topology:

```
$ bin/dsreplication
```

4. From the Replication Main menu, select the Manage the topology option.

```
>>>> Replication Main Menu

What do you want to do?

    1) Display replication status
    2) Manage the topology (add and remove servers)
    3) Initialize replica data over the network
    4) Initialize replica data manually
    5) Replace existing data on all servers

    q) quit

Enter choice: 2
```

5. From the Manage Replication Topology menu, choose the Enable Replication option.

```
>>>> Manage Replication Topology

Select an operation for more information.

    1)  Enable Replication -- add or re-attach a server to the topology
    2)  Disable Replication -- permanently remove a running replica from the topology
    3)  Remove Defunct Server -- permanently remove an unavailable server from the
          topology
    4)  Cleanup Server -- remove replication artifacts from an offline, local server
          (allowing it to be re-added to a topology)

    b)  back
    q)  quit

Enter choice [b]: 1
```

6. On the Enable Replication menu, read the brief introduction on what will take place during the setup, and then, enter "c" to continue the enable process.

7. Next, enter the LDAP connection parameters for the first of the two replicas that you are configuring. First, enter the host name or IP address of the first server.

8. Next, enter the type of LDAP connection to the first server: 1) LDAP, 2) LDAP with SSL, or 3) LDAP with StartTLS.

9. Type the LDAP listener port for the first replica. If you are a root user, you will see port 389 as the default. Others will see port 1389.

10. Authenticate as a root DN, such as `cn=Directory Manager`. You will be prompted later in the process to set up a global administrator and password. The global administrator is the user ID that manages the replication topology group.

11. Repeat steps 7–10 for the second replica.

12. Next, the `dsreplication` tool checks for the base DN on both servers. In order to enable replication, data must be present on at least one of the servers. For this example, press Enter to select the default base DN, `dc=example,dc=com`.

```
Choose one or more available base DNs for which to enable replication:

    1)  dc=example,dc=com

    c)  cancel

Enter one or more choices separated by commas [1]:
```

Note: If you see the following message:

```
There are no base DNs available to enable replication between the
 two servers.
```

In most cases, a base DN was not set up on one of the data stores or the backend is disabled.

13. Next, the prompt asks if you want to set up entry balancing using the Proxy Server. Press Enter to accept the default (no), since we are not setting up replication in an entry-balanced environment in this scenario. For more information, see the *UnboundID Proxy Server Administration Guide*.

```
Do you plan to configure entry balancing using the Proxy Server? (yes / no) [no]:
```

14. Next, enter the replication port for the first replica (default, 8989). The port must be free.

15. If the first server did not have a pre-defined location setting, `dsreplication` will prompt you to enter a location. Press Enter to accept the default (yes) to set up a Location for the first server. Enter the name of the server's location.

```
The first server has not been configured with a location.
Assigning a location to each server in the replication topology reduces
network traffic in multi-site deployments. Would you like to set the
location in the first server? (yes / no) [yes]

The location of the first server: Austin
```

16. Repeat the previous steps for the second data store. Again, if you did not pre-define a location setting for the second server, you will be prompted to enter this information.

17. At this time, set up the Global Administrator user ID (default is "admin") and a password for this account. The Global Administrator user ID manages the data stores used in the replication topology.

```
Specify the user ID of the global administrator account
that will be used to manage the UnboundID Data Store
instances to be replicated [admin]:

Password for the global administrator:
Confirm Password:
```

18. Return to the Replication Main Menu and enter the number corresponding to initializing data over the network.

19. On the Initialize Replica Data over the Network menu, select Initialize to initialize data on a single server, and then enter `c` to continue.

20. Next, specify a server in the replication topology. For this example, enter the host name or IP address, LDAP connection type, LDAP port, Global Admin user ID and password of the first server.

21. Next, select the source server that is hosting the data to which the target server will be initialized. For this example, select the first server, since the sample dataset has been loaded onto this server.

22. Next, select the base DN that will be initialized. In most cases, the base DN for the root suffix will be replicated. In this example, `dc=example,dc=com`.

23. Next, select the second server in this example that will have its data initialized, and then enter the Global Admin user ID and password for the target server. Any data present on the target server will be over-written.

24. Press Enter to confirm that you want to initialize data on the target server. When completed, you should see "Base DN initialized successfully."

```
Initializing the contents of a base DN removes all the existing contents of
that base DN. Do you want to remove the contents of the selected base DNs on server
server2.example.com:1389 and replace them with the contents of server
server1.example.com:1389? (yes / no) [yes]:
```

25. On the Initialize Replica Data Over Network menu, enter `b` to back out one level to the main menu. Then, on the Replication Main menu, enter the number to view the replication status.

```
     --- Replication Servers: dc=example,dc=com ---
Server                   : Location : Entries : Backlog : Recent Change Rate
-------------------------:----------:---------:---------:--------------------
server1.example.com:1389 : austin   : 10003   : 0       : 0
server2.example.com:1389 : austin   : 10003   : 0       : 0
```

A Deployment with Non-Interactive dsreplication

This example will create a four-server topology spanning two data centers. The four servers are already installed and have locations Austin and Budepest defined.

To Deploy with Non-Interactive dsreplication

1. Generate the sample data using the `make-ldif` tool on the first server.

```
$ bin/make-ldif --templateFile config/MakeLDIF/example-10K.template \
  --ldifFile ldif/10K.ldif
```

2. Select a server from which to import data, and to be the source for future initialization to other servers. Stop this server, import the sample LDIF and start again, or perform a task-based `import-ldif` with the connection options.

```
$ bin/stop-ds
$ bin/import-ldif --backendID userRoot --ldifFile ldif/10K.ldif
$ bin/start-ds
```

3. Enable replication by choosing a specific server and running `dsreplication enable` three times. For the first invocation, create the replication topology administrator with the name `admin`.

```
$ bin/dsreplication enable --host1 austin01.example.com --port1 1389 \
    --bindDN1 "cn=Directory Manager" --bindPassword1 password \
    --replicationPort1 8989 --host2 austin02.example.com --port2 1389 \
    --bindDN2 "cn=Directory Manager" --bindPassword2 password \
    --replicationPort2 8989 --baseDN dc=example,dc=com --adminUID admin \
    --adminPassword password --no-prompt

$ bin/dsreplication enable --host1 austin01.example.com --port1 1389 \
    --bindDN1 "cn=Directory Manager" --bindPassword1 password \
    --replicationPort1 8989 --host2 budapest01.example.com --port2 1389 \
    --bindDN2 "cn=Directory Manager" --bindPassword2 password \
    --replicationPort2 8989 --baseDN dc=example,dc=com --adminUID admin \
    --adminPassword password --no-prompt

$ bin/dsreplication enable --host1 austin01.example.com --port1 1389 \
    --bindDN1 "cn=Directory Manager" --bindPassword1 password \
    --replicationPort1 8989 --host2 budapest02.example.com --port2 1389 \
    --bindDN2 "cn=Directory Manager" --bindPassword2 password \
    --replicationPort2 8989 --baseDN dc=example,dc=com --adminUID admin \
    --adminPassword password --no-prompt
```

4. Initialize the other servers (the dc=example,dc=com replicas) from the server that had the data imported with `import-ldif`. To minimize the WAN transfers, initialize `budapest02` from `budapest01`.

```
$ bin/dsreplication initialize --hostSource austin01.example.com --portSource 1389 \
  --hostDestination austin02.example.com --portDestination 1389 \
  --adminUID admin --adminPassword password --baseDN dc=example,dc=com --no-prompt

$ bin/dsreplication initialize --hostSource austin01.example.com --portSource 1389 \
  --hostDestination budapest01.example.com --portDestination 1389 \
  --adminUID admin --adminPassword password --baseDN dc=example,dc=com --no-prompt

$ bin/dsreplication initialize --hostSource budapest01.example.com --portSource 1389
 \
  --hostDestination budapest02.example.com --portDestination 1389 \
  --adminUID admin --adminPassword password --baseDN dc=example,dc=com --no-prompt
```

5. View the state of replication.

```
$ bin/dsreplication status --adminPassword password --no-prompt --displayServerTable
 --showAll
```

To Use dsreplication with SASL GSSAPI (Kerberos)

This example procedure assumes that you have configured SASL GSSAPI on all servers in the replication topology and that they are working properly.

The Data Store's utilities all support SASL GSSAPI options for systems using Kerberos as its main authentication mechanism. The following procedure shows how to use `dsreplication` with SASL GSSAP to set up a new `replication.admin` identity, while enabling replication on a server. The following are important points about the configuration:

- A separate Kerberos identity is required to manage replication. Existing Kerberos credentials can be used to interact with the server when enabling replication and creating the new identity.

- The new identity, such as replication.admin, must not exist as the cn or uid value under any public base DN.

1. Set the LDAP Connection Handler to explicitly listen on the server's hostname address.

```
$ bin/dsconfig set-connection-handler-prop \
  --handler-name "LDAP Connection Handler" \
  --remove listen-address:0.0.0.0 --add listen-address:host.example.com
```

2. Update the identity mapper to have `cn=admin data` included in the list of base DNs and to add the `cn` attribute to match attributes. This step is required to map the admin account to the Kerberos realm.

```
$ bin/dsconfig set-identity-mapper-prop \
  --mapper-name "Regular Expression" \
  --add match-attribute:cn \
  --set "match-base-dn:cn=admin data" \
  --set match-base-dn:dc=example,dc=com
```

3. Invoke replication enable, authenticating as the existing kerberos `authid`. Note that no bind DNs and passwords are required to authenticate because we are using SASL binding. However, the new replication admin user requires a password at creation time, so we recommend using a strong random password. Once SASL is working, you will no longer have to provide this random password. Also note that we are forcing the use of the ticket cache, so make sure you have properly authenticated as `ds.admin` from your local host and the ticket is not expired in the cache.

```
$ kinit -p ds.admin
$ bin/dsreplication enable \
  --host1 server1.example.com --port1 1389 --replicationPort1 1989 \
  --host2 server2.example.com --port2 2389 --replicationPort2 2989 \
  --baseDN dc=example,dc=com \
  --adminUID replication.admin --adminPassword strongPassword \
  --saslOption1 mech=gssapi --saslOption1 authid=ds.admin@EXAMPLE.COM \
  --saslOption1 useTicketCache=true --saslOption1 requireCache=true \
  --saslOption2 mech=gssapi --saslOption2 authid=ds.admin@EXAMPLE.COM \
  --saslOption2 useTicketCache=true --saslOption2 requireCache=true
```

4. Use `dsreplication initialize` to initialize data on remote server.

```
$ kinit -p replication.admin
$ bin/dsreplication initialize \
  --hostSource server1.example.com --portSource 1389 \
  --hostDestination server2.example.com --portDestination 2389 \
  --baseDN dc=example,dc=com \
  --saslOption mech=GSSAPI \
  --saslOption authID=replication.admin@EXAMPLE.COM  \
  --no-prompt
```

5. The temporary `userPassword` can now be deleted from the `replication.admin` entry. Create a file called `remove-password.ldif` with these contents:

```
dn: cn=replication.admin,cn=Administrators,cn=admin data
changetype: modify
delete: userPassword
```

6. Apply the modifications using `ldapmodify`:

```
$ ./ldapmodify --filename remove-password.ldif -o mech=GSSAPI
-o authid=replication.admin@example.com \
  --saslOption useTicketCache=true \
  --hostname host.example.com --port 1389 \
  --noPropertiesFile
```

7. Check the topology's status by running `dsreplication status`. The `--saslOption useTicketCache=true` and `--saslOption requireCache=true` properties, instead of providing a password, for all `dsreplication` commands after properly creating the admin accounts and mappers.

```
$ bin/dsreplication status \
  --saslOption mech=gssapi \
  --saslOption authid=replication.admin@EXAMPLE.COM \
  --saslOption useTicketCache=true --saslOption requireCache=true \
  --hostname host.example.com --port 1389 \
  --no-prompt
```

Configuring Assured Replication

The UnboundID Data Store's replication mechanism is based on the eventual-consistency model, which is a loosely-connected topology that propagates updates to other servers without waiting for their corresponding replication response messages. As a result, there is a small window of time where updates are not all present on the replicas as the changes are replicating through the system. There are, however, deployments that require *immediate* access to replicated data. In such cases, administrators can configure *Assured Replication*, which ensures that replication has completed *before* the update response is returned to the client.

From the LDAP client's perspective, assured replication has no bearing on the result code of the operation, just on the time in which it takes to receive the response for those requests in which replication assurance is applied. Detailed information regarding assurance processing is available to an LDAP client with awareness of the assured replication control.

The assured replication mechanism takes advantage of server location to distinguish between local and remote servers to allow different policies to apply. For example, a common assurance approach is to respond to a client update after all servers in the same location have applied the update, and one or more servers in remote locations have received the update. In addition, the level of assurance applied to each operation can be explicitly requested by the client and/or specified by the server configuration using the Replication Assurance Policy.

Assured replication is supported by client requests directly to UnboundID Data Store and/or through an UnboundID Proxy Server.

About the Replication Assurance Policy

Assured replication uses a *Replication Assurance Policy* to define the properties needed to ensure that replication has satisfactorily completed before the update response is returned to the client. Multiple policies can be defined but only one policy is matched with a client update request. Each policy contains an evaluation order index which, together with an optional request and connection criteria, provides flexibility in matching a policy to request.

The Replication Assurance Policy defines local and remote assurance *levels*. A *level* defines how rigorous the policy should be when waiting for propagation of updates, while *local* and *remote* distinguish servers in the same location versus servers in remote locations. Although optional, it is recommended that request or connection criteria be associated with a policy to apply replication assurance appropriately.

The Data Store contains a Default Replication Assurance Policy that is enabled but has no assurance levels assigned. In addition to using the Default Replication Assurance Policy, any number of policies can be created and enabled. When a client request is received, the server iterates through the list of enabled policies according to each policy's *evaluation-order-index* property. A smaller *evaluation-order-index* value (e.g., 1) has precedence over policies with larger *evaluation-order-index* values (e.g., 2, 3, 4, etc.). The *evaluation-order-index* values do not need to be contiguous. The first policy that matches a request is associated with the operation.

The Replication Assurance Policy, which is defined on the UnboundID Data Store and not on the UnboundID Proxy Server, has the following properties:

- **evaluation-order-index**. Determines the evaluation order (the smaller value has precedence) among multiple Replication Assurance Policies that match against an operation.
- **local-level**. Specifies the assurance level used to replicate to local servers. A local server is defined as a server with the same `location` property value as set in the global configuration. The `local-level` property must be set to an assurance level as strict as the `remote-level` property. For example, if the `remote-level` is set to "`processed-all-remote-locations`," then the `local-level` property must be "`processed-all-servers`."
  - ➢ **None**. Replication to any local server is not assured.
  - ➢ **received-any-server**. At least one available local server must receive a replication update before a response is sent to the client.
  - ➢ **processed-all-servers**. All available local servers must complete replay of the replication update before the response is sent to the client. If a singular server is enabled, or only one server is available for a particular location, `processed-all-servers` will return a value of `false`.
- **remote-level**. Specifies the assurance level used to replicate to remote servers. A remote server is defined as a server that has a different `location` property value as set in the global configuration.
  - ➢ **None**. Replication to any remote server is not assured.
  - ➢ **received-any-remote-location**. At least one server at any available remote location must receive a replication update before a response is sent to the client.
  - ➢ **received-all-remote-locations**. All available remote servers must receive a replication update before the response is sent to the client.
  - ➢ **processed-all-remote-servers**. All available servers at all locations must complete replay of the replication update before the response is sent to the client. If a single server is enabled, or only one server is available for a particular location, `processed-all-remote-servers` will return a value of `false`.
- **timeout**. Specifies the maximum length of time to wait for the replication assurance requirements to be met before timeout and replying to the client.
- **connection-criteria**. Specifies connection criteria used to indicate which operations from clients matching this criteria use this policy. If both connection criteria and request criteria are specified for a policy, then both must match an operation for the policy to be assigned.

- **request-criteria**. Specifies request criteria used to indicate which operations from clients matching this criteria use this policy. If both connection criteria and a request criteria are specified for a policy, then both must match an operation for the policy to be assigned.

Servers in a replication topology are not required to share a homogeneous set of policies; you can configure the Replication Assurance Policies differently on the replicas in a topology. For example, if you configure server A to match add operations to a `processed-all-servers` assurance level, and server B to match add operations to a local `received-any-server` level, then add operations received on server A will have the assurance level of `processed-all-servers` and add operations received on server B will have the assurance level of `received-any-server`.

For more detailed information, see the *UnboundID Data Store Configuration Reference Guide*.

Points about Assured Replication

The following are some points when implementing Assured Replication:

- **Client Controls**. The client may optionally include an assured replication request control with each operation. This control allows the client to specify bounds on assurance levels and/or override the timeout assigned by the matching replication assurance policy for the associated operation. The server always honors these request controls. See *About the Assured Replication Controls* for more information.
- **Proxy Server**. Replication assurance policies are not supported on the UnboundID Proxy Server. Replication client controls are passed through to the underlying Data Store backend.
- **Schema and Admin Data Backend Replication**. The schema and admin data backends are not supported by Assured Replication. Replication assurance policies that include criteria to match either backend will be rejected.
- **Backward Compatibility**. Server versions that support assured replication are backwards-compatible with prior versions that do not support assured replication.
- **WAN-Friendly Replication**. Assured replication functions independently from WAN-Friendly Replication and the notion of WAN Gateways.
- **Global Configuration Properties**. The Data Store provides two configurable global configuration properties that determine the timing of the assurance source and maximum number of replication backup updates to be recognized as an available source.
    - **replication-assurance-source-timeout-suspend-duration**. Specifies the amount of time a replication assurance source will be suspended from assurance requirements if it experiences an assurance timeout. While suspended, the source will be excluded from assurance requirements for all operations originating on this Data Store. This avoids the situation of repeated timeouts caused by degraded or offline servers. Default is 10 seconds.
    - **replication-assurance-source-backlog-fast-start-threshold**. Specifies the maximum number of replication backlog updates a replication assurance source can have and be immediately recognized as an available source. If a source connects to this server with more than the configured threshold backlog updates, it will be excluded from assurance

requirements for all operations originating from this Data Store until it completes at least one assurance successfully (i.e. this Data Store receives an update acknowledgement message from it within the timeout window). Default is 1000.

To Configure Assured Replication

The following example procedure assumes that you have set up three servers on localhost, on ports 1389, 2389 and 3389. Note that each server has a default Replication Assurance Policy with no assurance levels set.

1. On server 1, use `dsconfig` to create request criteria for add operations. This request criteria will be used to match any add operation with the Replication Assurance Policy that will be configured in the next step.

```
$ bin/dsconfig create-request-criteria \
  --criteria-name Adds \
  --type simple \
  --set operation-type:add
```

2. On server 1, set up the Replication Assurance Policy to make all add operations assured with a level of `processed-all-servers`, which indicates that all local servers in the topology must complete replay of the replication update before the response is sent to the client. Specify the Adds request criteria configured in the previous step.

```
$ bin/dsconfig create-replication-assurance-policy \
  --policy-name "Adds Processed All Locally" \
  --set evaluation-order-index:1 \
  --set local-level:processed-all-servers \
  --set "timeout:500ms" \
  --set request-criteria:Adds
```

3. On server 1, repeat the previous two steps for modify operations. The Replication Assurance Policy "Mods Received Any Locally" ensures that at least one available local server must receive a replication modify update before a response is sent to the client.

```
$ bin/dsconfig create-request-criteria \
  --criteria-name Mods \
  --type simple \
  --set operation-type:modify

$ bin/dsconfig create-replication-assurance-policy \
  --policy-name "Mods Received Any Locally" \
  --set evaluation-order-index:2 \
  --set local-level:received-any-server \
  --set "timeout:500ms" \
  --set request-criteria:Mods
```

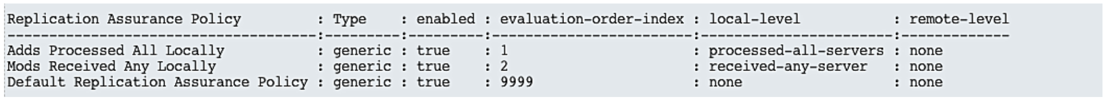
4. On server 2, repeat steps 1-3 to set up the Adds and Mods request criteria and its respective Replication Assurance Policy.

```
$ bin/dsconfig create-request-criteria \
  --criteria-name Adds \
  --type simple \
  --set operation-type:add

$ bin/dsconfig create-request-criteria \
  --criteria-name Mods \
  --type simple \
  --set operation-type:modify

$ bin/dsconfig create-replication-assurance-policy \
  --policy-name "Adds Received Any Locally" \
  --set evaluation-order-index:1 \
  --set local-level:received-any-server \
  --set "timeout:500ms" \
  --set request-criteria:Adds

$ bin/dsconfig create-replication-assurance-policy \
  --policy-name "Mods Processed All Locally" \
  --set evaluation-order-index:2 \
  --set local-level:processed-all-servers \
  --set "timeout:500ms" \
  --set request-criteria:Mods
```

5. Leave server 3 as is with the default Replication Assurance Policy configured with no assurance levels or criteria.

6. On server 1, list the policies on the server using the `dsconfig` command to confirm that they exist on the server.

```
$ bin/dsconfig list-replication-assurance-policies
```



```
Replication Assurance Policy        : Type    : enabled : evaluation-order-index : local-level           : remote-level
------------------------------------:---------:---------:------------------------:-----------------------:-------------
Adds Processed All Locally          : generic : true    : 1                      : processed-all-servers : none
Mods Received Any Locally           : generic : true    : 2                      : received-any-server   : none
Default Replication Assurance Policy : generic : true    : 9999                   : none                  : none
```

7. Repeat the previous step on server 2 and server 3. Server 3 should only show the Default Replication Assurance Policy.

8. Check the Replication Assurance counters on all servers before any add or modify operation using `ldapsearch`. They should be set to zero. These counters are on the replica server, which is where the policy is matched and assigned. On server 1, run the following command:

```
$ bin/ldapsearch --baseDN "cn=Replica dc_example_dc_com,cn=monitor" \
  "(objectclass=*)" | grep replication-assurance

replication-assurance-local-completed-normally: 0
replication-assurance-local-completed-abnormally: 0
replication-assurance-local-completed-with-timeout: 0
replication-assurance-local-completed-with-shutdown: 0
replication-assurance-local-completed-with-unavailable-server: 0
replication-assurance-remote-completed-normally: 0
replication-assurance-remote-completed-abnormally: 0
replication-assurance-remote-completed-with-timeout: 0
replication-assurance-remote-completed-with-shutdown: 0
replication-assurance-remote-completed-with-unavailable-server: 0
```

9. Check the Replication Summary table on all of the servers. For example, on server 1, run the following command:

```
$ bin/ldapsearch --baseDN "cn=Replication Summary dc_example_dc_com,cn=monitor" \
  "(objectclass=*)" | grep replication-assurance

replication-assurance-submitted-operations: 0
replication-assurance-local-completed-normally: 0
replication-assurance-local-completed-abnormally: 0
replication-assurance-local-completed-with-timeout: 0
replication-assurance-local-completed-with-shutdown: 0
replication-assurance-local-completed-with-unavailable-server: 0
replication-assurance-remote-completed-normally: 0
replication-assurance-remote-completed-abnormally: 0
replication-assurance-remote-completed-with-timeout: 0
replication-assurance-remote-completed-with-shutdown: 0
replication-assurance-remote-completed-with-unavailable-server: 0
```

10. Add an entry to the server 1 Data Store. Check that the counters matched the newly added entry to the "Adds Processed All Locally" Policy and that it completed assured.

```
$ bin/ldapmodify --filename add-user.ldif --defaultAdd

$ bin/ldapsearch --baseDN "cn=Replica dc_example_dc_com,cn=monitor" \
  "(objectclass=*)" | grep replication-assurance

replication-assurance-submitted-operations: 1
replication-assurance-local-completed-normally: 1
replication-assurance-local-completed-abnormally: 0
replication-assurance-local-completed-with-timeout: 0
replication-assurance-local-completed-with-shutdown: 0
replication-assurance-local-completed-with-unavailable-server: 0
replication-assurance-remote-completed-normally: 0
replication-assurance-remote-completed-abnormally: 0
replication-assurance-remote-completed-with-timeout: 0
replication-assurance-remote-completed-with-shutdown: 0
replication-assurance-remote-completed-with-unavailable-server: 0
replication-assurance-policy-matches: Adds Processed All Locally: 1
replication-assurance-policy-matches: Default Replication Assurance Policy: 0
replication-assurance-policy-matches: Mods Received Any Locally: 0
replication-assurance-local-level-uses: processed-all-servers: 1
replication-assurance-remote-level-uses: none: 1

$ bin/ldapsearch --baseDN "cn=Replication Summary dc_example_dc_com,cn=monitor" \
  "(objectclass=*)" | grep replication-assurance

replication-assurance-submitted-operations: 1
replication-assurance-local-completed-normally: 1
replication-assurance-local-completed-abnormally: 0
replication-assurance-local-completed-with-timeout: 0
replication-assurance-local-completed-with-shutdown: 0
replication-assurance-local-completed-with-unavailable-server: 0
replication-assurance-remote-completed-normally: 0
replication-assurance-remote-completed-abnormally: 0
replication-assurance-remote-completed-with-timeout: 0
replication-assurance-remote-completed-with-shutdown: 0
replication-assurance-remote-completed-with-unavailable-server: 0
```

11. Perform a modify of an entry under dc=example,dc=com on server 1. Check that the counters matched the modify operation to the "Mods Processed All Locally" policy and that the operations completed assured.

```
$ bin/ldapsearch --baseDN "cn=Replica dc_example_dc_com,cn=monitor" \
  "(objectclass=*)" | grep replication-assurance

replication-assurance-submitted-operations: 2
replication-assurance-local-completed-normally: 2
replication-assurance-local-completed-abnormally: 0
replication-assurance-local-completed-with-timeout: 0
replication-assurance-local-completed-with-shutdown: 0
replication-assurance-local-completed-with-unavailable-server: 0
replication-assurance-remote-completed-normally: 0
replication-assurance-remote-completed-abnormally: 0
replication-assurance-remote-completed-with-timeout: 0
replication-assurance-remote-completed-with-shutdown: 0
replication-assurance-remote-completed-with-unavailable-server: 0
replication-assurance-policy-matches: Adds Processed All Locally: 1
replication-assurance-policy-matches: Default Replication Assurance Policy: 0
replication-assurance-policy-matches: Mods Received Any Locally: 1
replication-assurance-local-level-uses: processed-all-servers: 1
replication-assurance-local-level-uses: received-any-server: 1
replication-assurance-remote-level-uses: none: 2

$ bin/ldapsearch --baseDN "cn=Replication Summary dc_example_dc_com,cn=monitor" \
  "(objectclass=*)" | grep replication-assurance

replication-assurance-submitted-operations: 2
replication-assurance-local-completed-normally: 2
replication-assurance-local-completed-abnormally: 0
replication-assurance-local-completed-with-timeout: 0
replication-assurance-local-completed-with-shutdown: 0
replication-assurance-local-completed-with-unavailable-server: 0
replication-assurance-remote-completed-normally: 0
replication-assurance-remote-completed-abnormally: 0
replication-assurance-remote-completed-with-timeout: 0
replication-assurance-remote-completed-with-shutdown: 0
```

```
replication-assurance-remote-completed-with-unavailable-server: 0
```

You have successfully configured Assured Replication.

About the Assured Replication Controls

The LDAP SDK for Java provides an implementation of an LDAP control that can be included in add, bind, modify, modify DN, and certain extended requests to indicate the level of replication assurance desired for the associated operation. The OID for this control is 1.3.6.1.4.1.30221.2.5.28, and may have a criticality of either TRUE or FALSE.

For specific details, see the LDAP SDK javadoc for the `AssuredReplicationRequestControl` class.

Managing the Topology

The following sections describe common topology management operations.

Note: When enabling or disabling replication within a topology that contains multiple product versions, the `dsreplication` tool must be run from the server root location of a member of the topology that has the oldest product version.

To Add a Server to the Topology

The following steps assume an existing data store topology. The commands are identical for initial enable between two servers, where one server contains data for the replication domain stored in the `userRoot` backend. If database encryption is being used on the servers in the topology, it is important that the server being initialized has a copy of the `encryption-settings` backend from the source server. A backup of the encryption-settings database should be restored on the destination server. The restore of encryption-settings does not overwrite the existing encryption-settings backend, because the restore of this backend is handled as an append.

1. All servers, in the topology and the new server, should be online.
2. Enable replication for the base DN, or base DNs, using an existing server as `host1` and the new server as `host2`.

```
$ bin/dsreplication enable --host1 austin01.example.com --port1 1389 \
    --bindDN1 "cn=Directory Manager" --bindPassword1 password \
    --replicationPort1 8989 --host2 austin03.example.com --port2 1389 \
    --bindDN2 "cn=Directory Manager" --bindPassword2 password \
    --replicationPort2 8989 --baseDN dc=example,dc=com --adminUID admin \
    --adminPassword password --no-prompt
```

3. Optionally, compare the configurations between the two hosts used in the `dsreplication enable` command. Make sure settings are consistent across the topology and are also consistent with the new system:

```
$ bin/config-diff --sourceLocal --targetHost austin03.example.com
--targetBindDN "cn=directory manager" --targetBindPassword pass --targetPort 1389
```

Disabling Replication and Removing a Server from the Topology

When removing a server from the topology, the remaining servers need to be made aware of the change. If the server to be removed is online, then one invocation of `dsreplication disable` is all that is necessary. If the server to be removed is offline, then two steps are required: `dsreplication remove-defunct-server` from another server in the topology, and `dsreplication cleanup-local-server` on the offline server to be removed. Similar to the `enable` command, all servers not being removed from the topology need to be online during the process. The following examples show the steps in more detail:

- **Removing a server that is still online**. The `dsreplication disable` command can be run from any server, but all servers in the topology need to be online.

```
$ bin/dsreplication disable --hostname austin03.example.com --port 1389 \
              --baseDN dc=example,dc=com --adminUID admin --adminPassword password \
              --no-prompt
```

- **Removing a server that is offline**.The `dsreplication remove-defunct-server` command can be run against any server not being removed from the topology. All servers in the topology, except for the offline servers being removed, must be online.

```
$ bin/dsreplication remove-defunct-server --hostname austin01.example.com --port 1389
 \
              --baseDN dc=example,dc=com --adminUID admin --adminPassword password \
              --no-prompt --defunctHost austin03.example.com --defunctPort 1389
              --defunctReplPort 8989
```

  Run the `dsreplication cleanup-local-server` subcommand on each server removed from the topology to remove any topology references.

```
$ bin/dsreplication cleanup-local-server --no-prompt
```

Replacing the Data for a Replicating Domain

In the rare event that the data for the entire replication domain (such as the backend) needs to be replaced, perform the following steps:

To Replace the Data

1. With all servers online, the `dsreplication pre-external-initialization` command must be run once against any server in the topology. This stops replication for the domain. No writes are made by clients to any of the servers.

```
$ bin/dsreplication pre-external-initialization --hostname austin01.example.com \
   --port 1389 --baseDN dc=example,dc=com --adminUID admin \
   --adminPassword password --no-prompt
```

2. Using `import-ldif`, replace the data for `dc=example,dc=com`. Make sure that the input LDIF is free of any replication attributes by using the `--excludeReplication` option. The `--overwriteExistingEntries` option is necessary to overwrite the existing data for the domain. For example, to perform the `import-ldif` with the server offline:

```
$ bin/import-ldif --ldifFile new-data.ldif --backendID userRoot --excludeReplication
 --overwriteExistingEntries
```

3. Initialize the other servers in the topology with `dsreplication initialize`, using the server which has the new data as the source host. For example:

```
$ bin/dsreplication initialize --hostSource austin01.example.com --portSource 1389 \
   --hostDestination budapest01.example.com --portDestination 1389 \
   --adminUID admin --adminPassword password --baseDN dc=example,dc=com \
   --no-prompt
```

4. Run `dsreplication post-external-initialization` once from any server in the topology. All servers in the topology must be online:

```
$ bin/dsreplication post-external-initialization --hostname austin01.example.com \
   --port 1389 --baseDN dc=example,dc=com --adminUID admin \
   --adminPassword password --no-prompt
```

Advanced Configuration

The following sections are advanced configuration procedures that may be appropriate for your company’s deployment.

Changing the replicationChanges DB Location

You can change the `replicationChanges` DB location if on-disk space issues arise. The replication changelog database can live outside `<server-root>` and be placed in another location on the filesystem. In that case, you must specify the absolute path of the replication changelog directory.

To Change the replicationChanges DB Location

1. Use `dsconfig` to change the database location for the replication changelog, which by default is at `<server-root>/changelogDb`. The following command sets the replication changelog backend to `<server-root>/data/directory/changelogDB` . Remember to include the LDAP connection parameters (hostname, port, bindDN, bindPassword).

```
$ bin/dsconfig set-replication-server-prop \
  --provider-name "Multimaster Synchronization" \
  --set "replication-db-directory:/data/directory/changelogDb" \
  --bindDN "cn=Directory Manager" --bindPassword secret --no-prompt
```

2. Stop the server, move the DB files, and then restart the server.

```
$ bin/stop-ds
$ mv changelogDb /data/directory
$ bin/start-ds
```

Modifying the Replication Purge Delay

The replication purge delay specifies the period after which the data store purges changes on the replication server database. Any change that is older than the purge delay is removed from the replication server database regardless of whether the change has been applied.

Currently, the UnboundID Data Store sets the default purge delay to one day. Administrators can change the default purge delay using the `dsconfig` tool. To ensure proper replication processing, you must have the same purge delay value set for all replication servers in the topology.

To Modify the Replication Purge Delay

- Use `dsconfig` to change the purge delay. The property accepts time units of seconds (s), minutes (m), hours (h), days (d), or weeks (w). The following command is entered on the command line and changes the purge delay from the default one day to two days.

  In `dsconfig` interactive mode, open the **Advanced objects** menu. Select **Replication Server**. Select the replication synchronization provider, and then select the option to change the replication purge delay.

  ```
  $ bin/dsconfig set-replication-server-prop \
    --provider-name "Multimaster Synchronization" \
    --set "replication-purge-delay:2 d"
  ```

Configuring a Single Listener-Address for the Replication Server

By default, the replication server binds the listening ports to all available interfaces of the machine. To bind the listener to a specific address, the address must be the hostname provided when replication is enabled and the `listen-on-all-addresses` property must be set to `FALSE`.

The replication server's configuration entry already stores a host name for itself so that it can resolve the address and specify it during the socket bind. If the server information is missing from the system, an error message will be generated with instructions on specific address binding. You can use the `dsconfig` tool to change the value of the `listen-on-all-addresses` property from TRUE (default) to FALSE.

To Configure a Replication Server to Listen on a Single Address

1. Create a new data storeinstance with replication enabled on port 8989.

2. Run `netstat` to see the ports bound for listening on port 8989. Notice that *.8989 means that it is listening on all addresses.

```
$ netstat -an | grep LISTEN | grep 8989
```

3. Run `dsconfig` to disable listening on all addresses for the replication server.

```
$ bin/dsconfig set-replication-server-prop \
  --provider-name "Multimaster Synchronization" \
  --set listen-on-all-addresses:false
```

4. Run `netstat` again to see the ports bound for listening on port 8989. Notice that `<address>.8989` (for example, 10.8.1.211.8989) means that it is listening on the one address.

Monitoring Replication

Replication in the UnboundID Data Store can be monitored the following ways:

- The `dsreplication status` subcommand displays basic information about the replicated base DNs, the number of entries replicated as well as the approximate size of replication backlogs at each Data Store.
- The more detailed information about the state of replication can be obtained via the information exposed in its monitoring framework under `cn=monitor`. Administrators can monitor their replication topologies using several tools and protocols: the Metrics Engine, SNMP, LDAP, JMX, or through the Management Console. See Managing Logging and Monitoring.
- The Periodic Stats Logger plug-in allows collecting replication statistics for profiling server performance. For more information, see Profiling Server Performance Using the Periodic Stats Logger.

Monitoring Replication Using cn=monitor

The `cn=monitor` branch has a number of entries that store the replication state of a topology.

- **Direct LDAP Server <baseDN> <host name:port> <serverID>**. Defines an LDAP server that is directly connected to the replication server that you are querying. The information in this entry applies to the replication server local to the `cn=monitor` entry. For detailed information, see *Summary of the Direct LDAP Monitor Information*.
- **Indirect LDAP Server <baseDN> <serverID>**. Defines an LDAP server that is connected to another replication server in the topology. While this server is connected to the same topology, it is not connected to the replication server being queried. For detailed information, see *Summary of the Indirect LDAP Server Monitor Information*.
- **Remote Repl Server <baseDN> <host name:port> <serverID>**. Defines a remote replication server that is connected to the local replication server. Information in this entry is in respect to the Replication Server local to the `cn=monitor` branch. For detailed information, see *Summary of the Remote Replication Server Monitor Information*.
- **Replica <baseDN>**. Stores information for an instance of the replicated naming context — also known as the replica—with respect to the Data Store and its communication with a

replication server. The Replica information is what is responsible for sending and receiving changes from the replication servers. For detailed information, see *Summary of the Replica Monitor Information*.

- **Replication Server <replPort> <serverID>**. Shows the information specific to the Replication Server running, for example, on the replication port <replPort> with a server ID of <serverID>. This entry defines the replication server. For detailed information, see *Summary of the Replication Server Monitor Information*.
- **Replication Server Database <baseDN> <serverID>**. Shows information for the changelog table of replica (suffix) in the replication server. As the Replication Server receives updates from the Data Store, it records those changes in the changelog table. For detailed information, see *Summary of the Replication Server Database Monitor Information*.
- **Replication Server Database Environment <baseDN>**. Shows the information for the database environment for the replication server backend plus the total number of records added to and deleted from the database. For detailed information, see *Summary of the Replication Server Database Environment Monitor Information*.
- **Replication Summary <baseDN>**. Shows summary information on the replication topology and the state for a particular base DN. For detailed information, see *Summary of the Replication Summary Monitor Information*.
- **Replication Changes Backend**. Shows the backend information for all replication changes. For detailed information, see *Summary of the Replication Changes Backend Monitor Information*.
- **Replication Protocol Buffer**. Shows the state of the buffer (initially 4k) for protocol operations, which is stored in thread local storage. For detailed information, see *Summary of the Replication Protocol Buffer Monitor Information*.

Replication Best Practices

The following are recommended best practices related to replication based on our observations in actual production environments.

About the dsreplication Command-Line Utility

The following points involve some security practices as applies to replication. For specific questions, please contact your authorized support provider.

- **Developing Scripts**. The `dsreplication` utility maintains the history of executed `dsreplication` commands with the full command-line arguments in the `logs/tools/dsreplication.history` file. The recorded commands may be used to develop scripts to set up and configure replication.

  Scripts invoking the `dsreplication` utility in non-interactive mode should check the return code from the dsreplication process. A non-zero return code indicates some sort of failure.

If output messages from the `dsreplication` utility are not desired, use the `--quiet` option to suppress them.

The utility, by default, fails if one or more warnings are issued during the command execution. Warnings can be suppressed using the `--ignoreWarnings` option. For example, this option is required when using `dsreplication` with non-fully-qualified hostnames (for example, localhost), otherwise `dsreplication` will fail. In production environments, use of this flag is strongly discouraged.

The `dsreplication` utility also provides an `--ignoreLock` option that specifies that the tool should continue processing in non-interactive mode or in scripts even if the replication topology has been locked by another invocation of `dsreplication`. However, this option should be used with caution.

- **Concurrent Use**. With the exception of the `dsreplication status` subcommand, the `dsreplication` subcommands cannot be executed concurrently. The command-line utility locks the replication topology at one or more servers to prevent accidental configuration changes caused by multiple `dsreplication` subcommands running at the same time. It is best to avoid concurrent configuration changes in general.
- **Status**. The `dsreplication status` subcommand requires the Replication Servers to provide monitoring information. This can lead to a delay before the output of `dsreplication status` is displayed. By default, `dsreplication` will display the status for all replicated domains (with the exception of the special domains of the schema and the server registry).

  It is recommended to select a particular base DN for `dsreplication status` if multiple base DNs are configured for replication.

  It is also recommended to avoid invoking `dsreplication status` too often (more than once every 15 seconds) or from multiple locations at the same time. Some of the information displayed by `dsreplication status` is based on monitor information that is not refreshed every time the monitor is queried.

  The `status` subcommand should not be used for collecting performance metrics. It is best to rely on replication-related information captured by the Periodic Stats Logger Plug-in.

Replication Conflicts

This section provides more in-depth information on replication conflicts than presented in earlier sections, so that administrators can understand the mechanisms and possible scenarios behind these conflicts.

Updates to Data Store entries in a replication topology may happen independently, since replication guarantees only eventual consistency, not strong consistency. The eventual consistency model also means that conflicting changes can be applied at different data store instances. In most cases, the Data Store is able to resolve these conflicts automatically and in a consistent manner (i.e., all data store instances in a replication topology will resolve each and every conflict the same way). However, in some scenarios, as seen below, manual administrative action is required. For any of these unresolved conflicts, the administrator is notified via administrative alerts.

On a high-level, the conflict resolution algorithm tries to resolve conflicts as if the operations causing the conflict in a distributed environment has been applied to a single data store instance. For example, if the same entry is added to two different data store instances at about the same time, then once these operations have been replicated, both data stores will keep only the entry that was added first. The following figure highlights the differences between standalone versus replicated environments.

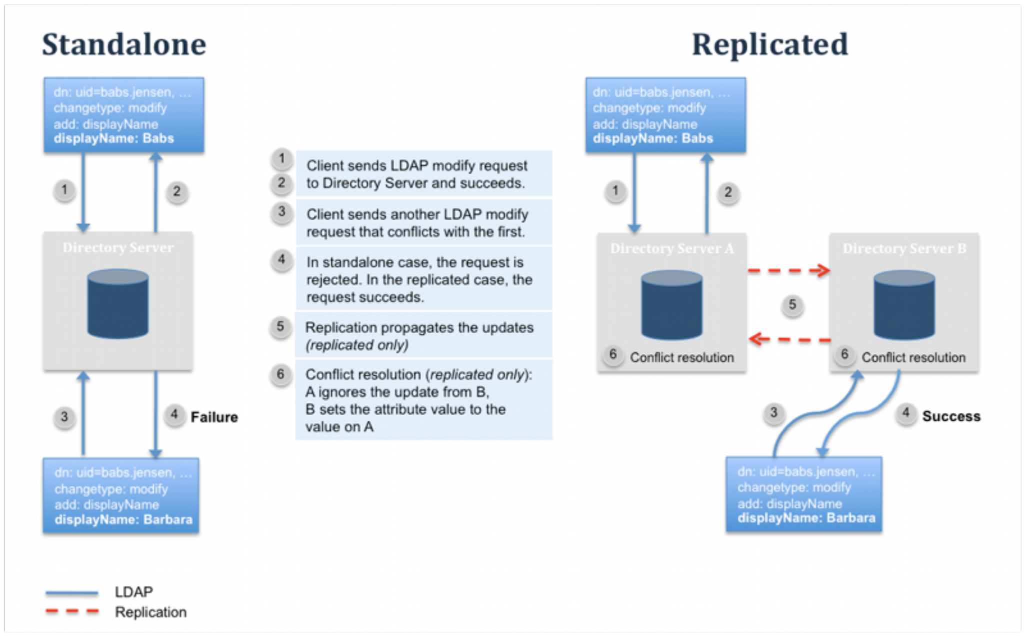

Standalone
Replicated
dn: uid=babs.jensen, ...
changetype: modify
add: displayName
displayName: Babs
Directory Server
Directory Server A
Directory Server B
1 Client sends LDAP modify request
2 to Directory Server and succeeds.
3 Client sends another LDAP modify request that conflicts with the first.
4 In standalone case, the request is rejected. In the replicated case, the request succeeds.
5 Replication propagates the updates (replicated only)
6 Conflict resolution (replicated only): A ignores the update from B, B sets the attribute value to the value on A
4 Failure
4 Success
6 Conflict resolution
dn: uid=babs.jensen, ...
changetype: modify
add: displayName
displayName: Barbara
LDAP
Replication

Figure 14: Conflicting Operations in Standalone versus Replicated Environments

Types of Replication Conflicts

There are fundamentally two types of replication conflicts: naming and modification conflicts. Naming conflicts include operations that cause conflicts with the naming (DN) of the existing or new entries, while modification conflicts include operations that result in conflicts in the modification of attributes.

Naming Conflict Scenarios

For all of the naming conflict scenarios in the table below, assume the folloing:

- Update 1 was applied at Data Store 1
- Update 2 was applied at Data Store 2
- Update 1 occurred shortly before Update 2, so that Data Store 2 received Update 1 after Update 2 was applied

The naming conflict scenario is illustrated in the following figure:

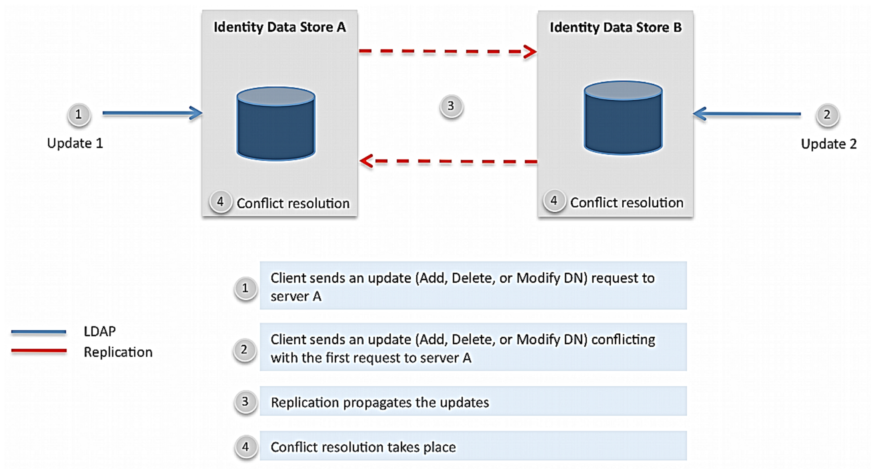

Identity Data Store A
Identity Data Store B
1
Update 1
2
Update 2
3
4 Conflict resolution
4 Conflict resolution
LDAP
Replication
1 Client sends an update (Add, Delete, or Modify DN) request to server A
2 Client sends an update (Add, Delete, or Modify DN) conflicting with the first request to server A
3 Replication propagates the updates
4 Conflict resolution takes place

Figure 15: Naming Conflict Scenario

The following table shows the result of a modification conflict depending on the type of updates that occurs. The code does not compare change sequence numbers (CSNs) but applies operations in the order they were received. This may lead to inconsistent replays.

Table 47: Naming Conflict Scenarios

Update 1	Update 2	Automatic Resolution?	Result of Conflict Resolution at Data Store 2 When Update 1 is received
Modify	Delete	Yes	Modify is discarded.
Modify	Modify DN	Yes	New entry is located based on the entryUUID and Modify is applied to the renamed entry.
Delete	Delete	Yes	Delete operation is ignored.
Delete	Modify DN	Yes	Delete operation is applied to the renamed entry.
Delete of A	Add of B under A	Yes	Entry B is renamed and Entry A is deleted.
Modify DN	Delete of the same entry targeted by the Modify DN	Yes	Modify DN operation is ignored.
Modify DN with a new parent	Delete of parent	No	The entry targeted in the Modify DN operation is marked as a conflict entry.
Modify DN with a new parent	Modify DN of the parent	Yes	The entry will be moved under the new DN of the parent.
Modify DN of A with new DN B	Modify DN of C with new DN B	No	A and B will be conflict entries.
Add A	Modify DN of the parent of A	Yes	The entry is added under the new DN of the parent.
Add A	Delete of the parent of A	No	The added entry is marked as a conflict entry.
Add A	Add A with same set of attributes	Yes	The entryUUID of the incoming Add operation applied to the existing entry.

Update 1	Update 2	Automatic Resolution?	Result of Conflict Resolution at Data Store 2 When Update 1 is received
Add A	Add A with different set of attributes (or values)	No	The existing entry is marked as a conflicting entry and the incoming Add is executed.

Modification Conflict Scenarios

Modification conflicts are always resolved automatically and no manual action is required. The LDAP Modify operation allows the following modification types:

- Add of one or more values
- Delete of one or more values or the entire attribute
- Replacement of all values

Replication does not currently support the increment LDAP modification type.

For all of the operations in the table below, assume the following:

- LDAP Modify 1 was applied at Data Store 1
- LDAP Modify 2 was applied at Data Store 2
- LDAP Modify 1 occurred shortly before LDAP Modify 2, so that Data Store 2 received LDAP Modify 1 after LDAP Modify 2 was applied.

The modification conflict scenario is illustrated in the figure below:

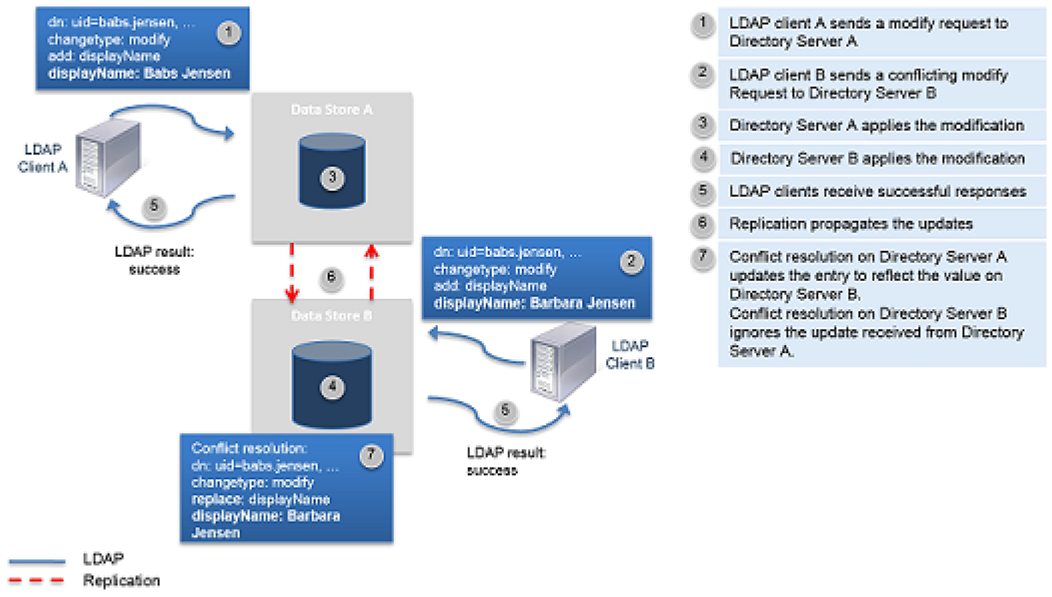

dn: uid=babs.jensen, ...
changetype: modify
add: displayName
displayName: Babs Jensen
1
LDAP Client A
Data Store A
3
5
LDAP result: success
6
Data Store B
4
dn: uid=babs.jensen, ...
changetype: modify
add: displayName
displayName: Barbara Jensen
2
LDAP Client B
5
LDAP result: success
Conflict resolution:
dn: uid=babs.jensen, ...
changetype: modify
replace: displayName
displayName: Barbara Jensen
7
LDAP
Replication
1 LDAP client A sends a modify request to Directory Server A
2 LDAP client B sends a conflicting modify Request to Directory Server B
3 Directory Server A applies the modification
4 Directory Server B applies the modification
5 LDAP clients receive successful responses
6 Replication propagates the updates
7 Conflict resolution on Directory Server A updates the entry to reflect the value on Directory Server B. Conflict resolution on Directory Server B ignores the update received from Directory Server A.

Figure 16: Modification Conflict Scenario

The following table shows the result of a modification conflict depending on the type of updates that occurs:

Table 48: Modification Conflict Scenarios

Modify 1	Modify 2	Result of Conflict Resolution at Data Store 2 When Modify 1 is received
Add of a single-value attribute	Add of the same attribute with a different value	Incoming Modify is ignored.
Delete of a single-valued attribute	Replacement of the value of the same attribute	Incoming Delete is ignored.
Replacement of a single-valued attribute	Delete of the same attribute	Incoming Replacement is ignored.
Delete some values from a multi-valued attribute	Delete some values from a multi-valued attribute	Incoming Delete is ignored.
Delete a multi-valued attribute	Delete of the same multi-valued attribute	Incoming Delete is ignored.
Delete a multi-valued attribute	Add the same multi-valued attribute	Incoming Delete is ignored.
Delete value X from a multi-valued attribute	Delete value X from the same multi-valued attribute	Incoming Delete is ignored.
Delete value X from a multi-valued attribute	Add value Y to the same multi-valued attribute	Delete of value X is applied.
Delete value X from a multi-valued attribute	Delete value Y from the same multi-valued attribute	Delete of value X is applied.
Delete value X from a multi-valued attribute	Replace all values of the same multi-valued attribute	Incoming Delete is ignored.
Add of values X and Y to a multi-valued attribute	Delete value X from the same multi-valued attribute	Only value Y is added.
Delete value X from a multi-valued attribute	Add of values X and Y to the same multi-valued attribute	Incoming Delete is ignored.

Troubleshooting Replication

The following sections provide information to troubleshoot your replication deployment.

Recovering a Replica with Missed Changes

If a server has been offline for a period of time longer than the replication purge delay, the `dsreplication initialize` command must be performed to bring the replica into sync with the topology.

Server startup is the only time missed changes are detected. A missed change is a change that the replica detects that it needs, but which cannot be found within any other replication server's replicationChanges backend (stored in the path server root `/changelogDb`). If missed changes are detected, the server enters lockdown mode, where only privileged clients can make requests. Any other server that is not missing changes can be used as a source for `dsreplication initialize`.

If a manual backup and restore of the server is required, then the following steps are equivalent to `dsreplication initialize`.

Performing a Manual Initialization

In the event that an online initialization is not possible, the following steps can be used to initialize a server.

1. From another server in the replication topology, backup the `userRoot`, `adminRoot`, `schema`, `replicationChanges` backends to the `/bak` directory. If encrypted attributes are present, then the `encryption-settings` backend should also be backed up.

```
$ <source-server-root>/bin/backup --backendID userRoot -d bak/userRoot
$ <source-server-root>/bin/backup --backendID adminRoot -d bak/adminRoot
$ <source-server-root>/bin/backup --backendID schema -d bak/schema
$ <source-server-root>/bin/backup --backendID replicationChanges -d bak/
replicationChanges
$ <source-server-root>/bin/backup --backendID encryption-settings -d bak/encryption-
settings
```

2. Copy the `bak` directory to the new replica.

```
$ scp -r <source-server-root>/bak <user>@<destination-server>:<destination-server-
root>/bak
```

3. Stop the server and restore the `userRoot`, `changelog`, `adminRoot`, `replicationChanges` backends. If the `encryption-settings` backend was backed up, it should also be restored.

```
$ <destination-server-root>/bin/restore -d bak/userRoot
$ <destination-server-root>/bin/restore -d bak/adminRoot
$ <destination-server-root>/bin/restore -d bak/schema
$ <destination-server-root>/bin/restore -d bak/replicationChanges
$ <destination-server-root>/bin/restore -d bak/encryption-settings
```

4. Start the server using `bin/start-ds`.

Fixing Replication Conflicts

Replication conflicts can occur when an incompatible change to an entry is made on two replicas at the same time. The change is processed on one replica and then replicated to the other replica, which causes the conflict. While most conflicts are resolved automatically, some require manual action.

To fix replication conflicts, initialize the replica containing the conflicts with the data from another replica that does not have conflicts. If the database is large and the number of conflicts small, running `ldapmodify` against the server with the conflict will work if the command includes the Replication Repair Control specified by OID value 1.3.6.1.4.1.30221.1.5.2. The Replication Repair Control prevents the change from replicating. It also enables changing operational attribute values, which are not normally writable.

The following steps provide an example of using the Replication Repair Control to fix replication conflicts by applying change to only the server with the conflict. There are two examples: one for a modification conflict found by performing an `ldap-diff`, and the other for a naming conflict.

To Fix a Modify Conflict

1. The `bin/ldap-diff` tool can be used to isolate conflicting entries between two replicas. The following uses the tool to search across the entire base DN for any difference in user attributes, and reports the difference in `difference.ldif`. Replace the `sourceHost` value with the server that needs the adjustment.

```
$ bin/ldap-diff --sourceHost austin02.exmple.com --sourcePort 1389 \
                        --sourceBindDN "cn=Directory Manager" --sourceBindPassword
 pass \
                        --targetHost austin01.example.com --targetPort 1389 \
                        --targetBindDN "cn=Directory Manager" --targetBindPassword
                        --baseDN "dc=example,dc=com" --outputLDIF difference.ldif \
                        --searchFilter "(objectclass=*)" --numPasses 3 "*" pass \
                        "^userPassword"
```

2. The `difference.ldif` file is in a format that can be used with `ldapmodify` to apply changes to the server that contains conflicts. The `ldap-diff` command must have been run with the `sourceHost` value as the server with conflicts. The following is an example of the contents of `difference.ldif`:

```
dn: uid=user.1,ou=people,dc=example,dc=com
                        changetype: modify
                        add: mobile
                        mobile: +1 568 232 6789
                        -
                        delete: mobile
                        mobile: +1 568 591 7372
                        -
```

3. Run `bin/ldapmodify` to correct the entries on only the server with conflicts.

```
$ bin/ldapmodify --bindPassword password -J "1.3.6.1.4.1.30221.1.5.2" \
                        --filename difference.ldif
```

To Fix a Naming Conflict

1. In this example, a naming conflict was encountered when the replica attempted to replay an ADD of `uid=user.200,ou=people,dc=example,dc=com`. In other words, two clients added the entry at the same time as an entry of the same name was added on another replica.

```
[18/Feb/2010:14:53:12 -0600] category=EXTENSIONS severity=SEVERE_ERROR
msgID=1880359005 msg="Administrative alert type=replication-unresolved-conflict
id=bbd2cbaf-90a4-42af-94a8-c1a42df32fc6
class=com.unboundid.directory.server.replication.plugin.ReplicationDomain
msg='An unresolved conflict was detected for DN
 uid=user.200,ou=People,dc=example,dc=com.
The conflicting entry has been renamed to
entryuuid=69807e3d-ab27-43a3-8759-
ec0d8d6b3107+uid=user.200,ou=People,dc=example,dc=com'"
```

2. The Data Store prepends the entryUUID to the DN of the conflicting attribute and adds a `ds-sync-conflict-entry` auxiliary object class to the entry to aid in search. For example, the following command searches for any entry that has the `ds-sync-conflict-entry` objectclass and returns only the DNs that match the filter. You should see the conflicting entry for uid=user.200.

```
$ bin/ldapsearch --baseDN dc=example,dc=com --searchScope sub \
  "(objectclass=ds-sync-conflict-entry)" "1.1"
```

```
dn: entryuuid=69807e3d-ab27-43a3-8759-
ec0d8d6b3107+uid=user.200,ou=People,dc=example,dc=com

dn: entryuuid=523c430e-
a870-4ebe-90f8-9cd811946420+uid=user.200,ou=People,dc=example,dc=com
```

Note: Conflict entries are not returned unless the `objectclass=ds-sync-conflict-entry` is present in the search filter.

3. After comparing the conflict entry with the target entry, the difference can be applied in a manner similar to the previous example using `ldapmodify` with the Replication Repair Control. The conflict entry can also be deleted using this command. Run `bin/ldapmodify` with the Replication Repair Control to make the fix. When making changes using the Replication Repair Control, the updates will not be propagated via replication. You should examine each and every replica one by one, and apply the necessary modifications using the request control.

```
$ bin/ldapmodify -J "1.3.6.1.4.1.30221.1.5.2" \
  --filename difference.ldif
```

Fixing Mismatched Generation IDs

A warning that multiple generation IDs were detected for a specific suffix indicates that one or more replicas need to be re-initialized. If the warning is presented from a server after an initialization, it could be that `post-external-initialization` was not run as part of a global change in data. Running this command will fix the situation. The `dsreplication status` command will warn when any generation IDs are different across the topology.

Replication Reference

The following section shows general reference information related to replication.

Summary of the dsreplication Subcommands

A summary of the `dsreplication` subcommands and functions is presented in the table below.

Table 49: dsreplication subcommands

Subcommand	Description
cleanup-local-server	Removes replication-related artifacts from the configuration, schema as well as the server registry while the local server is offline. The subcommand does not remove references to this server from other replicas and replication servers in the topology. Therefore, it is recommended to remove this server first from the replication topology either by using the `disable` or `remove-defunct-server` subcommands. Since this subcommand can only be executed when the server is offline, replication attributes

Subcommand	Description

	from suffixes other than the server registry or the schema will not be removed. The tool will produce an LDIF file, `logs/cleanup-backends.ldif` that may be used to the remove replica state from the base entry of these suffixes after the server is restarted.
	
	To remove the replication history from regular suffixes, export the formerly replicated suffixes using the `--excludeReplication` option of the `export-ldif` command. The resulting LDIF file can be re-imported using the `import-ldif` command. For example:
	
	`$ bin/export-ldif --backendID userRoot --excludeReplication \`
	`  --ldifFile cleansed.ldif`
	`$ bin/import-ldif --backendID userRoot --ldifFile cleansed.ldif`
	
	Exporting using the `--excludeReplication` option of the `export-ldif` command will also remove the replica state from the output. The LDIF created by the `cleanup-local-server` subcommand does not need to be applied after the server is restarted.

disable	Disables replication on the specified server for the provided base DN and removes references to this server in the other servers with which it is replicating data.
enable	Updates the configuration of the servers to replicate the data under the specified base DN. If one of the servers is already replicating the data under the base DN with other servers, executing this subcommand will update the configuration of all the servers (so it is sufficient to execute the command line once for each server you add to the replication topology).
initialize	Initializes the data under the specified base DN on the destination server with the contents on the source server.
initialize-all	Initializes the data under the specified base DN on all servers in the replication topology with the contents on the specified server.
post-external-initialization	Used with `pre-external-initialization`, the command resets the generation ID based on the newly-loaded data. This subcommand must be called after initializing the contents of all the replicated servers using the `import-ldif` tool or `dsreplication initialize`. Specify the list of base DNs that have been initialized and provide the credentials of any of the servers that are being replicated. See the usage of the `pre-external-initialization` subcommand for more information. This subcommand only needs to be run on one of the replicas once.
pre-external-initialization	Clears the existing generation ID and removes all accumulated changes of the replicated suffix from the replication changelog database at each and every replication server. This subcommand should be used when globally restoring the replicas on all of the servers in a topology. You must specify the list of base DNs that will be initialized and provide the credentials of any of the servers that are being replicated. After calling this subcommand, initialize the contents of all the servers in the topology, then call the `post-external-initialization` subcommand. This subcommand only needs to be run on one of the replicas once.
remove-defunct-server	Removes an offline defunct server from the replication on all servers in the topology.
status	Displays the status of replication domains. If no base DNs are specified as parameters, the information for all base DNs is displayed. Available options with the status subcommand are: `--showAll`, `--displayServerTable`, `--location`.

Summary of the Direct LDAP Monitor Information

The following table provides a description of the attributes in the `cn=Direct LDAP Server` monitor entry. The DN for the monitor entry is as follows:

```
dn: cn=Direct LDAP Server <baseDN> <host name:ldapPort> <serverID>,cn=monitor
```

Table 50: Direct LDAP Monitor Information

Monitor Attribute	Description
connected-to: Replication Server <replPort> <serverID>	Replication port number and server ID of the replication server to which this server is connected. The first number is the replication server port number and the second number is the server-id of the replication server.
replica-id:<serverID>	Replica ID number.
replication-backlog	Number of changes that the replication server has not seen from the server.
missing-changes	Number of missing changes.
approximate-delay	Difference between the time of the last change that the replication server has seen from the LDAP server and the most current time stamp on the latest change on the server.
base-dn	Base DN
ssl-encryption	Flag to indicate if SSL encryption is in use.
protocol-version	Displays the replication protocol version.
generation-id	Generation ID for the base DN on the Data Store.
restricted	Boolean that indicates whether the replication domain is restricted in an Entry Balancing Configuration with Proxy Server.
ack-sent	Number of acknowledgement messages sent to this replica (not currently used).
ack-received	Number of acknowledgement messages received from this replica (not currently used).
add-sent	Number of protocol messages with an LDAP Add sent to this replica.
add-received	Number of protocol messages with an LDAP Add received from this replica.
delete-sent	Number of protocol messages with an LDAP Delete sent to this replica.
delete-received	Number of protocol messages with an LDAP Delete received from this replica.
done-sent	Number of done messages sent to this replica. A done message indicates an end of online initialization session. If the value is non-zero, then this replica has been initialized over the replication protocol.
done-received	Number of done messages received from this replica. A done message indicates an end of online initialization session. If the value is non-zero, then this replica has completed the initialization of other replicas over the replication protocol.
entry-sent	Number of entry messages sent to this replica. Entry messages carry replicated data to initialize replicas over the replication protocol.
entry-received	Number of entry messages received from this replica. Entry messages carry replicated data to initialize replicas over the replication protocol.
error-sent	Number of error messages sent to this replica.
error-received	Number of error messages received from this replica.

Monitor Attribute	Description
heartbeat-sent	Number of heartbeat messages sent to this replica.
heartbeat-received	Number of heartbeat messages received from this replica (should always be 0, since the replica never sends a heartbeat message to the server).
initialize-request-sent	Number of initialize-request messages sent to this replica. This message is sent when another replica requested initialization of its data using the replication protocol.
initialize-request-received	Number of initialize-request messages received from this replica. This message is sent when this replica requested initialization of its data using the replication protocol from another replica.
initialize-target-sent	Number of initialize-target messages sent to this replica. This message is sent before another replica has started the initialization of this replica.
initialize-target-received	Number of initialize-target messages received from this replica. This message is sent before this replica starts the initialization of one or more replicas.
modify-sent	Number of protocol messages with an LDAP Modify sent to this replica.
modify-received	Number of protocol messages with an LDAP Modify received from this replica.
modify-dn-sent	Number of protocol messages with an LDAP Modify DN sent to this replica.
modify-dn-received	Number of protocol messages with an LDAP Modify DN received from this replica.
repl-server-start-sent	Number of replication-server-start messages sent to this replica (should never be more than 1). The Replication Server responds with this message to the start message received from the replica.
repl-server-start-received	Number of replication-server-start messages received from this replica (should always be 0).
reset-generation-id-sent	Number of reset generation ID messages received from this replica.
reset-generation-id-received	Number of reset generation ID messages sent to this replica (should always be 0).
server-start-sent	Number of server-start messages sent to this replica (should always be 0).
server-start-received	Number of server-start messages received from this replica (should never be more than 1). Server-start is the first message the replica sends after establishing a replication connection.
window-sent	Number of window messages sent to this replica. Window messages are used for cumulative acknowledgement in the replication protocol.
window-received	Number of window messages received from this replica. Window messages are used for cumulative acknowledgement in the replication protocol.
window-probe-sent	Number of window probe messages sent to this replica (should always be 0).
window-probe-received	Number of window probe messages received from this replica. The replica sends a window probe message to the server if the send window in the replica is closed and the replica is unable to publish updates to the server.
update-sent	Number of changes sent to this server.
update-received	Number of changes received from this server.
internal-connection	Indicates if the replica is in the same process as the replication server.
server-state	Displays the state of the replica. Displays the latest change number that the replica has seen from all the other replicas including itself.
consumed-update-recent-rate	Rate that the connected Data Store is consuming updates sent by this replication server, expressed as the number of updates per second and measured over the last five seconds.

Monitor Attribute	Description
consumed-update-peak-rate	Highest rate that the connected Data Store has consumed updates sent by this replication server, measured over a five second period since the replication server was started.
produced-update-recent-rate	Rate that the connected Data Store has sent updates to this replication server, expressed as the number of updates per second and measured over the last five seconds.
produced-update-peak-rate	Highest rate that the connected Data Store has sent updates to this replication server, measured over a five second period since the replication server was started.
max-send-window	Maximum number of changes that can be sent to the LDAP server before requiring an ACK.
current-send-window	Current number of changes remaining to be sent to the LDAP server before requiring an ACK.
max-rcv-window	Maximum number of changes that can be received by the LDAP server before sending an ACK.
current-rcv-window	Number of changes remaining to be received by the LDAP server before sending an ACK Server.
degraded	Indicates that the generation ID of the replica does not match the generation ID of the server. This is a temporary state, when loading data into the topology or the replica has not been initialized. Normally, it should be false.

Summary of the Indirect LDAP Server Monitor Information

The following table provides a description of the attributes in the `cn=Indirect LDAP Server` monitor entry. These attributes provide information about a Data Store that is connected to a different replication server in the topology.

```
dn: cn=Indirect LDAP Server <baseDN> <serverID>,cn=monitor
```

Table 51: Indirect LDAP Server Monitor Information

Monitor Attribute	Description
replica-id: <serverID>	ID number identifying the replica.
base-dn: <baseDN>	Base DN
connected-to: Remote Repl Server <baseDN> <host name:replPort> <replID>	Replication server to which the data store is connected.
replication-backlog	Number of changes that the replication server has not seen from the server.
approximate-delay	Amount of time between the last change seen by this Data Store and the most recent change seen by the remote replication server. This value is the amount of time between the time stamps, not the amount of time required to synchronize the two servers.
generation-id	Generation ID for this suffix on this remote replication server.
consumed-update-recent-rate	Rate that the connected Replication Server is consuming updates sent by this replication server, expressed as the number of updates per second and measured over the last five seconds.

Monitor Attribute	Description
consumed-update-peak-rate	Highest rate that the connected Replication Server has consumed updates sent by this replication server, measured over a five second period since the replication server was started.

Summary of the Remote Replication Server Monitor Information

The following table provides a description of the attributes in the `cn=Remote Repl Server` monitor entry. The DN for the monitor entry is as follows:

```
dn: cn=Remote Repl Server <baseDN> <host name:replPort> <serverID>,cn=monitor
```

Table 52: Remote Replication Server Monitor Information

Monitor Attribute	Description
replication-server: <host name>:<repl port>	Host name and replication port number of the Replication Server.
replication-server-id:<serverID>	Server ID for the Replication Server.
available	Indicates if the remote replication server is available or not. Values: true or false.
sending-paused	Indicates if sending is paused. Values: true or false.
receiving-paused	Indicates if receiving is paused. Values: true or false.
wan-gateway-priority	Specifies the WAN Gateway priority of the remote replication server.
is-wan-gateway	Indicates if the remote replication server is a WAN Gateway. Values: true or false.
wan-gateway-desired	Indicates if the remote replication server is a desired gateway. Values: true or false. This entry together with the `is-wan-gateway` property indicates the desired state. ➢ **is-wan-gateway=false, wan-gateway-desire=false**: Indicates another server with a higher gateway priority exists or the gateway priority is set to disabled. ➢ **is-wan-gateway=false, wan-gateway-desire=true**: Indicates that the remote replication server wants to be a WAN gateway. ➢ **is-wan-gateway=true, wan-gateway-desire=false**: Indicates that the remote replication server wants to give up its role as a WAN gateway. ➢ **is-wan-gateway=false, wan-gateway-desire=true**: Indicates the remote replication server wants to remain as a gateway server.
base-dn	base DN
ssl-encryption	Flag to indicate if SSL encryption is in use.
protocol-version	Replication protocol version.
generation-id	Generation ID for this suffix on this remote replication server.
restricted	Indicates that remote replication server is in an entry-balancing deployment.
add-sent	Number of protocol messages with an LDAP Add sent to the remote replication server.
add-received	Number of protocol messages with an LDAP Add received from the remote replication server.

Monitor Attribute	Description
delete-sent	Number of protocol messages with an LDAP Delete sent to the remote replication server.
delete-received	Number of protocol messages with an LDAP Delete received from the remote replication server.
done-sent	Number of done messages sent to the remote replication server. A done message indicates an end of online initialization session.
done-received	Number of done messages received from the remote replication server. A done message indicates an end of online initialization session.
entry-sent	Number of entry messages sent to the remote replication server. Entry messages carry replicated data to initialize replicas over the replication protocol.
entry-received	Number of entry messages received from the remote replication server. Entry messages carry replicated data to initialize replicas over the replication protocol.
error-sent	Number of error messages sent to the remote replication server.
error-received	Number of error messages received from the remote replication server.
heartbeat-sent	Number of heartbeat messages sent to the remote replication server.
heartbeat-received	Number of heartbeat messages received from the remote replication server.
initialize-request-sent	Number of initialize-request messages sent to the remote replication replication server. This message is used during online initialization from one replica to another.
initialize-request-received	Number of initialize-request messages received from the remote replication server. This message is used during online initialization from one replica to another.
initialize-target-sent	Number of initialize-target messages sent to the remote replication server. This message is used before online initialization from one replica to another.
initialize-target-received	Number of initialize-target messages received from the remote replication server. This message is used before online initialization from one replica to another.
modify-sent	Number of protocol messages with an LDAP Modify sent to the remote replication server.
modify-received	Number of protocol messages with an LDAP Modify received from the remote replication server.
modify-dn-sent	Number of protocol messages with an LDAP Modify DN sent to the remote replication server.
modify-dn-received	Number of protocol messages with an LDAP Modify DN received from the remote replication server.
monitor-sent	Number of monitor messages sent to the remote replication server. This message is primarily used when communicating with data stores running a prior release.
monitor-received	Number of monitor messages received from the remote replication server. This message is primarily used when communicating with data stores running a prior release.
monitor-request-sent	Number of monitor requests sent to the remote replication server. The receiving server will respond with a monitor message that includes server's information about the state of the topology.

Monitor Attribute	Description
monitor-request-received	Number of monitor requests received from the remote replication server. This server will respond with a monitor message that includes server's information about the state of the topology.
monitor-v2-sent	Number of monitor messages sent to the remote server. This monitor message is only used with Data Store v3.5 or later.
monitor-v2-received	Number of monitor messages received from the remote server. This monitor message is only used with Data Store v3.5 or later.
pause-sending-updates-sent	Number of pause-sending-updates messages sent to the remote server. The remote server must stop sending update messages to this server when receiving this message.
pause-sending-updates-received	Number of pause-sending-updates messages received from the remote server. This server will stop sending update messages to the remote server upon receiving this message.
repl-server-start-sent	Number of replication-server-start messages sent to the remote replication server (should never be more than 1). The Replication Server responds with this message to the replication-server-start message received from remote replication servers.
repl-server-start-received	Number of replication-server-start messages received from the remote replication server (should never be more than 1) window-sent: the number of window messages sent to the remote replication server. Window messages are used for cumulative acknowledgement in the replication protocol.
reset-generation-id-sent	Number of reset generation ID messages received from the remote replication server. This message is sent before and after the data is initialized in the topology.
reset-generation-id-received	Number of reset generation ID messages sent to the remote replication server. This message is sent before and after the data is initialized in the topology.
server-info-sent	Number of replication server information messages sent to the remote replication server. This message tells other replication servers about the replicas directly connected to the sending server. This message is also used to distribute information about the location of replicas.
server-info-received	Number of replication server information messages received from the remote replication server. This message tells other replication servers about the replicas directly connected to the sending server. This message is also used to distribute information about the location of replicas.
set-source-location-sent	Number of set-source-locations messages sent to the remote replication server. This message is used by WAN gateway servers to request update messages from additional locations.
set-source-location-received	Number of set-source-locations messages sent to the remote replication server. This message is used by WAN gateway servers to request update messages from additional locations.
start-sending-updates-sent	Number of start-sending-updates messages sent to the remote replication server. The remote server may only start sending updates to this server after receiving this message.
start-sending-updates-received	Number of start-sending-updates messages received from the remote server. Sending update messages to the remote server may only start after receiving this message.
window-sent	Number of window messages sent to the remote replication server. Window messages are used for cumulative acknowledgement in the replication protocol.

Monitor Attribute	Description
window-received	Number of window messages received from the remote replication server. Window messages are used for cumulative acknowledgement in the replication protocol.
messages-sent	Total number of messages sent.
messages-received	Total number of messages received.
update-sent	Total number of updates sent.
update-received	Total number of updates received.
server-state	Displays the server state of the remote replication server. It displays the last change seen on the remote replication server.
consumed-update-recent-rate	Rate that the connected Data Store is consuming updates sent by this replication server, expressed as the number of updates per second and measured over the last five seconds.
consumed-update-peak-rate	Highest rate that the connected Data Store has consumed updates sent by this replication server, measured over a five second period since the replication server was started.
produced-update-recent-rate	Rate that the connected Data Store has sent updates to this replication server, expressed as the number of updates per second and measured over the last five seconds.
produced-update-peak-rate	Highest rate that the connected Data Store has sent updates to this replication server, measured over a five second period since the replication server was started.
max-send-window	Maximum number of changes that can be sent to the remote replication server before requiring an ACK.
current-send-window	Number of changes remaining to be sent to the remote replication server before requiring an ACK.
max-rcv-window	Maximum number of changes that can be received from the remote replication server before sending an ACK.
current-rcv-window	Number of changes remaining to be received from the remote replication server before sending an ACK.
degraded	Indicates that the generation ID of the replica does not match the generation ID of the remote replication server. This is a temporary state, when loading data into the topology or the replica has not been initialized. Normally, it should be false.

Summary of the Replica Monitor Information

The following table provides a description of the attributes in the `cn=Replica` monitor entry for a specific base DN.

```
dn: cn=Replica <baseDN>,cn=monitor
```

Table 53: Indirect LDAP Server Monitor Information

Monitor Attribute	Description
base-DN: <baseDN>	Specified base DN. The monitor entries track your company's base DN (or `dc=example,dc=com`), `cn=schema`, and `cn=admin data`.

Monitor Attribute	Description
connected-to: Replication Server <replPort> <serverID>	Replication port number and server ID of the replication server to which this LDAP Server is connected. The first number is the replication server port number and the second number is the `server-id` of the replication server.
lost-connections	Number of times the Data Store has lost connection to a replication server.
received-updates	Number of updates that the Data Store Replica has received from the connected replication server.
sent-updates	Number of updates sent to the replication server.
pending-updates	Number of updates pending to send to the replication server.
replayed-updates	Total number of updates from the replication server that have been replayed for this replica.
replayed-updates-ok	Number of updates for this replica that have been successfully replayed with no conflicts.
replayed-update-failed	Number of updates for this replica that were successfully replayed after automatically resolving a modify conflict.
resolved-modify-conflicts	Number of updates for this replica that were successfully resolved after a modify conflict.
resolved-naming-conflicts	Number of updates for this replica that were successfully resolved after a naming conflict.
unresolved-naming-conflicts	Number of updates for this replica that could not be replayed due to an unresolvable naming conflict.
replica-id	Server ID for this replica.
max-rcv-window	Maximum number of changes that the Data Store Replica can receive at a time before sending an acknowledgment back to the replication server.
current-rcv-window	Current received window size for this replica.
max-send-window	Maximum number of changes that the Data Store Replica can send at a time to the replication server before requiring an ACK.
current-rcv-window	Number of changes remaining to be received from the replication server before it must send an ACK.
max-send-window	Maximum number of changes that the Data Store Replica can send at a time to the replication server before requiring an ACK.
current-send-window	Number of changes remaining to be sent to the replication server before requiring an ACK.
ssl-encryption	Flag to indicate if SSL encryption is in use.
generation-id	Generation ID for this suffix on the Data Store.
replication-backlog	Number of changes that are from this replica.

Summary of the Replication Server Monitor Information

The following table provides a description of the attributes in the `cn=Replication Server` monitor entry.

```
dn: cn=Replication Server <baseDN> <replServerID>,cn=monitor
```

Table 54: Replication Server Monitor Information

Monitor Attribute	Description
replication-server-id	Server ID for the Replication server ID.
replication-server-port	Port number on which the replication server listens for communication from other servers.
base-dn: <baseDN>	Indicates the suffix to which this replication server database applies.
Generation IDs by Base DN	List of generation IDs for each base DN on the server.
num-outgoing-replication-server-connections	Number of outgoing connections from the replication server.
num-incoming-replication-server-connections	Number of incoming connections into the replication server.
num-incoming-replica-connections	Number of incoming connections to the replica.

Summary of the Replication Server Database Monitor Information

The following table provides a description of the attributes in the `cn=Replication Server database` monitor entry.

```
dn: cn=Replication Server database <baseDN> <replServerID>,cn=monitor
```

Table 55: Replication Server Database Monitor Information

Monitor Attribute	Description
database-replica-id: <replicaID>	Specifies the replication server ID.
base-dn: <baseDN>	Indicates the suffix to which this replication server database applies.
first-change	First change number that is in this replication database table for this suffix from this `server-id`. For example, an example entry looks like the following: `0000012209EA622C390D00000002 Mon Jun 22 16:41:11 CDT 2011`
last-change	Last change number that is in this replication database table for this suffix from this `server-id`. For example, an example entry looks like the following: `0000012209EA622C390D00000002 Mon Jun 22 16:41:11 CDT 2011`
queue-size	Number of changes in the replication server queue waiting to be sent to this remote replication server database.
queue-size-bytes	Size in bytes of all the messages waiting in the queue.
records-added	Displays the number of records changed or added to the DIT.
records-removed	Displays the number of records removed from the DIT.

Summary of the Replication Server Database Environment Monitor Information

The following table provides a description of the attributes in the `cn=Replication Server Database Environment` monitor entry, which includes the environment variables associated with the Oracle Berkeley Database Java Edition backend.

```
dn: cn=Replication Server Database Environment,cn=monitor
```

Table 56: Replication Server Database Environment Monitor Information

Monitor Attribute	Description
je-version	Current version of the Oracle Berkeley Java Edition.
current-db-cache-size	Current DB cache size.
max-db-cache-size	Maximum DB cache size.
db-cache-percent-full	Percentage of the cache used by the Data Store.
db-directory	Directory that holds the changelogDb file.
db-on-disk-size	Size of the DB on disk.
cleaner-backlog	Number of log files that must be cleaned for the cleaner to meet its target utilization.
random-read-count	Number of disk reads which required repositioning the disk head more than 1MB from the previous file position.
random-write-count	Number of disk writes which required repositioning the disk head by more than 1MB from the previous file position.
sequential-read-count	Number of disk reads which did not require repositioning the disk head more than 1MB from the previous file position.
sequential-write-count	Number of disk writes which did not require repositioning the disk head by more than 1MB from the previous file position.
nodes-evicted	Accumulated number of nodes evicted.
active-transaction-count	Number of currently active transactions.
num-checkpoints	Number of checkpoints. A checkpoint is a process that writes to your log files all the internal BTree nodes and structures modified as a part of write operations to your log files to facilitate a quick recovery.
checkpoint-in-progress: false	Indicates if a checkpoint is in progress.
total-checkpoint-duration-millis	Total time in milliseconds for all checkpoints.
average-checkpoint-duration-millis	Average time in milliseconds for all checkpoints.
last-checkpoint-duration-millis	Duration in milliseconds of the last checkpoint run.
last-checkpoint-start-time	Start time of the last checkpoint.
last-checkpoint-stop-time	Stop time of the last checkpoint.
millis-since-last-checkpoint	Time in milliseconds since the last checkpoint.
read-locks-held	Total read locks currently held.
write-locks-held	Total write locks currently held.
transactions-waiting-on-locks	Total transactions waiting for locks
je-env-stat-AdminBytes	Number of bytes of JE cache used for log cleaning metadata and other administrative structure.
je-env-stat-BufferBytes	Total memory currently consumed by log buffers, in bytes.
je-env-stat-CacheDataBytes	Total memory of cache used for data.
je-env-stat-CacheTotalBytes	Total amount of JE cache in use, in bytes.
je-env-stat-CleanerBacklog	Number of files to be cleaned to reach the target utilization.
je-env-stat-CursorsBins	Number of bottom internal nodes (BINs) encountered by the INCompressor that had cursors referring to them when the compressor ran. The compressor thread cleans up the internal BTree as records are deleted to ensure unused nodes are not present.
je-env-stat-DataBytes	Amount of JE cache used for holding data, keys and internal Btree nodes, in bytes.

Monitor Attribute	Description
je-env-stat-DbClosedBins	Number of bins encountered by the INCompressor that had their database closed between the time they were put on the compressor queue and when the compressor ran.
je-env-stat-EndOfLog	Location of the next entry to be written to the log.
je-env-stat-InCompQueueSize	Number of entries in the INCompressor queue when the getStats() call was made.
je-env-stat-LastCheckpointEnd	Location in the log of the last checkpoint end.
je-env-stat-LastCheckpointId	ID of the last checkpoint.
je-env-stat-lastCheckpointStart	Location in the log of the last checkpoint start.
je-env-stat-lockBytes	Number of bytes of JE cache used for holding locks and transactions.
je-env-stat-NBINsStripped	Number of BINS stripped by the evictor.
je-env-stat-NCacheMiss	Total number of requests for database objects which were not in memory.
je-env-stat-NCheckpoints	Total number of checkpoints run so far.
je-env-stat-NCleanerDeletions	Number of cleaner file deletions this session.
je-env-stat-NCleanerEntriesRead	Accumulated number of log entries read by the cleaner.
je-env-stat-NCleanerRuns	Number of cleaner runs this session.
je-env-stat-NClusterLNsProcessed	Accumulated number of leaf nodes (LNs) processed because they qualify for clustering.
je-env-stat-NDeltaINFlush	Accumulated number of delta internal nodes (INs) flushed to the log.
je-env-stat-NEvictPasses	Number of passes made to the evictor.
je-env-stat-NFSyncRequests	Number of fsyncs requested through the group commit manager. `Fsync()` synchronizes the filesystem after a write or a transaction.
je-env-stat-NFSyncTimeouts	Number of fsync requests submitted to the group commit manager which timed out.
je-env-stat-NFSyncs	Number of fsyncs issued through the group commit manager.
je-env-stat-NFileOpens	Number of times a log file has been opened.
je-env-stat-NFullBINFlush	Accumulated number of full bottom internal nodes (BINS) flushed to the log.
je-env-stat-NFullINFlush	Accumulated number of full INs flushed to the log.
je-env-stat-NINsCleaned	Accumulated number of INs cleaned.
je-env-stat-NINsDead	Accumulated number of INs that were not found in the tree anymore (deleted).
je-env-stat-NINsMigrated	Accumulated number of INs migrated.
je-env-stat-NINsObsolete	Accumulated number of INs obsolete.
je-env-stat-NLNQueueHits	Accumulated number of LNs processed without a tree lookup.
je-env-stat-NLNsCleaned	Accumulated number of LNs cleaned.
je-env-stat-NLNsDead	Accumulated number of LNs that were not found in the tree anymore (deleted).
je-env-stat-NLNsLocked	Accumulated number of LNs encountered that were locked.
je-env-stat-NLNsMarked	Accumulated number of LNs that were marked for migration during cleaning.
je-env-stat-NLNsMigrated	Accumulated number of LNs migrated.
je-env-stat-NLNsObsolete	Accumulated number of LNs obsolete.
je-env-stat-NLogBuffers	Number of log buffers currently instantiated.
je-env-stat-NMarkedLNsProcessed	Accumulated number of LNs processed because they were previously marked for migration.
je-env-stat-NNodesExplicitlyEvicted	Accumulated number of nodes evicted.

Monitor Attribute	Description
je-env-stat-NNodesScanned	Accumulated number of nodes scanned to select the eviction set.
je-env-stat-NNodesSelected	Accumulated number of nodes selected to evict.
je-env-stat-NNotResident	Number of requests for database objects not contained within the in memory data structures.
je-env-stat-NOpenFiles	Number of files currently open in the file cache.
je-env-stat-NPendingLNsLocked	Sccumulated number of pending LNs that could not be locked for migration because of a long duration application lock.
je-env-stat-NPendingLNsProcessed	Accumulated number of LNs processed because they were previously locked.
je-env-stat-NRandomReadBytes	Number of bytes read which required repositioning the disk head more than 1MB from the previous file position.
je-env-stat-NRandomReads	Number of disk reads which required repositioning the disk head more than 1MB from the previous file position.
je-env-stat-NRandomWriteBytes	Number of bytes written which required repositioning the disk head more than 1MB from the previous file position.
je-env-stat-NRandomWrites	Number of disk writes which required repositioning the disk head by more than 1MB from the previous file position.
je-env-stat-NRepeatFaultReads	Number of reads which had to be repeated when faulting in an object from disk because the read chunk size controlled by `je.log.faultReadSize` is too small.
je-env-stat-NRepeatIteratorReads	Number of times we try to read a log entry larger than the read buffer size and can't grow the log buffer to accommodate the large object.
je-env-stat-NRootNodesEvicted	Accumulated number of database root nodes evicted.
je-env-stat-NSequentialReadBytes	Number of bytes read which did not require repositioning the disk head more than 1MB from the previous file position.
je-env-stat-NSequentialReads	Number of disk reads which did not require repositioning the disk head more than 1MB from the previous file position.
je-env-stat-NSequentialWriteBytes	Number of bytes written which did not require repositioning the disk head more than 1MB from the previous file position.
je-env-stat-NSequentialWrites	Number of disk writes which did not require repositioning the disk head by more than 1MB from the previous file position.
je-env-stat-NSharedCacheEnvironments	Number of environments using the shared cache.
je-env-stat-NTempBufferWrites	Number of writes which had to be completed using the temporary marshalling buffer because the fixed size log buffers specified by `je.log.totalBufferBytes` and `je.log.numBuffers` were not large enough.
je-env-stat-NToBe-CleanedLNsProcessed	Accumulated number of LNs processed because they are soon to be cleaned.
je-env-stat-NonEmptyBins	Number of non-empty bins.
je-env-stat-ProcessedBins	Number of bins that were successfully processed by the INCompressor.
je-env-stat-RequiredEvictBytes	Number of bytes that must be evicted to get within the memory budget.
je-env-stat-SharedCacheTotalBytes	Total amount of the shared JE cache in use, in bytes.
je-env-stat-SplitBins	Number of bins encountered by the INCompressor that were split between the time they were put on the compressor queue and when the compressor ran.
je-env-stat-TotalLogSize	Approximation of the current total log size in bytes.
je-env-stat-NOwners	Total lock owners in the lock table.

Monitor Attribute	Description
je-env-stat-NReadLocks	Total read locks currently held.
je-env-stat-NRequests	Total number of lock requests to date.
je-env-stat-NTotalLocks	Total locks currently in the lock table.
je-env-stat-NWaiters	Total transactions waiting for locks.
je-env-stat-NWaits	Total number of lock waits to date.
je-env-stat-NWriteLocks	Total write locks currently held.
je-env-stat-LastCheckpointTime	Time of the last checkpoint.
je-env-stat-LastTxnId	Last transaction ID allocated.
je-env-stat-NAborts	Number of transactions that have aborted.
je-env-stat-NActive	Number of transactions that are currently active.
je-env-stat-NBegins	Number of transactions that have begun.
je-env-stat-NCommits	Number of transactions that have committed.
je-env-stat-NXAAborts	Number of XA transactions that have aborted.
je-env-stat-NXACommits	Number of XA transactions that have committed.
je-env-stat-NXAPrepares	Number of XA transactions that have been prepared.

Summary of the Replication Summary Monitor Information

The following table provides a description of the attributes in the `cn=Replication Summary` monitor entry.

```
dn: cn=Replication Summary <baseDN>,cn=monitor
```

Table 57: Replication Summary Monitor Information

Monitor Attribute	Description
base-dn:<baseDN>	Base DN summary.
replica: replica-id, ldap-server connected-to, generation-id, replication-backlog, recent-update-rate, peak-update-rate, age-of-oldest-backlog-change	Summary information for each replica in the topology. This entry appears for each replica in the topology with its own respective properties.
replication-server: server-id, server, generation-id, status, last-connected, last-failed, failed-attempts, attributes.	Summary information for each remote replication server only in the topology. This entry appears for each Replication Server in the topology with its own respective `serverID` and `server` properties.
update-queue: id, max-count, current-count, max-size, current-size, polling-source, polling-source-changed	Summary information for each update queue on a server: ➢ **id**. The ID of the receiving replica or replication server ➢ **max-count**. The maximum number of update messages that the sending replication server will keep in memory for the receiving replica or replication server. If the receiver cannot accept messages fast enough for any reason (high load, network latency, etc), then this queue will fill up. When that happens, the sending replication server will read update messages from the changelog backend. This slows down the update processing considerably. ➢ **current-count**. The number of update messages currently on the queue that have not been sent to the receiving replica or replication server.

Monitor Attribute	Description
	Every time the sending replication server sends an update to the receiving replica or replication server, this counter is decremented. ➢ **max-size**. The maximum total size (in bytes) of update messages that may be in the queue. This queue is capped by both the maximum count (`max-count`) and the `max-size` setting, whichever is reached first. ➢ **current-size**. The total size of update messages currently on the queue that have not been sent to the receiving replica or replication server. Every time the sending replication server sends an update to the receiving replica or replication server, this value is decremented by the size of the published update message. ➢ **polling-source**. Either 'memory' or 'db'. If set to 'memory', the sending replication server relies only on the in-memory queue to push update messages to the receiving replica or replication server. If set to 'db', update messages are read and sorted from the changelog database, which is significantly slower than publishing updates from the in-memory queue. ➢ **polling-source-changed**. The total number of times the polling-source attribute has changed value (either from 'db' to 'memory' or from 'memory' to 'db'). If this value changes very frequently, then the queue size setting is probably too low.

Summary of the replicationChanges Backend Monitor Information

The following table provides a description of the attributes in the `cn=replicationChanges Backend` monitor entry.

```
dn: cn=replicationChanges Backend,cn=monitor
```

Table 58: replicationChanges Backend Monitor Information

Monitor Attribute	Description
ds-backend-id	ID descriptor for the backend. Typically, this will be "replicationChanges".
ds-backend-base-dn	Base DN for the backend. Typically, this will be `cn=replicationChanges`.
ds-backend-is-private	Flag to indicate if the backend is private.
ds-backend-entry-count	Entry count for the backend.
ds-base-dn-entry-count	Entry count for the base DN and the specified base DN.
ds-backend-writability-mode	Flag to indicate if the backend is writable or not.

Summary of the Replication Protocol Buffer Monitor Information

The following table provides a description of the attributes in the `cn=Replication Protocol` Buffer monitor entry. The monitors provide information on the state of the buffer for protocol operations, which is kept in the local storage.

```
dn: cn=Replication Protocol Buffer,cn=monitor
```

Table 59: Replication Protocol Buffer Monitor Information

Monitor Attribute	Description
saved-buffers	Number of protocol buffers. Initial buffer size is 4k.
reallocations	Number of times the buffers had to be reallocated due to insufficient size.
large-buffer-creates	Number of times a buffer larger than 512k was requested.
large-buffer-evictions	Number of times a buffer was removed from the thread local storage, because it has grown above 512k.

Advanced Topics Reference

This chapter presents background reference information covering advanced replication topics.

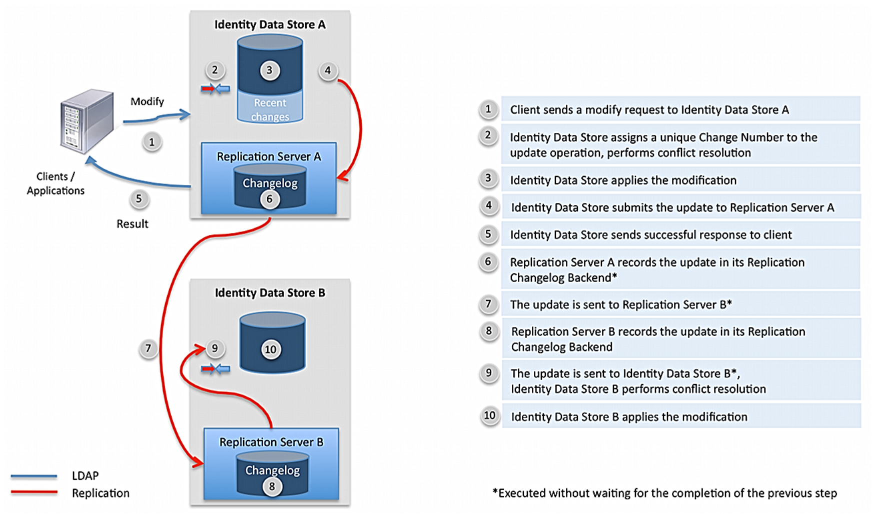
About the Replication Protocol

Replication communicates using a proprietary binary protocol that is implemented on top of the TCP/IP protocol using SSL encryption. Some protocol messages are used for administrative purposes (such as WAN Gateway server negotiation or flow control), some carry updates to replicated data, while others are directed to all servers for monitoring requests.

In a replicated topology, each participating Data Store is connected to every other server via the replication server port in order to monitor health. Servers which share the same location setting are also connected to rapidly replicate changes and lastly the WAN Gateway servers are all interconnected to replicate changes across locations.

Data Stores keep connections open as long as possible to reduce the communication latency when messages are exchanged. Heartbeat messages are transmitted on a regular basis to detect a network failure or an unresponsive data store as early as possible. Heartbeat messages also prevent idle connections from being closed by firewalls.

The following detailed communication flow will be used to describe major components of replication. This illustration is the expanded view of figure shown in the Overview section.



1 Client sends a modify request to Identity Data Store A

2 Identity Data Store assigns a unique Change Number to the update operation, performs conflict resolution

3 Identity Data Store applies the modification

4 Identity Data Store submits the update to Replication Server A

5 Identity Data Store sends successful response to client

6 Replication Server A records the update in its Replication Changelog Backend*

7 The update is sent to Replication Server B*

8 Replication Server B records the update in its Replication Changelog Backend

9 The update is sent to Identity Data Store B*, Identity Data Store B performs conflict resolution

10 Identity Data Store B applies the modification

*Executed without waiting for the completion of the previous step

Figure 17: Replication Communication Flow

Step 1. Client sends a Modify request to Data Store A.

Step 2. Data Store A assigns a unique change number to the operation. Conflict resolution is executed to see if the Modify request is in conflict with the existing attribute types or values in the existing entry. The change number is assigned before the Data Store backend is updated so that the arrival order of client requests can be preserved. Historical data in the target entry is updated to reflect the change. Note that historical data is only updated for ADD and MODIFY operations.

Step 3. Data Store applies the modifications in the corresponding backend.

Step 4. If the MODIFY operation successfully completes, then the Data Store will submit the update to its embedded *Replication Server*. The Replication Server is a component within the Data Store process responsible for propagating updates to and from the replication topology. The Data Store itself only communicates with a single replication server, whereas the replication server component is connected to all other replication servers. If the Data Store process exits unexpectedly and some updates have not been passed to the Replication Server, the backend has the ability to recover the last 50,000 recent changes that were processed at this server, guaranteeing that these changes can be replicated when the server starts up. The figure above also shows that replication protocol is used not just between replication servers but also between the Data Store and the Replication Server.

Step 5. The response is sent to the client. In this example, a successful response is assumed.

Step 6. The Replication Server records the update in its own Changelog backend (i.e., backend ID of `replicationChanges`) and on disk with the path to `changelogDb` under the server root. The Replication Changelog backend keeps track of updates at each and every Data Store in the replication topology. When a Data Store joins the replication topology after being disconnected for some reason, updates from the Replication Changelog backend are re-sent to this Data Store. Old records from the Replication Changelog backend are purged, which by default removes records older than 24 hours. If the backend does not contain all of the records that another Data Store needed when rejoining the replication topology, then the replicated data set in the Data Store must be re-initialized. In this case, the Data Store enters lockdown mode and an administrative alert is sent.

Step 7. The Replication Server submits the update to the replication server component in Data Store B. If there were more Data Stores in this example, the Replication Server would submit the update to all the other replication servers in the same location.

Step 8. Just like in Step 6, the Replication Server component receiving an update inserts the change into its Replication Changelog backend.

Step 9. The update is forwarded to the Replica in Data Store B. Conflict resolution is executed to see if the Modify request is in conflict with the existing attribute types or values in the existing entry.

Step 10. The Data Store applies the modification in the corresponding backend. The Recent Changes database is not updated, because only updates that originated at this Data Store are recorded in the Recent Changes database.

Change Number

As seen in the previous Figure, the Data Store assigns a unique change number to each update operation (specifically, ADD, DELETE, MODIFY, or MODIFY DN operations) to track each request when received from a client. The change number not only identifies each and every update, but it also allows ordering updates to the replicated data the same way on each Data Store. The change number is composed of the following multiple fields:

- **Timestamp** that identifies when the update was made. The timestamp is time-zone-independent and recorded with millisecond resolution.
- **Server ID** that uniquely identifies the Data Store where the update was made.
- **Sequence number** that defines the order of the updates received from external clients at a particular data store.

The replication protocol also sets a virtual clock that eliminates the need for synchronized time on servers. For troubleshooting purposes, however, it is still recommended to keep the system clocks synchronized.

Conflict Resolution

The eventual-consistency model employed in replication introduces a window where conflicting updates targeting the same entry may be applied at two different Data Stores. In general, two updates to the same Data Store are in conflict if the update that arrived later fails. Conflict resolution, when possible, corrects conflicts introduced by clients automatically. There are some exceptions, however, when manual administrative action is required. For example, adding an entry in one replica and deleting the parent of this entry on another replica simultaneously will introduce a conflict that requires manual action. In a carefully implemented deployment, the risk of introducing conflicts that require manual action can be significantly reduced or even eliminated.

The conflict resolution algorithm in the UnboundID Data Store uses a mechanism that orders all updates in the replication topology. Each update in the Data Store is assigned a unique change number. The change number is attached to each update propagated via replication and allows each Data Store to order updates exactly the same way.

Consider the following example that results in a conflict: add a single-valued attribute with different values to an entry concurrently at two Data Stores (shown in the figure below). It is easy to see that the second operation would fail if a client attempted to add the same attribute to the same entry at the same Data Store. In a replicated environment, the conflict is not immediately seen if these updates are applied concurrently at two different Data Stores. The conflict is handled only after replication propagates the updates. The Data Stores resolve the conflict independently of the other server. On one Data Store, the entry will be updated to reflect the correct value; on the other Data Store, the value will stay the same. As result, each Data Store will independently resolve the conflict the same way based on the ordering of the updates. This example is illustrated below:

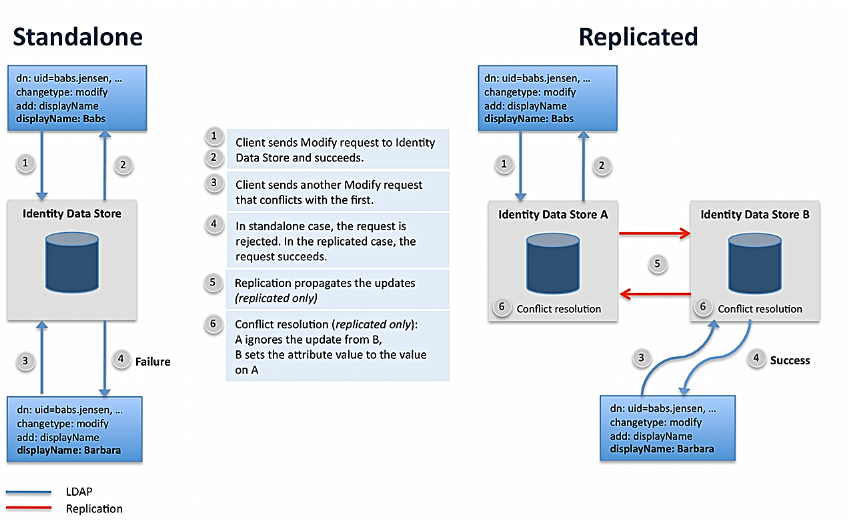

Standalone
Replicated
dn: uid=babs.jensen, …
changetype: modify
add: displayName
displayName: Babs
1
2
Identity Data Store
Identity Data Store A
Identity Data Store B
5
6 Conflict resolution
6 Conflict resolution
3
4 Failure
4 Success
dn: uid=babs.jensen, …
changetype: modify
add: displayName
displayName: Barbara
1 2 Client sends Modify request to Identity Data Store and succeeds.
3 Client sends another Modify request that conflicts with the first.
4 In standalone case, the request is rejected. In the replicated case, the request succeeds.
5 Replication propagates the updates (replicated only)
6 Conflict resolution (replicated only): A ignores the update from B, B sets the attribute value to the value on A
LDAP
Replication

Figure 18: Conflict Resolution Process Flow

WAN-Friendly Replication

Many multi-national corporations that have data centers in different countries must minimize latency over WAN to ensure acceptable performance for their client applications. To minimize WAN latency, the Data Store assigns one of two roles to the replication servers: the role of standard replication transmitting updates to the other co-located replication servers; the other role, a WAN-dedicated replication server designed to send updates to other WAN-designated replication servers in other locations. This two-role system minimizes WAN traffic by pushing all replication updates onto the connected replication servers that are designated as WAN Gateway Servers. Only the designated WAN Gateway Servers can transmit the update messages to other connected WAN Gateway servers at other locations.

WAN Gateway Server

The Data Store's replication mechanism relies on the server's location information to reduce protocol traffic on WAN links. During protocol negotiation, the replication server with the highest WAN Gateway priority (priority 1 indicates the highest priority) automatically assumes the role as the WAN Gateway Server for that particular location. The Gateway Server's main function is to route update messages from other non-gateway servers at the same location to remote WAN Gateway servers at other locations. Similarly, at the destination point, the replication server with the WAN Gateway role will receive update messages from other WAN gateway servers at other locations and push them out to all replication servers at the current location. This setup ensures that all WAN communication flows through the WAN Gateway Servers.

The figure below shows a basic connection configuration for updates. Keep in mind that all of the replication servers are fully connected to each other for monitoring or server negotiation purposes.

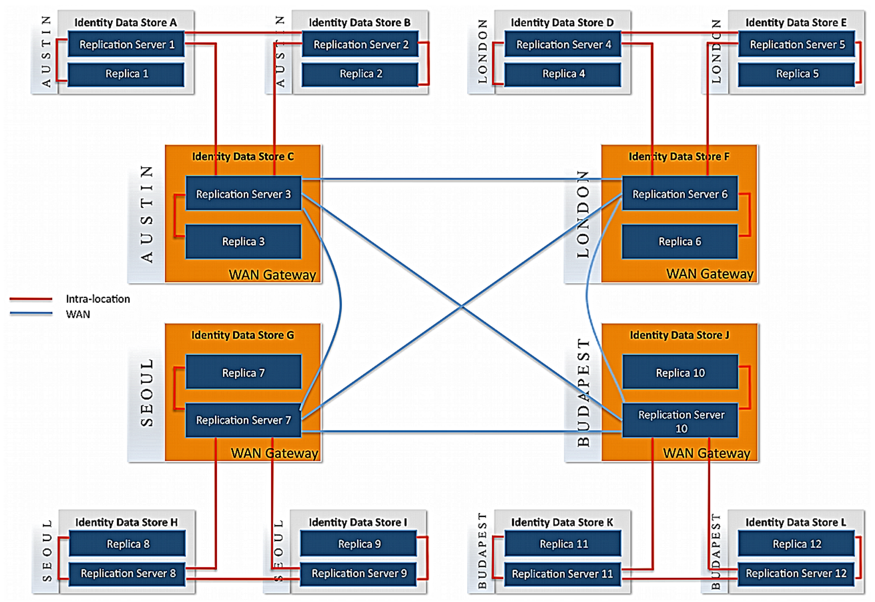


Figure 19: WAN Gateway Servers

If the WAN Gateway Server is temporarily unavailable due to a planned or unplanned downtime, the system will dynamically re-route updates to a newly designated WAN Gateway Server in the same location. The replication server with the next highest WAN Gateway priority number automatically assumes the WAN Gateway role. For deployments with entry-balancing proxy servers, there will be one WAN Gateway Server per data set.

By default, all servers are enabled to serve as WAN Gateways and all are set to priority 5, which is simply a way to make them all equal. If necessary, the WAN Gateway priority can be changed using `dsconfig` after replication has been enabled.

WAN Message Routing

Non-gateway replication servers forward update messages from replicas to co-located replication servers only. It is the responsibility of the WAN gateway server to forward these messages to WAN gateway servers at other locations. The figure below illustrates how an update message is routed from a non-gateway server to a remote location.

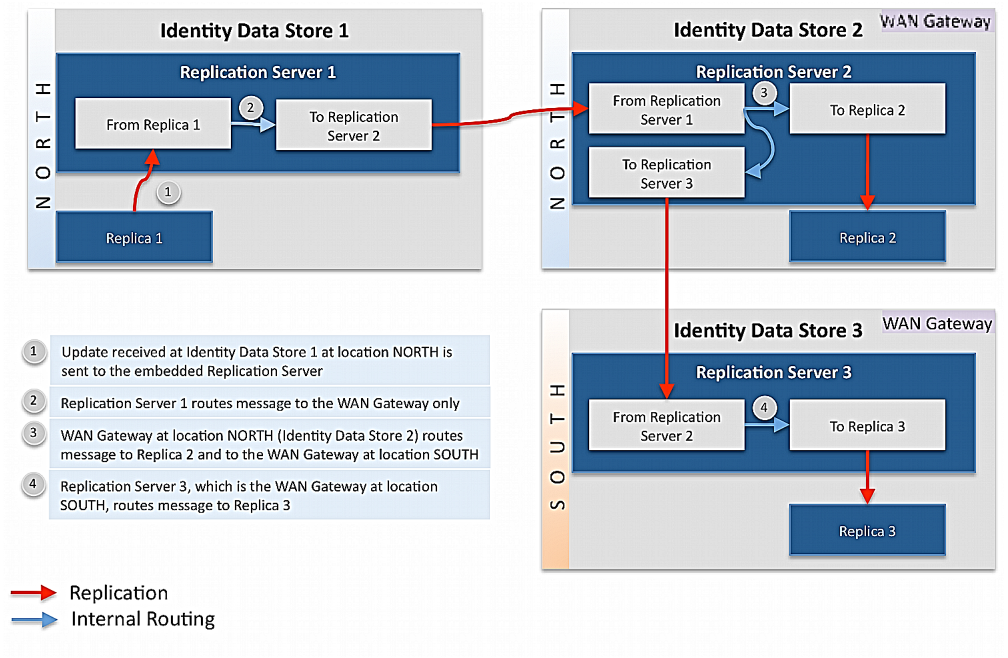

Identity Data Store 1
Replication Server 1
From Replica 1
To Replication Server 2
Replica 1
NORTH
Identity Data Store 2
WAN Gateway
Replication Server 2
From Replication Server 1
To Replica 2
To Replication Server 3
Replica 2
NORTH
Identity Data Store 3
WAN Gateway
Replication Server 3
From Replication Server 2
To Replica 3
Replica 3
SOUTH
1 Update received at Identity Data Store 1 at location NORTH is sent to the embedded Replication Server
2 Replication Server 1 routes message to the WAN Gateway only
3 WAN Gateway at location NORTH (Identity Data Store 2) routes message to Replica 2 and to the WAN Gateway at location SOUTH
4 Replication Server 3, which is the WAN Gateway at location SOUTH, routes message to Replica 3
Replication
Internal Routing

Figure 20: WAN Message Routing

WAN Gateway Server Selection

The WAN Gateway role is dynamically assigned to the most suitable server in a particular location. In most cases, the replication server with the higher WAN Gateway priority (e.g., priority 1 indicates the highest priority) assumes this role.

A replication server will not attempt to become a WAN Gateway if any of the following conditions exists:

- The WAN Gateway priority is set to 0
- The replication server is backlogged at server startup
- The current WAN Gateway has higher priority
- The WAN Gateway has not been elected yet, but higher priority replication servers are present in the location

The currently active WAN Gateway server will give up the gateway role in the following cases:

- The server has started the shutdown process
- The server is preparing for a scheduled maintenance cycle
- The server learns about a higher priority replication server in its location

Replication servers send WAN Gateway information to other servers at regular intervals using the replication protocol. This allows the replication servers to take the appropriate action, for example, to become a WAN Gateway, if necessary without any manual administrative action.

WAN Replication in Mixed-Version Environments

WAN Gateway Role assignment is only available on UnboundID Data Stores version 3.5 or later. Legacy servers (i.e., pre-3.5) will never be selected as WAN Gateways. Updates from legacy replication servers are forwarded to all replication servers and not funneled to a single WAN Gateway. Also, updates from remote WAN Gateways will be forwarded to the legacy replication servers. Both of these actions will effectively increase WAN traffic during replication.

Recovering a Replication Changelog

In the event that the replication changelog is compromised (`<server-root>/changelogDb`), possibly due to a disk or NAS failure, perform the following steps.

1. Stop the server.

2. Backup `replicationChanges` from a remote server with the following command:

```
$ bin/backup --backupDirectory /app/backups/replicationChanges \
  --backendID replicationChanges
```

3. Copy the `replicationChanges` backup from the remote server and restore it on the local host as follows:

```
$ bin/restore --backupDirectory /app/tmp/replicationChanges
```

4. Start the server.

Disaster Recovery

In the event that data is compromised across all systems and a restore is necessary, perform the following steps. These steps assume that no read or write operations are performed by any servers during this process.

1. Stop all servers.

2. Run the following command on all servers:

```
$ /bin/dsreplication cleanup-local-server
```

3. Locate the backup or exported LDIF file that represents the last working copy of the database.

4. Restore the backup or import the LDIF file on a single server. If importing an LDIF file, use the `--excludeReplication` option with the `import-ldif` command.

5. Start the restored server. The server can now receive client requests.

6. Start another server in lockdown mode with the following command:

```
$ start-ds --skipPrime --lockdownMode
```

7. Enable replication from the first server to the second server.

8. Initialize the second server from the first with the following command:

```
$ bin/dsreplication initialize
```

9. Restart the second server or use the `bin/leave-lockdown-mode` command to leave the server in lockdown mode. The second server can now receive client requests.

10. Repeat steps 6 through 9 for any other servers.

Chapter 21 Managing Logging

The UnboundID Data Store supports a rich set of log publishers to monitor access, debug, and error messages that occur during normal server processing. Administrators can view the standard set of default log files as well as configure custom log publishers with pre-defined filtering with its own log rotation and retention policies.

This chapter presents the following information:

Topics:

Default Data Store Logs

The Data Store provides a standard set of default log files to monitor the server activity. You can view this set of logs in the `UnboundID-DS/logs` directory. The following default log files are available on the Data Store and are presented below.

Table 60: Directory Server Logs

Log File	Description
access	File-based Access Log that records operations processed by the Data Store. Access log records can be used to provide information about problems during operation processing (for example, unindexed searches, failed requests, etc.), and provide information about the time required to process each operation.
change-notifications.log	Records changes to data anywhere in the server, which match one or more configured change subscriptions.
config-audit.log	Records information about changes made to the Data Store configuration in a format that can be replayed using the `dsconfig` tool
errors	File-based Error Log. Provides information about warnings, errors, and significant events that occur during server processing.
expensive-ops	Expensive Operations Log. Disabled by default. Provides only those operations that took longer than 1000 milliseconds to complete.
failed-ops	Failed Operations Log. Provides information on all operations that failed in single-line log format.
replication	Records any replication errors and publishes them to the filesystem.
searches-returning-no-entries	Searches Returning No Entries Log. Disabled by default. Provides information only on operations that did not return any entries.
server.out	Records anything written to standard output or standard error, which includes startup messages. If garbage collection debugging is enabled, then the information will be written to server.out.
server.pid	Stores the server's process ID.
server.status	Stores the timestamp, a status code, and an optional message providing additional information on the server status.
setup.log	Records messages that occur during the initial configuration of a Data Store with the `setup` tool.
tools	Directory that holds logs for long running utilities: `import-ldif`, `export-ldif`, `backup`, `restore`, `verify-index`. Current and previous copies of the log are present in the Data Store.
update.log	Records messages that occur during a Data Store update.

Types of Log Publishers

The UnboundID Data Store provides several classes of log publishers for parsing, aggregating, and filtering information events that occur during normal processing in the server. There are three primary types of Log Publishers: access logs, debug logs, and error logs. Each type has multiple subtypes of log files based on the log server type:

Table 61: Types of Log Publishers

Log Publisher Type	Description	
Access	Provides the requests received and responses returned by the Data Store. The information can be used to understand the operations performed by clients and to debug problems with the client applications. It can also be used for collecting usage information for performance and capacity planning purposes. There are tools described later that can analyze the access log to provide summaries of the LDAP activity and performance.	
	File-based Audit Log	Special type of access logger that provides detailed information about changes processed within the server. Disabled by default.
	JDBC-based Access Log	Stores access log information using a JDBC database connection. Disabled by default.
	File-based Access Logs	Provides a character-based stream used by TextWriter Publishers as a target for outputting log records. There are six types of file-based loggers: • **Admin Alert Access Log**. Generates administrative alerts for any operations that match the criteria for this access logger. Disabled by default. • **File-based Access Log**. Publishes access log messages to the filesystem. Enabled by default. • **Syslog-based Access Log**. Publishes access log messages to a syslogd port. Disabled by default. • **Expensive-Operations Access Log**. Publishes only those access log messages of operations that take longer than 1000 milliseconds. Disabled by default. • **Failed-Operations Access Log**. Publishes only those access log messages of operations that failed for any reason. Enabled by default. • **Successful Searches with No Entries Returned Log**. Publishes only those access log messages of search operations that failed to return any entries. Disabled by default.
Debug	Provides information about warnings, errors, or significant events that occur within the server.	
	Debug ACI Logger	Stores debug information on ACI evaluation for any request operations against the server
	File-based Error Logs	There are two types of File-based Error Logs: • **Error log**. Publishes error messages to the filesystem. Enabled by default. • **Replication log**. Publishes replication error messages to the filesystem. Enabled by default.
	JDBC-based Error Logs	Stores error log information using a JDBC database connection. Disabled by default.
	Syslog-based Error Logs	Publishes error messages to a syslogd port.

Viewing the List of Log Publishers

You can quickly view the list of log publishers on the Data Store using the `dsconfig` tool.

Note: Initially, the JDBC, syslog, and Admin Alert log publishers must specifically be configured using `dsconfig` before they appear in the list of log publishers. Procedures to configure these types of log publishers appear later in this chapter.

To View the List of Log Publishers

- Use `dsconfig` to view the log publishers.

```
$ bin/dsconfig list-log-publishers

Log Publisher                              : Type               : enabled
-------------------------------------------:--------------------:--------
Debug ACI Logger                           : debug-access       : false
Expensive Operations Access Logger         : file-based-access  : false
Failed Operations Access Logger            : file-based-access  : true
File-Based Access Logger                   : file-based-access  : true
File-Based Audit Logger                    : file-based-audit   : false
File-Based Debug Logger                    : file-based-debug   : false
File-Based Error Logger                    : file-based-error   : true
Replication Repair Logger                  : file-based-error   : true
Successful Searches with No Entries Returned : file-based-access : false
```

Enabling or Disabling a Default Log Publisher

You can enable or disable any log publisher available on the Data Store using the `dsconfig` tool. By default, the following loggers are disabled and should be enabled only when troubleshooting an issue on the server:

- ➢ Expensive Operations Access Logger
- ➢ File-Based Audit Logger
- ➢ File-Based Debug Logger
- ➢ Successful Searches with No Entries Returned

To Enable a Default Access Log

- Use `dsconfig` to enable an Access Log Publisher. In this example, enable the Expensive-Ops log, which will record only those access log messages that take 1000 milliseconds or longer.

```
$ bin/dsconfig set-log-publisher-prop \
  --publisher-name "Expensive Operations Access Logger" --set enabled:true
```

Managing Access and Error Log Publishers

The Access Log records every request received and response returned by the Data Store. The Access Log stores the IDs for the client connection, operation, the LDAP message involved with each client request, and the server response. The information can be used to debug any problems with a client application by correlating the numeric operation identifier to the client request or response.

The Data Store supports multiple classes of access log publishers depending on your logging requirements. The following types of access log publishers are available on the system:

- **File-Based Access Log Publishers**. Provides a character-based TextWriter stream for outputting log records. There are three subclasses of TextWriter access logs:
    - **File-Based Access Logs**. Enabled by default. The File-based Access Log publishes access messages to the filesystem as `<server-root>/logs/access`. The Failed-Operations Log, Expensive-Operations Log, and the Searches with No Entries Returned Log are specialized types of the File-Based Access Log and shows only specific information necessary for troubleshooting purposes.
    - **Admin-Alert Access Logs**. Disabled by default. The Admin-Alert Access Log is specialized type of logger that automatically generates administrative alerts for any operations that match a criteria for this access log publisher.
    - **Syslog-Based Access Logs**. Disabled by default. The Syslog Access Log publishes access messages to a syslogd port.
- **File-Based Audit Logs**. Disabled by default. The Audit Log provides detailed information about modifications (writes) processed within the Data Store. The File-based Audit Log publishes access messages to the filesystem as `<server-root>/logs/audit`.
- **JDBC-Based Access Logs**. Disabled by default. The JDBC-based Access Log provides information using a JDBC database connection.
- **JDBC-Based Error Logs**. Disabled by default. The JDBC-based Error Log provides information using a JDBC database connection.

Managing File-Based Access Log Publishers

The UnboundID Data Store supports a flexible and configurable Access Logging system that provides a full set of customized components to meet your system’s logging requirements. The default Access Log can be configured to write information to a log file with two records per operation, one for the request received and one for the response returned. It can also be configured to write one message per operation or configured to record information about a subset of operations processed by the server. In addition to modifying existing default log files, you can create custom log publishers to monitor specific properties or connection criteria. For more information, see *Creating New Log Publishers*.

The Data Store can be configured to use multiple access log publishers writing logs to different files using different configurations. This approach makes it possible to have fine-grained logging for various purposes (for example, a log that contains only failed operations, a log that contains only operations requested by root users, or a log that contains only operations that took longer than 20ms to complete).

The Data Store provides an additional mechanism to filter access logs to record only a subset of messages of one or more types. The access log filtering mechanism uses the operation criteria (connection, request, result, search-entry, search-reference) to determine whether a given message should be logged based on information associated with the client connection as well as information in the operation request/response messages. For more information, see *Configuring Filtered Logging*.

Access Log Format

The Access Log has a standard format that lists various elements identifying the connection and operation occurring within the Data Store. By default, each operation generates one access log message.

The Access Log displays the following common properties:

- **Timestamp**. Displays the date and time of the operation. Format: DD/Month/YYYY:HH:MM:SS <offset from UTC time>
- **Connection Type**. Displays the connection type requested by the client and the response by the server. Examples include the following:
  - CONNECT
  - BIND REQUEST/RESULT
  - UNBIND REQUEST
  - DISCONNECT
  - SEARCH REQUEST/RESULT
  - MODIFY REQUEST/RESPONSE
  - others include: ABANDON, ADD, COMPARE, DELETE, EXTENDED OPERATION, MODIFY, MODIFY DN
- **Connection ID**. Numeric identifier, starting incrementally with 0, that identifies the client connection that is requesting the operation. The connection ID is unique for a span of time on a single server. Values of the connection ID will be re-used when the server restarts or when it has had enough connections to cause the identifier to wrap back to zero.
- **Operation ID**. Numeric identifier, starting incrementally with 0, that identifies the operation. The operation ID is unique for a span of time on a single server. Values of the operation ID will be re-used when the server restarts or when it has serviced enough operations to cause the identifier to wrap back to zero.
- **Result Code**. LDAP result code that determines the success or failure of the operation result. Result messages include a result element that indicates whether the operation was successful or if failed, the general category for the failure, and an etime element that indicates the length of time in milliseconds that the server spent processing the operation.

  The Data Store provides a useful tool `<server-root>/bin/ldap-result-code` (UNIX, Linux) or `<server-root>\bat\ldap-result-code` (Windows), that displays all of the result codes used in the system. You can use the utility if you are not sure what a result code means. For example, use the following:

- `ldap-result-code --list` displays all of the defined result codes in the Data Store.
- `ldap-result-code --int-value 16654` displays the name of the result code with a numeric value of 16654.
- `ldap-result-code --search operation` displays a list of all result codes whose name includes the substring "operation".

- **Elapsed Time**. Displays the elapsed time (milliseconds) during which the operation completed its processing.
- **Message ID**. Numeric identifier, starting incrementally with 1, which identifies the LDAP message used to request the operation.

Access Log Example

The following example shows output from the Access Log in `<server-root>/logs/access`:

```
[01/Jun/2011:14:48:17 -0500] CONNECT conn=0 from="10.8.1.243" to="10.8.1.243"
 protocol="LDAP"
[01/Jun/2011:14:48:17 -0500] BIND REQUEST conn=0 op=0 msgID=1 version="3"
 dn="cn=Directory Manager"
  authType="SIMPLE"
[01/Jun/2011:14:48:17 -0500] BIND RESULT conn=0 op=0 msgID=1 resultCode=0 etime=26.357
  authDN="cn=Directory Manager,cn=Root DNs,cn=config"
[01/Jun/2011:14:48:17 -0500] UNBIND REQUEST conn=0 op=1 msgID=2
[01/Jun/2011:14:48:17 -0500] DISCONNECT conn=0 reason="Client Unbind"
... (more output) ...
```

Modifying the Access Log Using dsconfig Interactive Mode

The File-Based Access Log can be modified to include or exclude all log messages of a given type using the `dsconfig` tool in interactive or non-interactive mode.

To Modify the Access Log Using dsconfig Interactive Mode

1. Use `dsconfig` in interactive mode to modify the access log properties.

   ```
   $ bin/dsconfig
   ```

2. Follow the prompts to specify the LDAP connection parameters for host name or IP address, connection type (LDAP, SSL, or StartTLS), port number, bind DN and password.
3. On the Data Store **Configuration Console main** menu, type the number corresponding to the Log Publisher.
4. On the **Log Publisher Management** menu, enter the option to view and edit an existing log publisher.
5. On the **Log Publisher** menu, type the number corresponding to File-based Access Logger.

6. On the **File-Based Access Log Publisher** menu, type the number corresponding to the property that you want to change, and then follow the prompts.

7. Type `f` to apply the changes.

Modifying the Access Log Using dsconfig Non-Interactive Mode

You can use the `dsconfig` tool in non-interactive mode to quickly modify a log publisher property on the command line or in a script. For information on each property, see the *Data Store Configuration Reference Guide*, which is an HTML document listing the various properties for each Data Store component.

To Modify the Access Log Using dsconfig Non-Interactive Mode

- Use `dsconfig` with the `--no-prompt` option with the properties that you want to modify or set for your access log. In this example, enable the properties to include the instance name and startup ID.

```
$ bin/dsconfig set-log-publisher-prop --publisher-name "File-Based Access Logger" \
  --set include-instance-name:true --set include-startup-id:true
```

Modifying the Maximum Length of Log Message Strings

By default, the Data Store sets the maximum length of log message strings to 2000 characters. This value is configurable for any access log publisher, except the Syslog publisher, which is set to 500 characters. You can change the maximum length of log message strings by setting the `max-string-length` configuration property. If any string has more than the configured number of characters, then that string will be truncated and a placeholder will be appended to indicate the number of remaining characters in the original string.

To Modify the Maximum Length of Log Message Strings

- Use `dsconfig` to set the `max-string-length` property for an access log. The following command configures the "File-based Access Logger" to include the instance name and the maximum length of the log message strings to 5000 characters.

```
$ bin/dsconfig set-log-publisher-prop \
  --publisher-name "File-Based Access Logger" \
  --set include-instance-name:true \
  --set max-string-length:5000
```

Generating Access Logs Summaries

The Data Store provides a convenience tool, `summarize-access-log`, that generates a summary of one or more file-based access logs. The summary provides analytical metric information that could be useful for administrators. The following metrics are provided in each summary:

- Total time span covered by the log files.
- Number of connections established and the average rate of new connections per second.
- IP addresses of up to the top 20 of the clients that most frequently connect to the server, the number of connections by each address, and the percentage of connections of each.
- Total number of operations processed, the number of operations of each type, the percentage of each type out of the total number, and the average rate per second for each type of operation.
- Average processing time for all operations and for each type of operation.
- Histogram of the processing times for each type of operation.
- Up to the 20 most common result codes for each type of operation, the number of operations of that type with that result code, and the percentage of operations of that type with that result code.
- Number of unindexed searches processed by the server.
- Breakdown of the scopes used for search operations with the number of percentage of searches with each scope.
- Breakdown of the most common entry counts for search operations with the number and percentage of searches that returned that number of entries.
- Breakdown of the most commonly used filter types for searches with a scope other than "base" (that is, those searches for which the server will use es when processing the filter). These filters will be represented in a generic manner so that any distinct assertion values or substring assertion elements will be replaced with question marks and attribute names in all lowercase characters (for example, `(givenName=John)` would be represented as `(givenName=?)`).

To Generate an Access Log Summary

- Use the `bin/summarize-access-log` with path to one or more access log files.

```
$ bin/summarize-access-log /path/to/logs/access
```

```
Examining access log /path/to/logs/access Examined 500 lines in 1 file covering a
 total duration of 1 day, 22 hours, 57 minutes, 31 seconds

Total connections established: 69 (0.000/second)
Total disconnects: 69 (0.000/second)

Most common client addresses:
127.0.0.1: 61 (88.406)
10.8.1.209: 8 (11.594)

Total operations examined: 181 ...
(metric for each operation examined) ...

Average operation processing duration: 22.727ms
Average add operation processing duration: 226.600ms
Average bind operation processing duration: 5.721ms
Average delete operation processing duration: 77.692ms
Average modify operation processing duration: 35.530ms
Average search operation processing duration: 4.017ms

Count of add operations by processing time:
```

```
... (histogram for add operations) ...

Count of bind operations by processing time:
... (histogram for bind operations) ...

Count of delete operations by processing time:
... (histogram for delete operations) ...

Count of modify operations by processing time:
... (histogram for modify operations) ...

Count of search operations by processing time:
... (histogram for search operations) ...

Most common add operation result codes:
success: 11 (84.615%)
entry already exists: 2 (15.385%)

Most common bind operation result codes:
success: 4 (50.000%)
invalid credentials: 4 (50.000%)

Most common delete operation result codes:
success: 1 (100.000%)

Most common modify operation result codes:
success: 9 (69.231%)
no such object: 4 (30.769%)

Most common search operation result codes:
success: 133 (91.724%)
no such object: 12 (8.276%)

Number of unindexed searches: 0

Most common search scopes:
BASE: 114 (78.621%)
SUB: 16 (11.034%)
ONE: 15 (10.345%)

Most common search entry counts:
1: 119 (82.069%)
0: 17 (11.724%)
2: 5 (3.448%)
10: 4 (2.759%)

Most common generic filters for searches with a non-base scope:
(objectclass=?): 19 (61.290%)
(ds-backend-id=?): 12 (38.710%)
```

About Log Compression

The Data Store supports the ability to compress log files as they are written. This feature can significantly increase the amount of data that can be stored in a given amount of space, so that log information can be kept for a longer period of time.

Because of the inherent problems with mixing compressed and uncompressed data, compression can only be enabled at the time the logger is created. Compression cannot be turned on or off once the logger is configured. Further, because of problems in trying to append to an existing compressed file, if the server encounters an existing log file at startup, it will rotate that file and begin a new one rather than attempting to append to the previous file.

Compression is performed using the standard gzip algorithm, so compressed log files can be accessed using readily-available tools. The `summarize-access-log` tool can also work directly on compressed log files, rather than requiring them to be uncompressed first. However, because it can be useful to have a small amount of uncompressed log data available for troubleshooting purposes, administrators using compressed logging may wish to have a second logger defined that does not use compression and has rotation and retention policies that will minimize the amount of space consumed by those logs, while still making them useful for diagnostic purposes without the need to uncompress the files before examining them.

You can configure compression by setting the `compression-mechanism` property to have the value of "gzip" when creating a new logger.

About Log Signing

The Data Store supports the ability to cryptographically sign a log to ensure that it has not been modified in any way. For example, financial institutions require audit logs for all transactions to check for correctness. Tamper-proof files are therefore needed to ensure that these transactions can be propertly validated and ensure that they have not been modified by any third-party entity or internally by unscrupulous employees. You can use the `dsconfig` tool to enable the `sign-log` property on a Log Publisher to turn on cryptographic signing.

When enabling signing for a logger that already exists and was enabled without signing, the first log file will not be completely verifiable because it still contains unsigned content from before signing was enabled. Only log files whose entire content was written with signing enabled will be considered completely valid. For the same reason, if a log file is still open for writing, then signature validation will not indicate that the log is completely valid because the log will not include the necessary "end signed content" indicator at the end of the file.

To validate log file signatures, use the `validate-file-signature` tool provided in the `bin` directory of the server (or the `bat` directory for Windows systems).

Once you have enabled this property, you must disable and then re-enable the Log Publisher for the changes to take effect.

To Configure Log Signing

1. Use `dsconfig` to enable log signing for a Log Publisher. In this example, set the `sign-log` property on the File-based Audit Log Publisher.

```
$ bin/dsconfig set-log-publisher-prop --publisher-name "File-Based Audit Logger" \
  --set sign-log:true
```

2. Disable and then re-enable the Log Publisher for the change to take effect.

```
$ bin/dsconfig set-log-publisher-prop --publisher-name "File-Based Audit Logger" \
  --set enabled:false
$ bin/dsconfig set-log-publisher-prop --publisher-name "File-Based Audit Logger" \
  --set enabled:true
```

To Validate a Signed File

The Data Store provides a tool, `validate-file-signature`, that checks if a file has not been tampered with in any way.

- Run the `validate-file-signature` tool to check if a signed file has been tampered with. For this example, assume that the `sign-log` property was enabled for the File-Based Audit Log Publisher.

```
$ bin/validate-file-signature --file logs/audit
```

```
All signature information in file 'logs/audit' is valid
```

Note: If any validations errors occur, you will see a message similar to the one as follows:

```
One or more signature validation errors were encountered
while validating the contents of file 'logs/audit':
* The end of the input stream was encountered without
  encountering the end of an active signature block.
  The contents of this signed block cannot be trusted
  because the signature cannot be verified
```

Creating New Log Publishers

The UnboundID Data Store provides customization options to help you create your own log publishers with the `dsconfig` command.

When you create a new log publisher, you must also configure the log retention and rotation policies for each new publisher. For more information, see Configuring Log Rotation and Configuring Log Retention.

To Create a New Log Publisher

1. Use the `dsconfig` command in non-interactive mode to create and configure the new log publisher. This example shows how to create a logger that only logs disconnect operations.

```
$ bin/dsconfig create-log-publisher \
  --type file-based-access --publisher-name "Disconnect Logger" \
  --set enabled:true \
  --set "rotation-policy:24 Hours Time Limit Rotation Policy" \
  --set "rotation-policy:Size Limit Rotation Policy" \
  --set "retention-policy:File Count Retention Policy" \
  --set log-connects:false \
  --set log-requests:false --set log-results:false \
  --set log-file:logs/disconnect.log
```

Note: To configure compression on the logger, add the option to the previous command:

```
--set compression-mechanism: gzip
```

Compression cannot be disabled or turned off once configured for the logger. Therefore, careful planning is required to determine your logging requirements including log rotation and retention with regards to compressed logs.

2. If needed, view log publishers with the following command:

```
$ bin/dsconfig list-log-publishers
```

To Create a Log Publisher Using dsconfig Interactive Command-Line Mode

1. On the command line, type `bin/dsconfig`.
2. Authenticate to the server by following the prompts.
3. On the Configuration Console main menu, select the option to configure the log publisher.
4. On the **Log Publisher Management** menu, select the option to create a new log publisher.
5. Select the Log Publisher type. In this case, select **File-Based Access Log Publisher**.
6. Type a name for the log publisher.
7. Enable it.
8. Type the path to the log file, relative to the Data Store root. For example, `logs/disconnect.log`.
9. Select the rotation policy you want to use for your log publisher.
10. Select the retention policy you want to use for your log publisher.
11. On the Log Publisher Properties menu, select the option for `log-connects:false`, `log-disconnects:true`, `log-requests:false`, and `log-results:false`.
12. Type `f` to apply the changes.

Configuring Log Rotation

The Data Store allows you to configure the log rotation policy for the server. When any rotation limit is reached, the Data Store rotates the current log and starts a new log. If you create a new log publisher, you must configure at least one log rotation policy.

You can select the following properties:

- **Time Limit Rotation Policy**. Rotates the log based on the length of time since the last rotation. Default implementations are provided for rotation every 24 hours and every 7 days.
- **Fixed Time Rotation Policy**. Rotates the logs every day at a specified time (based on 24-hour time). The default time is 2359.
- **Size Limit Rotation Policy**. Rotates the logs when the file reaches the maximum size for each log. The default size limit is 100 MB.
- **Never Rotate Policy**. Used in a rare event that does not require log rotation.

To Configure the Log Rotation Policy

- Use `dsconfig` to modify the log rotation policy for the access logger.

```
$ bin/dsconfig set-log-publisher-prop \
  --publisher-name "File-Based Access Logger" \
  --remove "rotation-policy:24 Hours Time Limit Rotation Policy" \
  --add "rotation-policy:7 Days Time Limit Rotation Policy"
```

Configuring Log Retention

The Data Store allows you to configure the log retention policy for each log on the server. When any retention limit is reached, the Data Store removes the oldest archived log prior to creating a new log. Log retention is only effective if you have a log rotation policy in place. If you create a new log publisher, you must configure at least one log retention policy.

- **File Count Retention Policy**. Sets the number of log files you want the Data Store to retain. The default file count is 10 logs. If the file count is set to 1, then the log will continue to grow indefinitely without being rotated.
- **Free Disk Space Retention Policy**. Sets the minimum amount of free disk space. The default free disk space is 500 MBytes.
- **Size Limit Retention Policy**. Sets the maximum size of the combined archived logs. The default size limit is 500 MBytes.
- **Custom Retention Policy**. Create a new retention policy that meets your Data Store’s requirements. This will require developing custom code to implement the desired log retention policy.
- **Never Delete Retention Policy**. Used in a rare event that does not require log deletion.

To Configure the Log Retention Policy

- Use `dsconfig` to modify the log retention policy for the access logger.

```
$ bin/dsconfig set-log-publisher-prop \
  --publisher-name "File-Based Access Logger" \
  --set "retention-policy:Free Disk Space Retention Policy"
```

Configuring Filtered Logging

The UnboundID Data Store provides a mechanism to filter access log messages based on specific criteria. The filtered log can then be used with a custom log publisher to create and to generate your own custom logs. Adding new filtered logs and associate publishers does not change the behavior of any existing logs. For example, adding a new log that only contains operations that were unsuccessful does not result in those operations being removed from the default access log.

The following example shows how to create a set of criteria that matches any operation that did not complete successfully. It then explains how to create a custom access log publisher that logs only operations matching that criteria. Note that this log does not include messages for connects or disconnects, and only a single message is logged per operation. This message contains both the request and result details.

To run log filtering based on any operation result (for example, result code, processing time, and response controls), turn off request logging and set the `include-request-details-in-result-messages` property to TRUE. Since filtering based on the results of an operation cannot be done until the operation completes, the server has no idea whether to log the request. Therefore, it might log request messages but not log any result messages. Instead, if you can only log result messages and include request details in the result messages, then only messages for operations that match the result criteria are logged. All pertinent information about the corresponding requests are included.

To Configure a Filtered Log Publisher

1. Use the `dsconfig` command in non-interactive mode to create a result criteria object set to failure-result-codes, a predefined set of result codes that indicate when an operation did not complete successfully.

```
$ bin/dsconfig create-result-criteria --type simple \
  --criteria-name "Failed Operations" --set result-code-criteria:failure-result-codes
```

2. Use `dsconfig` to create the corresponding log publisher that uses the result criteria. The log rotation and retention policies are also set with this command.

```
$ bin/dsconfig create-log-publisher \
  --type file-based-access \
  --publisher-name "Filtered Failed Operations" \
  --set enabled:true \
  --set log-connects:false \
  --set log-disconnects:false \
  --set log-requests:false \
  --set "result-criteria:Failed Operations" \
  --set log-file:logs/failed-ops.log \
  --set include-request-details-in-result-messages:true \
  --set "rotation-policy:7 Days Time Limit Rotation Policy" \
  --set "retention-policy:Free Disk Space Retention Policy"
```

3. View the `failed-ops.log` in the `logs` directory. Verify that only information about failed operations is written to it.

Managing Admin Alert Access Logs

Admin Alert Access Logs are a specialized form of filtered log that automatically generates an administrative alert when criteria configured for the log publisher matches those messages in the access log.

About Access Log Criteria

Configuring an Admin Alert Access Log requires that you configure the criteria for the access log messages. Each criteria can be either a Simple or an Aggregate type. The Simple type uses the set of properties for the client connection, operation request, and the contents of any operation-specific requests or results. The Aggregate type provides criteria that contains Boolean combination of other operation-specific criteria objects. For more information, see the *UnboundID Data Store Configuration Reference*.

The criteria can be one or more of the following:

- **Connection Criteria**. Defines sets of criteria for grouping and describing client connections based on a number of properties, including protocol, client address, connection security, and authentication state.
- **Request Criteria**. Defines sets of criteria for grouping and describing operation requests based on a number of properties, including properties for the associated client connection, the type of operation, targeted entry, request controls, target attributes, and other operation-specific terms.
- **Result Criteria**. Defines sets of criteria for grouping and describing operation results based on a number of properties, including the associated client connection and operation request, the result code, response controls, privileges missing or used, and other operation-specific terms.
- **Search Entry Criteria**. Defines sets of criteria for grouping and describing search result entries based on a number of properties, including the associated client connection and operation request, the entry location and contents, and included controls.
- **Search Reference Criteria**. Defines sets of criteria for grouping and describing search result references based on a number of properties, including the associated client connection and operation request, reference contents, and included controls.

Configuring an Admin Alert Access Log Publisher

Prior to configuring an Admin Alert Access Log, you must establish an administrative alert handler in your system. For more information, see *Working with Administrative Alert Handlers*.

To Configure an Admin Alert Access Log Publisher

1. Use `dsconfig` to create a criteria object for the Admin Alert Access Log. For this example, we want to log only write operations that target user entries. The following command matches any of the specified operations whose target entry matches the filter `“(objectClass=person)”`.

   If you are using the `dsconfig` tool in interactive mode, the menu items for the criteria operations are located in the Standard objects menu.

```
$ bin/dsconfig create-request-criteria --type simple \
  --criteria-name “User Updates” \
  --set operation-type:add \
  --set operation-type:delete \
  --set operation-type:modify \
  --set operation-type:modify-dn \
  --set “any-included-target-entry-filter:(objectClass=person)”
```

2. Use `dsconfig` to create a log publisher of type `admin-alert-access`.

```
$ bin/dsconfig create-log-publisher \
  --publisher-name ”User Updates Admin Alert Access Log” \
  --type admin-alert-access \
  --set “request-criteria:User Updates” \
  --set include-request-details-in-result-messages:true \
  --set enabled:true
```

Managing Syslog-Based Access Log Publishers

The Data Store supports access logging using the syslog protocol that has been part of the Berkeley Software Distribution (BSD) operating systems for many years. Syslog provides a flexible, albeit simple, means to generate, store and transfer log messages that is supported on most UN*X and Linux operating systems.

The quasi-standard syslog message format cannot exceed 1 kbytes and has three important parts:

- **PRI**. Specifies the message priority based on its facility and severity. The message facility is a numeric identifier that specifies the type of log messages, such as kernel messages, mail system messages, etc. The severity is a numeric identifier that specifies the severity level of the operation that is being reported. The following values are for Solaris systems. For Linux systems, refer to the `syslog.h` file for the specific numbers on their target operating system:

  - 0 (emergency level)
  - 1 (Alert: action must be taken immediately)
  - 2 (Critical: cirtical conditions)
  - 3 (Error: error conditions)
  - 4 (Warning: warning conditions)
  - 5 (Notice: normal but significant condition)
  - 6 (Informational: informational messages)
  - 7 (Debug: debug level messages)

  Together, the facility and the severity determine the priority of the log message indicated by angled brackets and 1-3 digit priority number. For example, "<0>", "<13>", "<103>" are valid representations of the PRI.

- **Timestamp and Host Name**. The timestamp displays the current date and time of the log. The host name or IP address displays the source of the log.

- **Message**. Displays the actual log message.

Administrators can configure syslog to handle log messages using log priorities that are based on the message’s facility and severity. This feature allows users to configure the logging system in such a way that messages with high severities can be sent to a centralized repository, while lower severity messages can be stored locally on a server.

Note: Since the numeric values of the severity and facility are operating system-dependent, the central repository must only include syslog messages from compatible OS types, otherwise the meanings of the PRI field is ambiguous.

Before You Begin

You will need to identify the host name and port to which you want to connect. Because the Syslog Protocol uses User Datagram Protocol (UDP) packets, we highly recommend that you use `localhost` and utilize some additional logging tools, such as `syslog-ng`. UDP is unreliable and unsecure means to transfer data packets between hosts.

Default Access Log Severity Level

All messages are logged at the syslog severity level of 6, which is `Informational: informational` messages. Note that this value is not standard across different types of UNIX or Linux systems. Please consult your particular operating system.

Syslog Facility Properties

When using syslog, you have to specify a facility for the access log messages. As an advanced property, you can select a number that corresponds to the facility you wish to use. The default value for the `syslog-facility` property is 1 (one) for user-level messages. The following facility properties are available on the Data Store. Note that this value is not standard across different types of UNIX or Linux systems. Please consult your particular operating system documentation.

Table 62: Syslog Facility Properties (Solaris)

Facility	Description
0	kernel messages
1	user-level messages (default)
2	mail system
3	system daemons
4	security/authorization messages
5	messages generated internally by syslogd
6	line printer subsystem
7	network news subsystem
8	UUCP subsystem
9	clock daemon
10	security/authorization messages
11	FTP daemon
12	NTP subsystem
13	log audit

Facility	Description
14	log alert
15	clock daemon
16	local use 0
17	local use 1
18	local use 2
19	local use 3
20	local use 4
21	local use 5
22	local use 6
23	local use 7

Queue-Size Property

The maximum number of log records that can be stored in the asynchronous queue is determined by the `queue-size` property. The default queue size set is 10000, which means that the server will continuously flush messages from the queue to the log. The server does not wait for the queue to fill up before flushing to the log. Therefore, lowering this value can impact performance.

Configuring a Syslog-Based Access Log Publisher

You can configure a Syslog-based Access Log Publisher using the `dsconfig` tool. We recommend that you use syslog locally on localhost and use `syslog-ng` to send the syslog messages to remote syslog servers.

Because syslog implementations differ by vendor, please review your particular vendor's syslog configuration.

To Configure a Syslog-Based Access Log Publisher

- Use `dsconfig` to create a log publisher of type syslog-based-access.

  If you are using the `dsconfig` tool in interactive mode, the menu item for Syslog Facility is an advanced property, which can be exposed by typing `a` (for "show advanced properties") on the Syslog-Based Access Log Publisher menu.

  ```
  $ bin/dsconfig create-log-publisher \
  --publisher-name "syslog-access" \
  --type syslog-based-access \
  --set syslog-facility:4 \
  --set enabled:true
  ```

Managing the File-Based Audit Log Publishers

The Data Store provides an audit log, a specialized version of the access log, for troubleshooting problems that may occur in the course of processing. The log records all changes to the data in LDIF format so that administrators can quickly diagnose the changes an application made to the data or replay the changes to another server for testing purposes.

The audit log does not record authentication attempts but can be used in conjunction with the access log to troubleshoot security-related issues. The audit log is disabled by default because it does adversely impact the server's write performance.

Audit Log Format

The audit log uses standard LDIF format, so that administrators can quickly analyze what changes occurred to the data. The audit log begins logging when enabled and should be used to debug any issues that may have occurred. Some common properties are the following:

- **Timestamp**. Displays the date and time of the operation. Format: DD/Month/YYYY:HH:MM:SS <offset from UTC time>
- **Connection ID**. Numeric identifier, starting incrementally with 0, that identifies the client connection that is requesting the operation.
- **Operation ID**. Numeric identifier, starting incrementally with 0, that identifies the operation.
- **Modifiers Name**. Displays the DN of the user who made the change.
- **Update Time**. Records the `modifyTimestamp` operational attribute.

Audit Log Example

The following example shows output from the Audit Log in the `<server-root>/ logs/audit`. The first entry shows when the audit log was enabled. The second entry show changes made to a user entry.

```
# 05/Jun/2011:10:29:04 -0500; conn=0; op=55
dn: cn=File-Based Audit Logger,cn=Loggers,cn=config
changetype: modify
replace: ds-cfg-enabled
ds-cfg-enabled: true
-
replace: modifiersName
modifiersName: cn=Directory Manager,cn=Root DNs,cn=config
-
replace: modifyTimestamp
modifyTimestamp: 20131010020345.546Z

# 05/Jun/2011:10:31:20 -0500; conn=2; op=1
dn: uid=user.996,ou=People,dc=example,dc=com
changetype: modify
replace: pager
pager: +1 115 426 4748
-
replace: homePhone
```

```
homePhone: +1 407 383 4949
-
replace: modifiersName
modifiersName: cn=Directory Manager,cn=Root DNs,cn=config
-
replace: modifyTimestamp
modifyTimestamp: 20131010020345.546Z
```

Enabling the File-Based Audit Log Publisher

You can enable the File-Based Audit Log Publisher using the `dsconfig` tool. The audit log can impact the Data Store’s write performance, so enable it only when troubleshooting any issues.

To Enable the File-Based Audit Log Publisher

- Use `dsconfig` to enable the File-Based Audit Log Publisher. For this example, the instance name and startup ID is also enabled in the audit log.

```
$ bin/dsconfig set-log-publisher-prop \
  --publisher-name "File-Based Audit Logger" \
  --set enabled:true \
  --set include-instance-name:true \
  --set include-startup-id:true
```

Obscuring Values in the Audit Log

You can obscure the values of specific attributes in the audit log using the `obscure-attribute` property. Each value of an obscured attribute is replaced in the audit log with a string of the form "***** OBSCURED VALUE *****". By default, attributes are not obscured, because the values of password attributes appear in hashed form rather than in the clear.

Managing the JDBC Access Log Publishers

The Data Store supports the Java Database Connectivity (JDBCTM) API, which allows access to SQL data stores by means of its JDBC drivers. The JDBC 4.0 API, part of the Java SDK, provides a seamless method to interface with various database types in heterogeneous environments.

By easily connecting to a database, the Data Store can be configured to implement a centralized logging system with different databases. Centralized logging simplifies log correlation and analysis tasks and provides security by storing data in a single repository. Some disadvantages of centralized logging are that data flow asymmetries may complicate synchronization or network provisioning and may unduly burden the central repository with possibly heavy loads.

Before You Begin

Before configuring the JDBC Access Log Publisher, you need to carry out two essential steps to set up the database.

- Install the database drivers in the Data Store `lib` directory.
- Define the log mapping tables needed to map access log elements to the database column data. Only those elements in the log mapping table gets logged by the JDBC Log Publisher.

The following sections provide more information about these tasks.

Configuring the JDBC Drivers

The Data Store supports a number of JDBC drivers available in the market. We highly recommend using the JDBC 4 drivers supported in the Java platform. For example, for Oracle databases, you need to use the `ojdbc.jar` driver for Java and any associated JAR files (National Language Support jars, and others) required to connect with the particular database. The following databases are supported:

- DB2
- MySQL
- Oracle Call Interface (OCI)
- Oracle Thin
- PostgreSQL
- SQL Server

To Configure the JDBC Driver

- Obtain the JAR file(s) for your particular database, and copy it into the `<server-root>/lib` directory.

Configuring the Log Field Mapping Tables

The log field mapping table associates access log fields to the database column names. You can configure the log field mapping table using the `dsconfig` tool, which then generates a DDL file that you can import into your database. The DDL file is generated when you create the JDBC Log Publisher.

To uniquely identify a log record, we recommend always mapping the following fields: `timestamp`, `startupid`, `message-type`, `connection-id`, `operation-type`, `instance-name`.

The table name is not part of this mapping.

The Data Store also provides three options that you can quickly select for creating a log field mapping table:

- **Complete JDBC Access Log Field Mappings**. Maps all 52 object properties.
- **Complete JDBC Error Log Field Mappings**. Maps all 8 object properties.
- **Simple JDBC Access Log Field Mappings**. Maps a common set of object properties.
- **Custom JDBC Access Log Field Mappings**. Create a custom set of JDBC log field mappings.

- **Custom JDBC Error Log Field Mappings**. Create a custom set of JDBC error log field mappings.

To Configure the Log Field Mapping Tables

1. Use `dsconfig` to create a log field mapping table. On the Configuration Console main menu, type `o` to change to the Standard Object menu, and type the number corresponding to Log Field Mapping.
2. On the **Log Field Mapping management** menu, enter the option to create a new Log Field Mapping.
3. On the **Log Field Mapping template** menu, enter the option to select a complete JDBC Access Log Field mapping to use as a template for your new field mapping.
4. Next, enter a name for the new field mapping. In this example, type `my-jdbc-test`.
5. On the **Access Log Field Mapping Properties** menu, select a property for which you want to change the value. Any property that is undefined will not be logged by the JDBC Access Log Publisher. When complete, type `f` to save and apply the changes.
6. On the **Log Field Mapping Management** menu, type `q` to exit the menu.
7. View the existing Log Mappings on the system.

```
$ bin/dsconfig list-log-field-mappings
```

```
Log Field Mapping                    : Type
-------------------------------------:-------
Complete JDBC Access Log Field Mappings : access
Complete JDBC Error Log Field Mappings  : error
my-jdbc-test                            : access
Simple JDBC Access Log Field Mappings   : access
```

Configuring the JDBC Access Log Publisher using dsconfig Interactive Mode

After setting up the drivers and the log mapping table, use the `dsconfig` utility to configure the JDBC Access Log Publisher on the Data Store. The following example uses `dsconfig` interactive mode to illustrate the steps required to configure the log publisher and the external database server.

To Configure the JDBC Access Log Publisher

1. Copy the database JAR files to the `<server-root>/lib` directory, and then restart the Data Store.
2. Launch the `dsconfig` tool in interactive command-line mode.

```
$ bin/dsconfig
```

3. Next, type the connection parameters to bind to the Data Store. Enter the host name or IP address, type of LDAP connection (LDAP, SSL, or StartTLS) that you are using on the Data Store, the LDAP listener port number, the user bind DN, and the bind DN password.
4. On the Configuration Console main menu, type the number corresponding to Log Publisher.
5. On the **Log Publisher management** menu, enter the option to create a new Log Publisher.
6. On the **Log Publisher template** menu, type `n` to create a new Log Publisher.
7. On the **Log Publisher Type** menu, enter the option to create a new JDBC-Based Access Log Publisher.
8. Type a name for the JDBC Access Log Publisher.
9. On the **Enabled Property** menu, enter the option to enable the log publisher.
10. On the **Server Property** menu, enter the option to create a new JDBC External Server.
11. Next, type the name for the JDBC External Server. This is a symbolic name used to represent the DBMS.
12. On the **JDBC Driver Type Property** menu, type the number corresponding to the type of JDBC database driver type.
13. Next, type a name for the `database-name` property. This is the DBMS database name. The database name must contain the table referred to in the generated DDL.
14. Next, type the host name or IP address (server-host-name) of the external server.
15. Type the server listener port. In this example, type `1541`.
16. Review the properties for the external server, and the type `f` to apply the changes.
17. If you need to supply your own JDBC URL, type a for advanced properties to open the `jdbc-driver-url` property and supply the appropriate URL. The example below shows how to access an Oracle Thin Client connection using a SID instead of a Service.

```
>>>> Configure the properties of the JDBC External Server

Property Value(s)
-----------------------------------------------------
1) description -
2) jdbc-driver-type oraclethin
3) jdbc-driver-url jdbc:oracle:thin@myhost:1541:my_SID
4) database-name jdbc-test
5) server-host-name localhost
6) server-port 1541
7) user-name -
8) password -

?) help
f) finish - create the new JDBC External Server
a) hide advanced properties of the JDBC External Server
d) display the equivalent dsconfig arguments to create this object
b) back
q) quit

Enter choice [b]: f
```

```
JDBC External Server was created successfully
```

18. When the JDBC Log Publisher is created, the Data Store automatically generates a DDL file of the Log Field Mappings in the `<server-root>/logs/ddls/<name-of-logger>.sql` file. Import the DDL file to your database.

Configuring the JDBC Access Log Publisher Using dsconfig Non-Interactive Mode

The following example uses `dsconfig` non-interactive mode to illustrate the steps to configure the log publisher and the external database server presented in the previous section.

To Configure the JDBC Access Log Publisher in Non-Interactive Mode

1. Use `dsconfig` with the `--no-prompt` option to create the JDBC external server.

```
$ bin/dsconfig --no-prompt create-external-server \
  --server-name jdbc-external \ --type jdbc \
  --set jdbc-driver-type:oraclethin \
  --set database-name:ubid_access_log \
  --set server-host-name:localhost --set server-port:1541
```

2. Use `dsconfig` to create the log publisher.

```
$ bin/dsconfig --no-prompt create-log-publisher \
  --publisher-name jdbc-test \
  --type jdbc-based-access \
  --set enabled:true \
  --set server:jdbc-external \
  --set "log-field-mapping:Simple JDBC Access Log Field Mappings"
```

3. When the JDBC Log Publisher is created, the Data Store automatically generates a DDL file of the Log Field Mappings in the `&lt;server-root>/logs/ddls/&lt;name- of-logger>.sql` file. Import the DDL file to your database.

   The procedure to configure the JDBC-Based Error Log Publisher is similar to creating a JDBC-Based Access Log Publisher. You can run the previous `dsconfig` command with the `--type jdbc-based-error` as follows:

```
$ bin/dsconfig --no-prompt create-log-publisher \
--publisher-name jdbc-error-test \
--type jdbc-based-error \
--set enabled:true \
--set server:jdbc-external \
--set "log-field-mapping:Simple JDBC Access Log Field Mappings"
```

Managing the File-Based Error Log Publisher

The Error Log reports errors, warnings, and informational messages about events that occur during the course of the Data Store’s operation. Each entry in the error log records the following properties (some are disabled by default and must be enabled):

- **Time Stamp**. Displays the date and time of the operation. Format: DD/Month/YYYY:HH:MM:SS <offset from UTC time>
- **Category**. Specifies the message category that is loosely based on the server components.
- **Severity**. Specifies the message severity of the event, which defines the importance of the message in terms of major errors that need to be quickly addressed. The default severity levels are: `fatal-error`, `notice`, `severe-error`, `severe-warning`.
- **Message ID**. Specifies the numeric identifier of the message.
- **Message**. Stores the error, warning, or informational message.

Error Log Example

The following example displays the error log for the Metrics Engine. The log is enabled by default and is accessible in the `<server-root>/logs/errors` file.

```
[21/Oct/2012:05:15:23.048 -0500] category=RUNTIME_INFORMATION severity=NOTICE
msgID=20381715 msg="JVM Arguments: '-Xmx8g', '-Xms8g', '-XX:MaxNewSize=1g',
'-XX:NewSize=1g', '-XX:+UseConcMarkSweepGC', '-XX:+CMSConcurrentMTEnabled',
'-XX:+CMSParallelRemarkEnabled', '-XX:+CMSParallelSurvivorRemarkEnabled',
'-XX:+CMSScavengeBeforeRemark', '-XX:RefDiscoveryPolicy=1',
'-XX:ParallelCMSThreads=4', '-XX:CMSMaxAbortablePrecleanTime=3600000',
'-XX:CMSInitiatingOccupancyFraction=80', '-XX:+UseParNewGC', '-XX:+UseMembar',
'-XX:+UseBiasedLocking', '-XX:+UseLargePages', '-XX:+UseCompressedOops',
'-XX:PermSize=128M', '-XX:+HeapDumpOnOutOfMemoryError',
'-Dcom.unboundid.directory.server.scriptName=setup'"
[21/Oct/2012:05:15:23.081 -0500] category=EXTENSIONS severity=NOTICE
msgID=1880555611 msg="Administrative alert type=server-starting
id=4178daee-ba3a-4be5-8e07-5ba17bf30b71
class=com.unboundid.directory.server.core.MetricsEngine
msg='The Metrics Engine is starting'"
[21/Oct/2012:05:15:23.585 -0500] category=CORE severity=NOTICE
msgID=1879507338 msg="Starting group processing for backend api-users"
[21/Oct/2012:05:15:23.586 -0500] category=CORE severity=NOTICE
msgID=1879507339 msg="Completed group processing for backend api-users"
[21/Oct/2012:05:15:23.586 -0500] category=EXTENSIONS severity=NOTICE
msgID=1880555575 msg="'Group cache (2 static group(s) with 0 total
memberships and 0 unique members, 0 virtual static group(s),
1 dynamic group(s))' currently consumes 7968 bytes and can grow to a maximum
of an unknown number of bytes"
[21/Oct/2012:05:16:18.011 -0500] category=CORE severity=NOTICE
msgID=458887 msg="The Metrics Engine (UnboundID Metrics Engine 5.2.0.0
build 20121021003738Z, R12799) has started successfully"
```

To Modify the File-Based Error Logs

- Use `dsconfig` to modify the default File-Based Error Log.

```
$ bin/dsconfig set-log-publisher-prop \
  --publisher-name "File-Based Error Logger" \
  --set include-product-name:true --set include-instance-name:true \
  --set include-startup-id:true
```

Managing the Syslog-Based Error Log Publisher

The Data Store supports a Syslog-Based Error Log Publisher using the same mechanism as the Syslog-Based Access Log Publisher. You can easily configure the error logger using the `dsconfig` tool.

Syslog Error Mapping

The Data Store automatically maps error log severities to the syslog severities. The following mappings are used:

Table 63: Error to Syslog Severities Mappings to Syslog

Error Log Facility	Syslog Severity
FATAL_ERROR,0	Syslog Emergency
SEVERE_ERROR,1	Syslog Alert
SEVERE_WARNING,2	Syslog Critical
MILD_ERROR,3	Syslog Error
MILD_WARNING,4	Syslog Warn
NOTICE,5	Syslog Notice
INFORMATION,6	Syslog Info
DEBUG,7	Syslog Debug

Configuring a Syslog-Based Error Log Publisher

You can configure a Syslog-based Error Log Publisher using the `dsconfig` tool. Again, we recommend that you use syslog locally on `localhost` and use `syslog-ng` to send the data packets over the UDP protocol.

Because syslog implementations differ by vendor, please review your particular vendor’s syslog configuration.

To Configure a Syslog-Based Error Log Publisher

- Use `dsconfig` to create a log publisher of type `syslog-based-error`. In this example, set the syslog facility to 4 for security/authorization messages.

```
$ bin/dsconfig create-log-publisher --publisher-name "syslog-error" \
  --type syslog-based-error --set syslog-facility:4 --set enabled:true
```

Creating File-Based Debug Log Publishers

The Data Store provides a File-Based Debug Log Publisher that can be configured when troubleshooting a problem that might occur during server processing. Because the debug data may be too large to maintain during normal operations, the Debug Log Publisher must be specifically configured and enabled. The Debug Log reports the following types of information:

- ➢ Exception data thrown by the server.
- ➢ Data read or written to network clients.
- ➢ Data read or written to the database.
- ➢ Access control or password policy data made within the server.

You can use the `dsconfig` tool to create a debug log publisher. You should only create a debug logger when troubleshooting a problem due to the voluminous output the Data Store generates.

To Create a File-Based Debug Log Publisher

- Use `dsconfig` to create the debug log publisher. The `log-file` property (required) sets the debug log path. You must also specify the rotation and retention policy for the debug log.

```
$ bin/dsconfig create-log-publisher \
  --publisher-name "File-Based Debug Logger" \
  --type file-based-debug \
  --set enabled:true \
  --set log-file:/logs/debug \
  --set "rotation-policy:24 Hours Time Limit Rotation Policy" \
  --set "rotation-policy:Size Limit Rotation Policy" \
  --set "retention-policy:File Count Retention Policy"
```

To Delete a File-Based Debug Log Publisher

- Use `dsconfig` to create the debug log publisher.

```
$ bin/dsconfig delete-log-publisher \
  --publisher-name "File-Based Debug Logger"
```

Chapter 22 Managing Monitoring

The UnboundID Data Store also provides a flexible monitoring framework that exposes its monitoring information under the `cn=monitor` entry and provides interfaces via the UnboundID® Metrics Engine, the Management Console, SNMP, JMX, and over LDAP. The Data Store also provides a tool, the Periodic Stats Logger, to profile server performance.

This chapter presents the following information:

Topics:

The Monitor Backend

The Data Store exposes its monitoring information under the `cn=monitor` entry. Administrators can use various means to monitor the servers, including the UnboundID Metrics Engine, through SNMP, the Management Console, JConsole, LDAP command-line tools, and the Periodic Stats Logger. Use the `bin/status` tool to display server component activity and state.

The list of all monitor entries can be seen using ldapsearch as follows:

```
$ bin/ldapsearch --hostname server1.example.com --port 1389 \
 --bindDN "uid=admin,dc=example,dc=com" --bindPassword secret \
 --baseDN "cn=monitor" "(objectclass=*)" cn
```

The following table describes a subset of the monitor entries:

Table 64: Data Store Monitoring Components

Component	Description
Active Operations	Provides information about the operations currently being processed by the Data Store. Shows the number of operations, information on each operation, and the number of active persistent searches.
Backends	Provides general information about the state of an a Data Store backend, including the entry count. If the backend is a local database, there is a corresponding database environment monitor entry with information on cache usage and on-disk size.
Client Connections	Provides information about all client connections to the Data Store. The client connection information contains a name followed by an equal sign and a quoted value (e.g., connID="15", connectTime="20100308223038Z", etc.)
Connection Handlers	Provides information about the available connection handlers on the Data Store, which includes the LDAP and LDIF connection handlers. These handlers are used to accept client connections and to read requests and send responses to those clients.
Disk Space Usage	Provides information about the disk space available to various components of the Data Store.
General	Provides general information about the state of the Data Store, including product name, vendor name, server version, etc.
Index	Provides on each index. The monitor captures the number of keys preloaded, and counters for read/write/remove/open-cursor/read-for-search. These counters provide insight into how useful an index is for a given workload.
HTTP/HTTPS Connection Handler Statistics	Provides statistics about the interaction that the associated HTTP connection handler has had with its clients, including the number of connections accepted, average requests per connection, average connection duration, total bytes returned, and average processing time by status code.
JVM Stack Trace	Provides a stack trace of all threads processing within the JVM.
LDAP Connection Handler Statistics	Provides statistics about the interaction that the associated LDAP connection handler has had with its clients, including the number of connections established and closed, bytes read and written, LDAP messages read and written, operations initiated, completed, and abandoned, etc.
Processing Time Histogram	Categorizes operation processing times into a number of user-defined buckets of information, including the total number of operations processed, overall average response time (ms), number of processing times between 0ms and 1ms, etc.

Component	Description
System Information	Provides general information about the system and the JVM on which the Data Store is running, including system host name, operation system, JVM architecture, Java home, Java version, etc.
Version	Provides information about the Data Store version, including build ID, version, revision number, etc.
Work Queue	Provides information about the state of the Data Store work queue, which holds requests until they can be processed by a worker thread, including the requests rejected, current work queue size, number of worker threads, and number of busy worker threads. The work queue configuration has a `monitor-queue-time` property set to `true` by default. This logs messages for new operations with a `qtime` attribute included in the log messages. Its value is expressed in milliseconds and represents the length of time that operations are held in the work queue. A dedicated thread pool can be used for processing administrative operations. This thread pool enables diagnosis and corrective action if all other worker threads are processing operations. To request that operations use the administrative thread pool, using the `ldapsearch` command for example, use the `--useAdministrativeSession` option. The requester must have the `use-admin-session` privilege (included for root users). By default, eight threads are available for this purpose. This can be changed with the `num-administrative-session-worker-threads` property in the work queue configuration.

Monitoring Disk Space Usage

The disk space usage monitor provides information about the amount of usable disk space available for Data Store components. The disk space usage monitor evaluates the free space at locations registered through the `DiskSpaceConsumer` interface by various components of the server. Disk space monitoring excludes disk locations that do not have server components registered. However, other disk locations may still impact server performance, such as the operating system disk, if it becomes full. When relevant to the server, these locations include the server root, the location of the `/config` directory, the location of every log file, all JE backend directories, the location of the changelog, the location of the replication environment database, and the location of any server extension that registers itself with the DiskSpaceConsumer interface.

The disk space usage monitor provides the ability to generate administrative alerts, as well as take additional action if the amount of usable space drops below the defined thresholds.

Three thresholds can be configured for this monitor:

- **Low space warning threshold**. This threshold is defined as either a percentage or absolute amount of usable space. If the amount of usable space drops below this threshold, then the Data Store will generate an administrative alert but will remain fully functional. It will generate alerts at regular intervals that you configure (such as once a day) unless action is taken to increase the amount of usable space. The Data Store will also generate additional alerts as the amount of usable space is further reduced (e.g., each time the amount of usable space drops below a value 10% closer to the low space error threshold). If an administrator frees up disk space or adds additional capacity, then the server should automatically recognize this and stop generating alerts.

- **Low space error threshold**. This threshold is also defined as either a percentage or absolute size. Once the amount of usable space drops below this threshold, then the server will generate an alert notification and will begin rejecting all operations requested by non-root users with "UNAVAILABLE" results. The server should continue to generate alerts during this time. Once the server enters this mode, then an administrator will have to take some kind of action (e.g., running a command to invoke a task or removing a signal file) before the server will resume normal operation. This threshold must be less than or equal to the low space warning threshold. If they are equal, the server will begin rejecting requests from non-root users immediately upon detecting low usable disk space.
- **Out of space error threshold**. This threshold may also be defined as a percentage or absolute size. Once the amount of usable space drops below this threshold, then the UnboundID Data Store will generate a final administrative alert and will shut itself down. This threshold must be less than or equal to the low space error threshold. If they are equal, the server will shut itself down rather than rejecting requests from non-root users.

The threshold values may be specified either as absolute sizes or as percentages of the total available disk space. All values must be specified as absolute values or as percentages. A mix of absolute values and percentages cannot be used. The low space warning threshold must be greater than or equal to the low space error threshold, the low space error threshold must be greater than or equal to the out of space error threshold, and the out of space error threshold must be greater than or equal to zero.

If the out of space error threshold is set to zero, then the server will not attempt to automatically shut itself down if it detects that usable disk space has become critically low. If the amount of usable space reaches zero, then the database will preserve its integrity but may enter a state in which it rejects all operations with an error and requires the server (or at least the affected backends) to be restarted. If the low space error threshold is also set to zero, then the server will generate periodic warnings about low available disk space but will remain fully functional for as long as possible. If all three threshold values are set to zero, then the server will not attempt to warn about or otherwise react to a lack of usable disk space.

Monitoring with the Metrics Engine

The UnboundID Metrics Engine is an invaluable tool for collecting, aggregating and exposing historical and instantaneous data from the various UnboundID servers in a deployment. The Metrics Engine relies on a captive PostgreSQL data store for the metrics, which it collects from internal instrumentation across the instances, replicas, and data centers in your environment. The data is available via a Monitoring API that can be used to build custom dashboards and monitoring applications to monitor the overall health of your UnboundID Platform system. For more information, see the *UnboundID Metrics Engine Administration Guide*.

About the Collection of System Monitoring Data

All UnboundID servers have the capability to monitor the health of the server and host system they run on for diagnostic review and troubleshooting. Initially, the servers do not collect any performance data until they are prepared for monitoring by an UnboundID Metrics Engine using the `monitored-servers add-servers` tool or an administrator enables system health data collection for real-time inspection and querying. At a high level, all of the important server and machine metrics which can be monitored are available in the `cn=monitor` backend.

The Stats Collector plugin is the primary driver of performance data collection for LDAP, server response, replication, local JE databases, and host system machine metrics. Stats Collector configuration determines the sample and collection intervals, granularity of data (basic, extended, verbose), types of host system collection (cpu, disk, network) and what kind of data aggregation occurs for LDAP application statistics. The Stats Collector plugin ensures that an UnboundID Metrics Engine is able to gather all of the detailed data required for a comprehensive diagnostic review.

The Stats Collector plugin relies exclusively on entries in the `cn=monitor` backend to sample data using LDAP queries. The Stats Collector plugin is the primary driver of performance data collection for LDAP, server response, replication, local JE databases, and host system machine metrics. Stats Collector configuration determines the sample and collection intervals, granularity of data (basic, extended, verbose), types of host system collection (cpu, disk, network) and the type of data aggregation that occurs for LDAP application statistics. The Stats Collector plugin is configured with the `dsconfig` tool and collects data using LDAP queries. For example, the `--server-info:extended` option includes collection for the following:

- CPU
- JVM memory
- Memory
- Disk information
- Network information

Utilization metrics are gathered via externally invoked OS commands, such as `iostat` and `netstat`, using platform-specific arguments and version-specific output parsing.

Enabling the Host System monitor provider automatically gathers CPU and memory utilization but only optionally gathers disk and network information. Disk and network interfaces are enumerated in the configuration by device names (e.g., `eth0` or lo), and by disk device names (e.g., `sd1, sdab, sda2, scsi0`).

Monitoring Key Performance Indicators by Application

The UnboundID Data Store can be configured to track many key performance metrics (for example, throughput and response-time) by the client applications requesting them. This feature is invaluable for measuring whether the UnboundID identify infrastructure meets all of your service-level agreements (SLA) that have been defined for client applications.

When enabled, the per-application monitoring data can be accessed in the `cn=monitor` backend, the Periodic Stats Logger, and made available for collection by the UnboundID Metrics Engine. See the “Profiling Server Performance Using the Periodic Stats Logger” for more information on using that component. Also, see the Data Store Configuration section of the *UnboundID Metrics Engine Administration Guide* for details on configuring the server to expose metrics that interest you. Tracked application information is exposed in the Metrics Engine by metrics having the 'application-name' dimension. See the documentation under `docs/metrics` of the

Metrics Engine for information on which metrics are available with the 'application-name' dimension.

Configuring the External Servers

Before you install the Metrics Engine, you need to configure the servers you will be monitoring: UnboundID Data Store, UnboundID Proxy Server, and UnboundID Data Sync Server. The Metrics Engine requires all servers to be version 3.5.0 or later. See the administration guides for each product for installation instructions.

Once you have installed the Data Store, you can use the `dsconfig` tool to make configuration changes for the Metrics Engine. When using the `dsconfig` tool interactively, set the complexity level to Advanced, so that you can make all the necessary configuration changes.

Preparing the Servers Monitored by the Metrics Engine

The Metrics Backend manages the storage of metrics and provides access to the stored blocks of metrics via LDAP. The Metrics Backend is configured to keep a maximum amount of metric history based on log retention policies. The default retention policy uses the Default Size Limit Retention Policy, Free Disk Space Retention Policy, and the File Growth Limit Policy, limiting the total disk space used to 500 MB. This amount of disk typically contains more than 24 hours of metric history, which is ample. The Data Store keeps a metric history so that the Metrics Engine can be down for a period and then catch up when it comes back online.

The following two commands create a Retention Policy that limits the number of files to 2000, and sets the Metrics Backend to flush data to a new file every 30 seconds.

```
$ bin/dsconfig create-log-retention-policy \
  --policy-name StatsCollectorRetentionPolicy \
  --type file-count --set number-of-files:2000

$ bin/dsconfig set-backend-prop \
  --backend-name metrics --set sample-flush-interval:30s \
  --set retention-policy:StatsCollectorRetentionPolicy
```

These commands configure the Metrics Backend to keep 16 hours of metric history, which consumes about 250 MB of disk, ensuring that captured metrics are available to the Metrics Engine within 30 seconds of when the metric was captured. The value of the `sample-flush-interval` attribute determines the maximum delay between when a metric is captured and when it can be picked up by the Metrics Engine.

The flush interval can be set between 15 seconds and 60 seconds, with longer values resulting in less processing load on the Metrics Engine. However, this flush interval increases the latency between when the metric was captured and when it becomes visible in the Dashboard Application. If you change the `sample-flush-interval` attribute to 60 seconds in the example above, then the Data Store keeps 2000 minutes of history. Because the number of metrics produced per unit of time can vary depending on the configuration, no exact formula can be used to compute how much storage is required for each hour of history. However, 20 MB per hour is a good estimate.

Configuring the Processing Time Histogram Plugin

The Processing Time Histogram plugin is configured on each Data Store and Proxy Server as a set of histogram bucket ranges. When the bucket ranges for a histogram change, the Metrics Engine notices the change and marks samples differently. This process allows for histograms with the same set of bucket definitions to be properly aggregated and understood when returned in a query. If different servers have different bucket definitions, then a single metric query cannot return histogram data from the servers.

You should try to keep the Processing Time Histogram bucket definitions the same on all servers. Having different definitions restricts the ability of the Metrics Engine API to aggregate histogram data across servers and makes the results of a query asking "What percentage of the search requests took less than 12 milliseconds?" harder to understand.

For each server in your topology, you must set the `separate-monitor-entry-per-tracked-application` property of the processing time histogram plugin to true. This property must be set to expose per-application monitoring information under `cn=monitor`. When the `separate-monitor-entry-per-tracked-application` property is set to true, then the `per-application-ldap-stats` property must be set to `per-application-only` on the Stats Collector Plugin and vice versa.

For example, the following `dsconfig` command line sets the required properties of the Processing Time Histogram plugin:

```
$ bin/dsconfig set-plugin-prop --plugin-name “Processing Time Histogram” \
  --set separate-monitor-entry-per-tracked-application:true
```

The following `dsconfig` command line sets the `per-application-ldap-stats` property of the Stats Collector plugin to `per-application-only`:

```
$ bin/dsconfig set-plugin-prop --plugin-name “Stats Collector” \
 --set per-application-ldap-stats:per-application-only
```

Setting the Connection Criteria to Collect SLA Statistics by Application

If you want to collect data about your SLAs, you need to configure connection criteria for each Service Level Agreement that you want to track. The connection criteria are used in many areas within the server. They are used by the client connection policies, but they can also be used when the server needs to perform matching based on connection-level properties, such as filtered logging. For assistance using connection criteria, contact your authorized support provider.

For example, imagine that we are interested in collecting statistics on data that is accessed by clients authenticating as the Directory Manager. We need to create connection criteria on the Data Store that identifies any user authenticating as the Directory Manager. The connection criteria name corresponds to the `application-name` dimension value that clients will specify when accessing the data via the API. When you define the Connection Criteria, change the `included-user-base-dn` property to include the Directory Manager’s full LDIF entry.

The following `dsconfig` command line creates connection criteria for the Directory Manager:

```
$ bin/dsconfig create-connection-criteria \
  --criteria-name “Directory Manager” \
  --type simple \
  --set “included-user-base-dn:cn=Directory Manager,cn=Root DNs,cn=config”
```

Updating the Global Configuration

You also need to create Global Configuration-tracked applications for each app (connection criteria) you intend to track. The `tracked-application` property allows individual applications to be identified in the server by connection criteria. The name of the tracked application is the same as the name you defined for the connection criteria.

For example, the following `dsconfig` command line adds the connection criteria we created in the previous step to the list of tracked applications:

```
$ bin/dsconfig set-global-configuration-prop \
  --set "tracked-application:Directory Manager”
```

The value of the `tracked-application` field corresponds to the value of the `application-name` dimension value that clients will specify when accessing the data via the API.

Proxy Considerations for Tracked Applications

In a proxy environment, the criteria should be defined in the Proxy Server since the Proxy Server passes the application name through to the Data Store in the intermediate client control. If a client of the Proxy Server or Data Store happens to use the intermediate client control, then the client name specified in the control will be used as the application name regardless of the criteria listed in the `tracked-application` property.

Monitoring Using SNMP

The UnboundID Data Store supports real-time monitoring using the Simple Network Management Protocol (SNMP). The Data Store provides an embedded SNMPv3 subagent plugin that, when enabled, sets up the server as a managed device and exchanges monitoring information with a master agent based on the AgentX protocol.

SNMP Implementation

In a typical SNMP deployment, many production environments use a network management system (NMS) for a unified monitoring and administrative view of all SNMP-enabled devices. The NMS communicates with a master agent, whose main responsibility is to translate the SNMP protocol messages and multiplex any request messages to the subagent on each managed device (for example, Data Store instance, Proxy Server, Sync Server, or OS Subagent).
The master agent also processes responses or traps from the agents. Many vendors provide commercial NMS systems, such as Alcatel-Lucent (Omnivista EMS), HP (OpenView), IBM-Tivoli (Netview), Oracle-Sun (Solstice Enterprise Manager), and others. Specific discussion on integrating an SNMP deployment on an NMS system is beyond the scope of this chapter. Consult with your NMS system for specific information.

The UnboundID Data Store contains an SNMP subagent plug-in that connects to a Net-SNMP master agent over TCP. The main configuration properties of the plug-in are the address and port of the master agent, which default to localhost and port 705, respectively. When the plug-in is initialized, it creates an AgentX subagent and a managed object server, and then registers as a MIB server with the Data Store instance. Once the plug-in's startup method is called, it starts a session thread with the master agent. Whenever the connection is lost, the subagent automatically attempts to reconnect with the master agent. The Data Store's SNMP subagent plug-in only transmits read-only values for polling or trap purposes (set and inform operations are not supported). SNMP management applications cannot perform actions on the server on their own or by means of an NMS system.

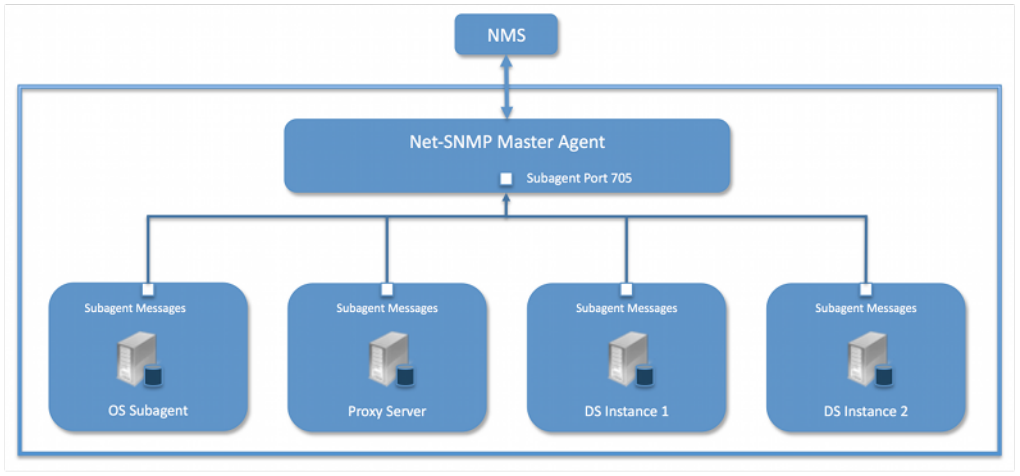


Figure 21: Example SNMP Deployment

One important note is that the UnboundID Data Store was designed to interface with a Net-SNMP (version 5.3.2.2 or later) master agent implementation with AgentX over TCP. Many operating systems provide their own Net-SNMP module, such as the System Management Agent (SMA) on Solaris or OpenSolaris. However, SMA disables some features present in the Net-SNMP package and only enables AgentX over UNIX Domain Sockets, which cannot be supported by Java. If your operating system has a native Net-SNMP master agent that only enables UNIX Domain Sockets, you must download and install a separate Net-SNMP binary from its web site.

Configuring SNMP

Because all server instances provide information for a common set of MIBs, each server instance provides its information under a unique SNMPv3 context name, equal to the server instance name. The server instance name is defined in the Global Configuration, and is constructed from the host name and the server LDAP port by default. Consequently, information must be requested using SNMPv3, specifying the context name that pertains to the desired server instance. This context name is limited to 30 characters or less. Any context name longer than 30 characters will result in an error message. Since the default context name is limited to 30 characters or less, and defaults to the server instance name and the LDAP port number, pay special attention to the length of the fully-qualified (DNS) hostname.

Note: The Data Store supports SNMPv3, and only SNMPv3 can access the MIBs. For systems that implement SNMP v1 and v2c, Net-SNMP provides a proxy function to route requests in one version of SNMP to an agent using a different SNMP version.

To Configure SNMP

1. Enable the Data Store's SNMP plug-in using the `dsconfig` tool. Make sure to specify the address and port of the SNMP master agent. On each Data Store instance, enable the SNMP subagent. Note that the SNMPv3 context name is limited to 30 bytes maximum. If the default dynamically-constructed instance name is greater than 30 bytes, there will be an error when attempting to enable the plugin.

```
$ bin/dsconfig set-plugin-prop --plugin-name "SNMP Subagent" \
  --set enabled:true --set agentx-address:localhost \
  --set agentx-port:705 --set session-timeout:5s \
  --set connect-retry-max-wait:10s
```

2. Enable the SNMP Subagent Alert Handler so that the sub-agent will send traps for administrative alerts generated by the server.

```
$ bin/dsconfig set-alert-handler-prop \
  --handler-name "SNMP Subagent Alert Handler" --set enabled:true
```

3. View the error log. You will see a message that the master agent is not connected, because it is not yet online.

```
The SNMP sub-agent was unable to connect to the master
agent at localhost/705: Timeout
```

4. Edit the SNMP agent configuration file, `snmpd.conf`, which is often located in `/etc/snmp/snmpd.conf`. Add the directive to run the agent as an AgentX master agent:

```
master agentx agentXSocket tcp:localhost:705
```

   Note that the use of `localhost` means that only sub-agents running on the same host can connect to the master agent. This requirement is necessary since there are no security mechanisms in the AgentX protocol.

5. Add the trap directive to send SNMPv2 traps to `localhost` with the community name, public (or whatever SNMP community has been configured for your environment) and the port.

```
trap2sink localhost public 162
```

6. To create a SNMPv3 user, add the following lines to the `/etc/snmp/snmpd.conf` file.

```
rwuser initial
createUser initial MD5 setup_passphrase DES
```

7. Run the following command to create the SNMPv3 user.

```
snmpusm -v3 -u initial -n "" -l authNoPriv -a MD5 -A setup_passphrase \
localhost create snmpuser initial
```

8. Start the `snmpd` daemon and after a few seconds you should see the following message in the Data Store error log:

```
The SNMP subagent connected successfully to the master agent
at localhost:705. The SNMP context name is host.example.com:389
```

9. Set up a trap client to see the alerts that are generated by the Data Store. Create a config file in `/tmp/snmptrapd.conf` and add the directive below to it. The directive specifies that the trap client can process traps using the public community string, and can log and trigger executable actions.

```
authcommunity log, execute public
```

10. Install the MIB definitions for the Net-SNMP client tools, usually located in the `/usr/share/snmp/mibs` directory.

```
$ cp resource/mib/* /usr/share/snmp/mibs
```

11. Then, run the trap client using the `snmptrapd` command. The following example specifies that the command should not create a new process using `fork()` from the calling shell (`-f`), do not read any configuration files (`-C`) except the one specified with the `-c` option, print to standard output (`-Lo`), and then specify that debugging output should be turned on for the User-based Security Module (`-Dusm`). The path after the `-M` option is a directory that contains the MIBs shipped with our product (i.e., `server-root/resource/mib`) .

```
$ snmptrapd -f -C -c /tmp/snmptrapd.conf -Lf /root/trap.log -Dusm \
  -m all -M +/usr/share/snmp/mibs
```

12. Run the Net-SNMP client tools to test the feature. The following options are required: `-v <SNMP version>`, `-u <user name>`, `-A <user password>`, `-l <security level>`, `-n <context name (instance name)>` . The `-m` all option loads all MIBs in the default MIB directory in `/usr/share/snmp/mibs` so that MIB names can be used in place of numeric OIDs.

```
$ snmpget -v 3 -u snmpuser -A password -l authNoPriv -n host.example.com:389 \
-m all localhost localDBBackendCount.0

$ snmpwalk -v 3 -u snmpuser -A password -l authNoPriv -n host.example.com:389 \
-m all localhost systemStatus
```

13. If you want alerts sent from the SNMP Subagent through the Net-SNMP master agent and onwards, you must enable the SNMP Subagent Alert Handler. The SNMP Alert Handler is used in deployments that do not enable the Subagent.

```
$ bin/dsconfig --no-prompt set-alert-handler-prop \
  --handler-name "SNMP Subagent Alert Handler" \
  --set enabled:true \
  --set server-host-name:host2 \
  --set server-port:162 \
  --set community-name:public
```

Configuring SNMP on AIX

Native AIX SNMP implementations do not support AgentX sub-agents, which is a requirement for the UnboundID Data Store. To implement SNMP on AIX platforms, any freely-available `net-snmp` package must be installed.

Special care must be made to ensure that you are using the `net-snmp` binary packages and not the native snmp implementation. Third-party net-snmp binary packages typically install under `/opt/freeware` and have the following differences:

```
Native Daemon: /usr/sbin/snmpd
Native Configuration File: /etc/snmpd.conf, /etc/snmpdv3.conf
Native Daemon Start and Stop: startsrc -s snmpd, stopsrc -s snmpd

net-snmp Daemon: /opt/freeware/sbin/snmpd
net-snmp Configuration File: /opt/freeware/etc/snmp/snmpd.conf
net-snmp start and stop: /etc/rc.d/init.d/snmpd start|stop
```

When configuring an SNMP implementation on AIX, remember to check the following items so that the Data Store is referencing the `net-snmp` installation:

- The shell PATH will reference the native implementation binaries. Adjust the PATH variable or invoke the `net-snmp` binaries explicitly.
- If the native daemon is not stopped, there will likely be port conflicts between the native daemon and the `net-snmp` daemon. Disable the native daemon or use distinct port numbers for each.

SNMP on AIX Security Considerations

On AgentX sub-agent-compliant systems, it is recommended to use `agentXSocket tcp:localhost:705` to configure the net-snmp master agent to allow connections only from sub-agents located on the same host. On AIX systems, it is possible to specify an external IP network interface (for example, `agentXSocket tcp:0.0.0.0:708` would listen on all external IP interfaces), which would allow the UnboundID Data Store to be located on a different host to the snmp master agent.

While it is possible to implement non-local sub-agents, administrators should understand the security risks that are involved with this configuration. Primarily, because there is no communication authentication or privacy between the UnboundID Data Store and the master agent. An eavesdropper might be able to listen in on the monitoring data sent by the UnboundID Data Store. Likewise, a rogue sub-agent might be able to connect to the master agent and provide false monitoring data or deny access to SNMP monitoring data.

In general, it is recommended that sub-agents be located on the same host as the master agent.

MIBS

The Data Store provides SMIv2-compliant MIB definitions (RFC 2578, 2579, 2580) for distinct monitoring statistics. These MIB definitions are to be found in text files under `resource/mib` directory under the server root directory.

Each MIB provides managed object tables for each specific SNMP management information as follows:

- **LDAP Remote Server MIB**. Provides information related to the health and status of the LDAP servers that the Proxy Server connects to, and statistics about the operations invoked by the Proxy Server on those LDAP servers.
- **LDAP Statistics MIB**. Provides a collection of connection-oriented performance data that is based on a connection handler in the Data Store. A server typically contain only one connection handler and therefore supplies only one table entry.
- **Local DB Backend MIB**. Provides key metrics related to the state of the local database backends contained in the server.
- **Processing Time MIB**. Provides a collection of key performance data related to the processing time of operations broken down by several criteria but reported as a single aggregated data set.
- **Replication MIB**. Provides key metrics related to the current state of replication, which can help diagnose how much outstanding work replication may have to do.
- **System Status MIB**. Provides a set of critical metrics for determining the status and health of the system in relation to its work load.

For information on the available monitoring statistics for each MIB available on the Data Store and the Proxy Server, see the text files provided in the `resource/mib` directory below the server installation.

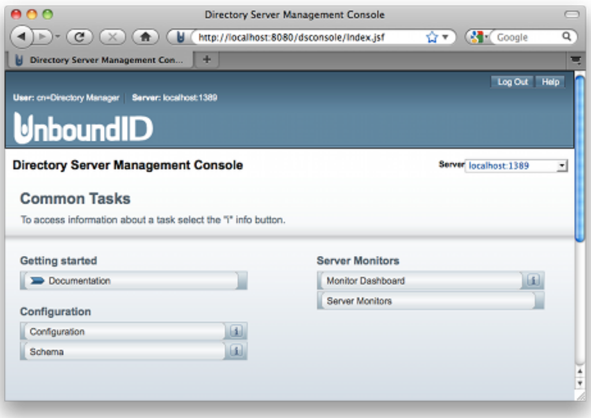
The Data Store generates an extensive set of SNMP traps for event monitoring. The traps display the severity, description, name, OID, and summary. For information about the available alert types for event monitoring, see the `resource/mib/UNBOUNDID-ALERT-MIB.txt` file.

Monitoring with the Management Console

UnboundID has developed a graphical web console for administrators to configure the data store. The console also provides a monitoring component that accesses the server's monitor content.

To View the Monitor Dashboard

1. Ensure that the Data Store is running.
2. Open a browser to `http://hostname:8080/dsconsole/`. For information about installing the Management Console, see Installing the Management Console.
3. Type the root user DN (or any authorized administrator user name) and password, and then click **Login**.
4. Click **Monitor Dashboard**.


Directory Server Management Console
http://localhost:8080/dsconsole/index.jsf
Google
Directory Server Management Con...
Log Out
Help
User: cn=Directory Manager
Server: localhost:1389
UnboundID
Directory Server Management Console
Server localhost:1389
Common Tasks
To access information about a task select the "i" info button.
Getting started
Documentation
Configuration
Configuration
Schema
Server Monitors
Monitor Dashboard
Server Monitors

5. View the monitoring information on the dashboard.

Accessing the Processing Time Histogram

The UnboundID Data Store provides a processing time histogram that classifies operation response time into user-defined buckets. The histogram tracks the processing on a per operation basis and as a percentage of the overall processing time for all operations. It also provides statistics for each operation type (add, bind, compare, delete, modify, modify DN, search).

To Access the Processing Time Histogram

1. On the Management Console, click **Server Monitors**.

2. Click **Processing Time Histogram**. Other monitor entries can be accessed in similar ways.

Monitoring with JMX

The UnboundID Data Store supports monitoring the JVM™ through a Java Management Extensions (JMX™) management agent, which can be accessed using JConsole or any other kind of JMX client. The JMX interface provides JVM performance and resource utilization information for applications running Java. You can monitor generic metrics exposed by the JVM itself, including memory pools, threads, loaded classes, and MBeans, as well as all the monitor information that the Data Store provides. You can also subscribe to receive JMX notifications for any administrative alerts that are generated within the server.

Running JConsole

Before you can access JConsole, you must configure and enable the JMX Connection Handler for the Data Store using the `dsconfig` tool. See Configuring the JMX Connection Handler and Alert Handler.

To invoke the JConsole executable, type `jconsole` on the command line. If *JDK_HOME* is not set in your path, you can access JConsole in the `bin` directory of the `JDK_HOME` path.

To Run JConsole

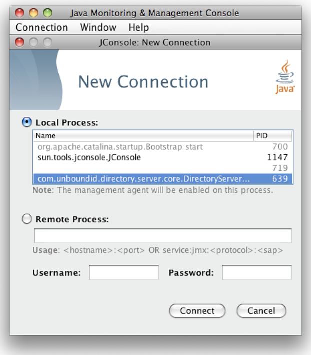
1. Use `JConsole` to open the Java Monitoring and Management Console. You can also run JConsole to monitor a specific process ID for your application: `jconsole PID`. Or you can run JConsole remotely using: `jconsole hostname:port`.

   ```
   $ jconsole
   ```

   Note: If SSL is configured on the JMX Connection Handler, you must specify the Data Store jar file in the class path when running `jconsole` over SSL. For example, run the following `jconsole` command:

   ```
   $ jconsole \
     -J-Djavax.net.ssl.trustStore=/path/to/certStores/truststore \
     -J-Djavax.net.ssl.trustStorePassword=secret \
     -J-Djava.class.path=$SERVER_ROOT/UnboundID-DS.jar:/Library/Java/
   JavaVirtualMachines/jdk-version.jdk/Contents/Home/lib/jconsole.jar
   ```

2. On the **Java Monitoring & Management Console**, click **Local Process**, and then click the **PID** corresponding to the data store.

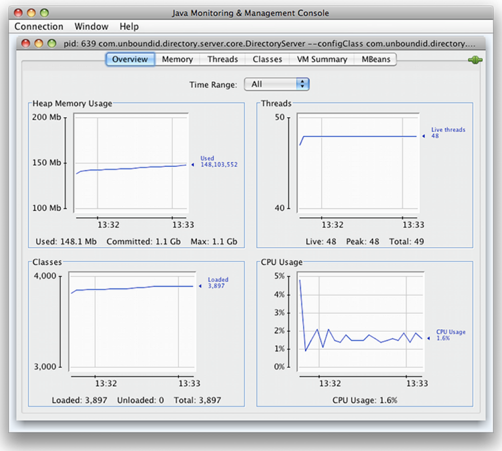


```
Name                                              PID
org.apache.catalina.startup.Bootstrap start       700
sun.tools.jconsole.JConsole                      1147
                                                  719
com.unboundid.directory.server.core.DirectoryServer...  639
```

Note: The management agent will be enabled on this process.

Usage: <hostname>:<port> OR service:jmx:<protocol>:<sap>

3. Review the resource monitoring information.


Java Monitoring & Management Console
Connection Window Help
pid: 639 com.unboundid.directory.server.core.DirectoryServer --configClass com.unboundid.directory....
Overview Memory Threads Classes VM Summary MBeans
Time Range: All
Heap Memory Usage
Used 148,103,552
Used: 148.1 Mb Committed: 1.1 Gb Max: 1.1 Gb
Threads
Live threads 48
Live: 48 Peak: 48 Total: 49
Classes
Loaded 3,897
Loaded: 3,897 Unloaded: 0 Total: 3,897
CPU Usage
CPU Usage 1.6%
CPU Usage: 1.6%

Monitoring the Data Store Using JConsole

You can set up JConsole to monitor the Data Store using a remote process. Make sure to enable the JMX Connection Handler and to assign at least the `jmx-read` privilege to a regular user account (the `jmx-notify` privilege is required to subscibe to receive JMX notifications). Do not use a root user account, as this would pose a security risk.

To Monitor the Data Store using JConsole

1. Start the Data Store.

```
$ bin/start-ds
```

2. Enable the JMX Connection handler using the `dsconfig` tool. The handler is disabled by default. Remember to include the LDAP connection parameters (hostname, port, bindDN, bindPassword).

```
$ bin/dsconfig set-connection-handler-prop \
  --handler-name "JMX Connection Handler" --set enabled:true
```

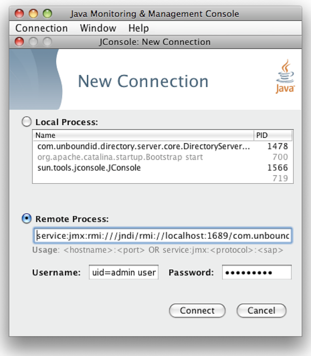
3. Assign `jmx-read`, `jmx-write`, and `jmx-notify` (if the user receives notifications) to the user.

```
$ bin/ldapmodify --hostname server1.example.com --port 1389 \
  --bindDN "cn=Directory Manager" --bindPassword secret
dn: uid=admin,dc=example,dc=com
changetype: modify
replace: ds-privilege-name
ds-privilege-name: jmx-read
ds-privilege-name: jmx-write
ds-privilege-name: jmx-notify
```

4. On the **Java Monitoring & Management Console**, click **Remote Process**, and enter the following JMX URL using the host and port of your Data Store.

```
service:jmx:rmi:///jndi/rmi://<host>:<port>/
com.unboundid.directory.server.protocols.jmx.client-unknown
```

5. In the **Username** and **Password** fields, type the bind DN and password for a user that has at least the `jmx-read` privilege. Click **Connect**.



Local Process:

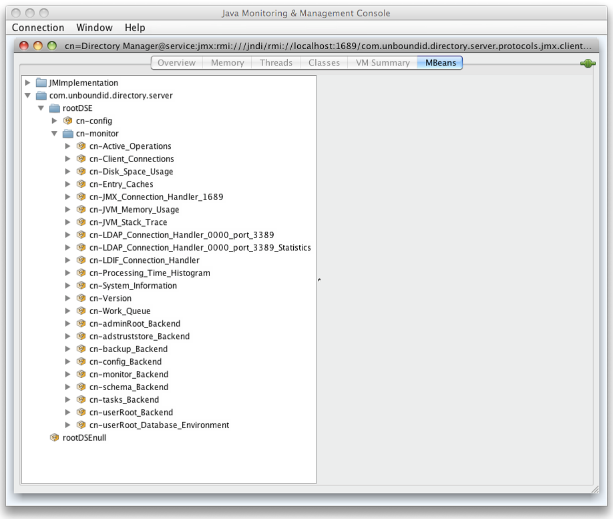
Name	PID
com.unboundid.directory.server.core.DirectoryServer...	1478
org.apache.catalina.startup.Bootstrap start	700
sun.tools.jconsole.JConsole	1566
	719

Remote Process: service:jmx:rmi:///jndi/rmi://localhost:1689/com.unbounc

Usage: <hostname>:<port> OR service:jmx:<protocol>:<sap>

Username: uid=admin user Password: ••••••••••

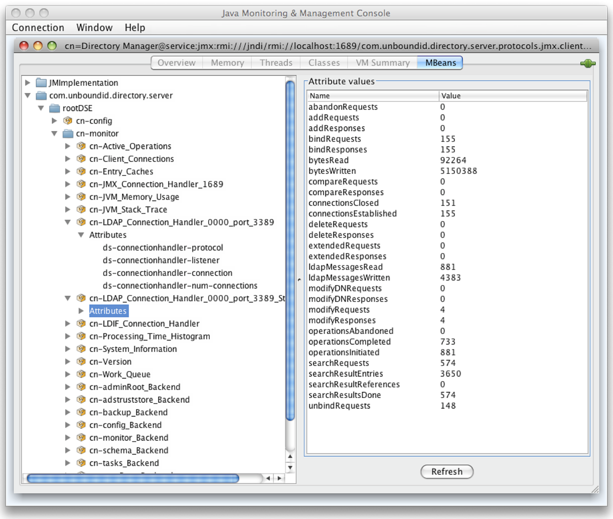
6. Click **com.unboundid.directory.server**, and expand the `rootDSE` node and the `cn-monitor` sub-node.



cn=Directory Manager@service:jmx:rmi:///jndi/rmi://localhost:1689/com.unboundid.directory.server.protocols.jmx.client...

```
JMImplementation
com.unboundid.directory.server
  rootDSE
    cn-config
    cn-monitor
      cn-Active_Operations
      cn-Client_Connections
      cn-Disk_Space_Usage
      cn-Entry_Caches
      cn-JMX_Connection_Handler_1689
      cn-JVM_Memory_Usage
      cn-JVM_Stack_Trace
      cn-LDAP_Connection_Handler_0000_port_3389
      cn-LDAP_Connection_Handler_0000_port_3389_Statistics
      cn-LDIF_Connection_Handler
      cn-Processing_Time_Histogram
      cn-System_Information
      cn-Version
      cn-Work_Queue
      cn-adminRoot_Backend
      cn-adstruststore_Backend
      cn-backup_Backend
      cn-config_Backend
      cn-monitor_Backend
      cn-schema_Backend
      cn-tasks_Backend
      cn-userRoot_Backend
      cn-userRoot_Database_Environment
  rootDSEnull
```

7. Click a monitoring entry. In this example, click the **LDAP Connection Handler** entry.


Java Monitoring & Management Console
Connection Window Help
Overview Memory Threads Classes VM Summary MBeans
Attribute values
Refresh

cn=Directory Manager@service:jmx:rmi:///jndi/rmi://localhost:1689/com.unboundid.directory.server.protocols.jmx.client...

```
JMImplementation
com.unboundid.directory.server
  rootDSE
    cn-config
    cn-monitor
      cn-Active_Operations
      cn-Client_Connections
      cn-Entry_Caches
      cn-JMX_Connection_Handler_1689
      cn-JVM_Memory_Usage
      cn-JVM_Stack_Trace
      cn-LDAP_Connection_Handler_0000_port_3389
        Attributes
          ds-connectionhandler-protocol
          ds-connectionhandler-listener
          ds-connectionhandler-connection
          ds-connectionhandler-num-connections
      cn-LDAP_Connection_Handler_0000_port_3389_St
        Attributes
      cn-LDIF_Connection_Handler
      cn-Processing_Time_Histogram
      cn-System_Information
      cn-Version
      cn-Work_Queue
      cn-adminRoot_Backend
      cn-adstruststore_Backend
      cn-backup_Backend
      cn-config_Backend
      cn-monitor_Backend
      cn-schema_Backend
      cn-tasks_Backend
```

Name	Value
abandonRequests	0
addRequests	0
addResponses	0
bindRequests	155
bindResponses	155
bytesRead	92264
bytesWritten	5150388
compareRequests	0
compareResponses	0
connectionsClosed	151
connectionsEstablished	155
deleteRequests	0
deleteResponses	0
extendedRequests	0
extendedResponses	0
ldapMessagesRead	881
ldapMessagesWritten	4383
modifyDNRequests	0
modifyDNResponses	0
modifyRequests	4
modifyResponses	4
operationsAbandoned	0
operationsCompleted	733
operationsInitiated	881
searchRequests	574
searchResultEntries	3650
searchResultReferences	0
searchResultsDone	574
unbindRequests	148

Monitoring Using the LDAP SDK

You can use the monitoring API to retrieve monitor entries from the Proxy Server as well as to retrieve specific types of monitor entries.

For example, you can retrieve all monitor entries published by the Data Store and print the information contained in each using the generic API for accessing monitor entry data as follows:

```
for (MonitorEntry e : MonitorManager.getMonitorEntries(connection))
  {
    System.out.println("Monitor Name: " + e.getMonitorName());
    System.out.println("Monitor Type: " + e.getMonitorDisplayName());
    System.out.println("Monitor Data:");
    for (MonitorAttribute a : e.getMonitorAttributes().values())
    {
      for (Object value : a.getValues())
      {
        System.out.println(" " + a.getDisplayName() + ": " + String.valueOf(value));
      }
     }
     System.out.println();
  }
```

For more information about the LDAP SDK and the methods in this example, see the *UnboundID LDAP SDK* documentation.

Monitoring over LDAP

The UnboundID Data Store exposes a majority of its information under the `cn=monitor` entry. You can access these entries over LDAP using the `ldapsearch` tool.

```
$ bin/ldapsearch --hostname server1.example.com --port 1389 \
  --bindDN "uid=admin,dc=example,dc=com" --bindPassword secret \
  --baseDN "cn=monitor" "(objectclass=*)"
```

Profiling Server Performance Using the Stats Logger

The Data Store ships with a built-in Stats Logger that is useful for profiling server performance for a given configuration. At a specified interval, the Stats Logger writes server statistics to a log file in a comma-separated format (.csv), which can be read by spreadsheet applications. The logger has a negligible impact on server performance unless the `log-interval` property is set to a very small value (less than 1 second). The statistics logged and their verbosity can be customized.

The Stats Logger can also be used to view historical information about server statistics including replication, LDAP operations, host information, and gauges. Either update the configuration of the existing Stats Logger Plugin to set the advanced `gauge-info` property to `basic/extended` to include this information, or create a dedicated Periodic Stats Logger for information about statistics of interest.

To Enable the Stats Logger

By default, the Data Store ships with the built-in "Stats Logger' disabled. To enable it using the `dsconfig` tool or the web console, go to **Plugins** menu (available on the Advanced object menu), and then, select Stats Logger.

1. Run `dsconfig` in interactive mode. Enter the LDAP or LDAPS connection parameters when prompted.

```
$ bin/dsconfig
```

2. Enter `o` to change to the Advanced Objects menu.

3. On the Data Store configuration console menu, enter the number for Plugins.

4. On the **Plugin management** menu, enter the number corresponding to view and edit an existing plug-in.

5. On the **Plugin selection** list, enter the number corresponding to the Stats Logger.

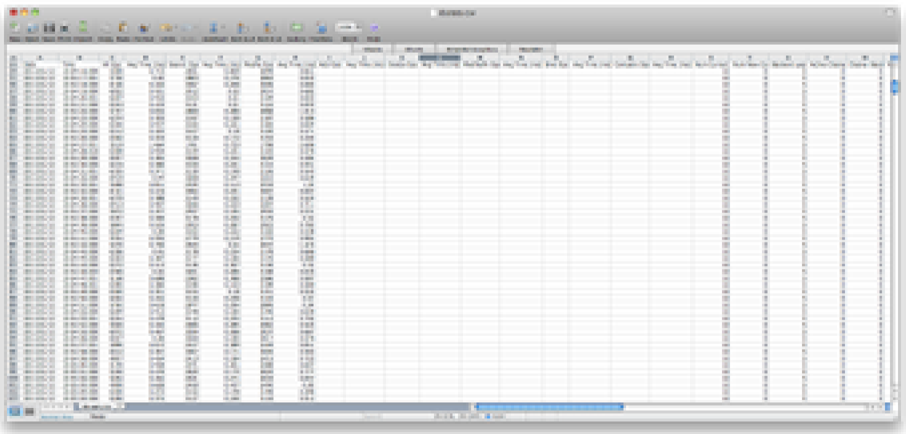
6. On the **Stats Logger Plugin** menu, enter the number to set the `enabled` property to `TRUE`. When done, enter `f` to save and apply the configuration. The default logger will log information about the server every second to `<server-root>/logs/dsstats.csv`. If the server is idle, nothing will be logged, but this can be changed by setting the `suppress-if-idle` property to `FALSE` (`suppress-if-idle=false`).

```
>>>> Configure the properties of the Stats Logger Plugin

Property                Value(s)
----------------------------------------------------------------------
1)   description        Logs performance stats to a log file
                        periodically.
2)   enabled                     false
3)   local-db-backend-info       basic
4)   replication-info            basic
5)   entry-cache-info            -
6)   host-info                   -
```

```
7)   included-ldap-application   If per-application LDAP stats is enabled,
                                 then stats will be included for all
                                 applications.
8)   log-interval                1 s
9)   collection-interval         200 ms
10)  suppress-if-idle            true
11)  header-prefix-per-column    false
12)  empty-instead-of-zero       true
13)  lines-between-header        50
14)  included-ldap-stat          active-operations, num-connections,
                                 op-count-and-latency, work-queue
15)  included-resource-stat      memory-utilization
16)  histogram-format            count
17)  histogram-op-type           all
18)  per-application-ldap-stats  aggregate-only
19)  ldap-changelog-info         -
20)  gauge-info                  none
21)  log-file                    logs/dsstats.csv
22)  log-file-permissions        640
23)  append                      true
24)  rotation-policy             Fixed Time Rotation Policy, Size Limit
                                 Rotation Policy
25)  retention-policy            File Count Retention Policy

?)   help
f)   finish - apply any changes to the Periodic Stats Logger Plugin
a)   hide advanced properties of the Periodic Stats Logger Plugin
d)   display the equivalent dsconfig command lines to either re-create this
           object or only to apply pending changes
b)   back
q)   quit

Enter choice [b]:
```

7. Run the Data Store. For example, if you are running in a test environment, you can run the `search-and-mod-rate` tool to apply some searches and modifications to the server. You can run `search-and-mod-rate --help` to see an example command.

8. View the Stats log output at `<server-root>/logs/dsstats.csv`. You can open the file in a spreadsheet. The following image displays a portion of the file's output. On the actual file, you will need to scroll right for more statistics.



To Configure Multiple Periodic Stats Loggers

Multiple Periodic Stats Loggers can be created to log different statistics, view historical information about gauges, or to create a log at different intervals (such as logging cumulative operations statistics every hour). To create a new log, use the existing Stats Logger as a template to get reasonable settings, including rotation and retention policy.

1. Run `dsconfig` by repeating steps 1–3 in *To Enable the Stats Logger*.
2. From the **Plugin management** menu, enter the number to create a new plug-in.
3. From the **Create a New Periodic Stats Logger Plugin** menu, enter `t` to use an existing plug-in as a template.
4. Enter the number corresponding to the existing stats logger as a template.
5. Next, enter a descriptive name for the new stats logger. For this example, type `Stats Logger-10s`.
6. Enter the log file path to the file. For this example, type `logs/dsstats2.csv`.
7. On the menu, make any other change to the logger. For this example, change the `log-interval` to 10s, and the `suppress-if-idle` to false. When finished, enter `f` to save and apply the configuration.
8. You should now see two loggers `dsstats.csv` and `dsstats2.csv` in the `logs` directory.

Adding Custom Logged Statistics to a Periodic Stats Logger

Add custom statistics based on any attribute in any entry under `cn=monitor` using the Custom Logged Stats object. This configuration object provides powerful controls for how monitor attributes are written to the log. For example, you can extract a value from a monitor attribute using a regular expression. Newly created Custom Logged Stats will automatically be included in the Periodic Stats Logger output.

Besides allowing a straight pass-through of the values using the 'raw' statistic-type, you can configure attributes to be treated as a counter (where the interval includes the difference in the value since the last interval), an average, a minimum, or a maximum value held by the attribute during the specified interval. The value of an attribute can also be scaled by a fixed value or by the value of another monitor attribute.

Note: Custom third-party server extensions that were written using the Server SDK can also expose interval statistics using a Periodic Stats Logger. The extension must first implement the SDK's `MonitorProvider` interface and register with the server. The monitor attributes produced by this custom `MonitorProvider` are then available to be referenced by a Custom Logged Stats object.

To illustrate how to configure a Custom Logged Statistics Logger, the following procedure reproduces the built-in "Consumer Total GB" column that shows up in the output when the `included-resource-stat` property is set to memory-utilization on the Periodic Stats Logger. The column is derived from the `total-bytes-used-by-memory-consumers` attribute of the `cn=JVM Memory Usage,cn=monitor` entry as follows:

```
dn: cn=JVM Memory Usage,cn=monitor
objectClass: top
objectClass: ds-monitor-entry
objectClass: ds-memory-usage-monitor-entry
objectClass: extensibleObject
cn: JVM Memory Usage
...
total-bytes-used-by-memory-consumers: 3250017037
```

To Configure a Custom Logged Statistic Using dsconfig Interactive

1. Run `dsconfig` and enter the LDAP/LDAPS connection parameters when prompted.

   ```
   $ bin/dsconfig
   ```

2. On the Data Store configuration main menu (Advanced Objects menu), enter the number corresponding to Custom Logged Stats.

3. On the Custom Logged Stats menu, enter the number corresponding to Create a new Custom Logged Stats.

4. Select the Stats Logger Plugin from the list if more than one is present on the system. If you only have one stats logger, press **Enter** to confirm that you want to use the existing plugin.

5. Enter a descriptive name for the Custom Logged Stats. For this example, enter `Memory Usage`.

6. From the `monitor-objectclass` property menu, enter the objectclass attribute to monitor. For this example, enter `ds-memory-usage-monitor-entry`. You can run `ldapsearch` using the base DN "cn=JVM Memory Usage,cn=monitor" entry to view the entry.

7. Next, specify the attributes of the monitor entry that you want to log in the stats logger. In this example, enter `total-bytes-used-by-memory-consumers`, and then press **Enter** again to continue.

8. Next, specify the type of statistics for the monitored attribute that will appear in the log file. In this example, enter the option for raw statistics as recorded by the logger.

9. In the Custom Logged Stats menu, review the configuration. At this point, we want to set up a column name that lists the Memory Usage. Enter the option to change the `column-name` property.

10. Next, we want to add a specific label for the column name. Enter the option to add a value, and then enter **Memory Consumer Total (GB)**, and press **Enter** again to continue.

11. Confirm that you want to use the `column-name` value that you entered in the previous step, and then press `Enter` to use the value.

12. Next, we want to scale the Memory Consumer Totals by one gigabyte. On the **Custom Logged Stats** menu, enter the option to change the `divide-value-by` property.

13. On the `divide-value-by` property menu, enter the option to change the value, and then enter 1073741824 (i.e., 1073741824 bytes = 1 gigabytes).

14. On the **Custom Logged Stats** menu, review your configuration. When finished, enter `f` to save and apply the settings.

```
>>>> Configure the properties of the Custom Logged Stats
 >>>> via creating 'Memory Usage' Custom Logged Stats

         Property                   Value(s)
         ---------------------------------------------------------------
    1)   description                -
    2)   enabled                    true
    3)   monitor-objectclass        ds-memory-usage-monitor-entry
    4)   include-filter             -
    5)   attribute-to-log           total-bytes-used-by-memory-consumers
    6)   column-name                Memory Consumer Total (GB)
    7)   statistic-type             raw
    8)   header-prefix              -
    9)   header-prefix-attribute    -
    10)  regex-pattern              -
    11)  regex-replacement          -
    12)  divide-value-by            1073741824
    13)  divide-value-by-attribute  -
    14)  decimal-format             #.##
    15)  non-zero-implies-not-idle  false

    ?)   help
    f)   finish - create the new Custom Logged Stats
    a)   hide advanced properties of the Custom Logged Stats
    d)   display the equivalent dsconfig arguments to create this object
    b)   back
    q)   quit

Enter choice [b]:
```

```
The Custom Logged Stats was created successfully
```

When the Custom Logged Stats configuration change is completed, the new stats value should immediately show up in the Stats Logger output file.

To Configure a Custom Stats Logger Using dsconfig Non-Interactive

- Use the `dsconfig` non-interactive command-line equivalent to create your custom stats logger. The following one-line command replicates the procedure in the previous section. This command produces a column named "Memory Consumer Total (GB)" that contains the value of the of `total-bytes-used-by-memory-consumers` attribute pulled from the entry with the `ds-memory-usage-monitor-entry` objectclass. This value is scaled by 1073741824 to get to a value represented in GBs.

```
$ bin/dsconfig create-custom-logged-stats --plugin-name "Stats Logger" \
  --stats-name "Memory Usage" --type custom \
  --set monitor-objectclass:ds-memory-usage-monitor-entry \
  --set attribute-to-log:total-bytes-used-by-memory-consumers \
  --set "column-name:Memory Consumer Total (GB)" --set statistic-type:raw \
  --set divide-value-by:1073741824
```

Chapter 23 Managing Notifications and Alerts

The UnboundID Data Store provides delivery mechanisms for account status notifications and administrative alerts using SMTP, JMX, or SNMP in addition to standard error logging. Alerts and events reflect state changes within the server that may be of interest to a user or monitoring service. Notifications are typically the delivery of an alert or event to a user or monitoring service. Account status notifications are only delivered to the account owner notifying a change in state in the account.

This chapter presents the following topics:

Topics:

Working with Account Status Notifications

The UnboundID Data Store supports notification handlers that can be used to notify users and/ or administrators of significant changes related to password policy state for user entries. The following two notification handlers are available:

- **Error Log Account Status Notification Handler**. Enabled by default. The handlers send alerts to the error log when an account event occurs.
- **SMTP Account Status Notification Handler**. Disabled by default. You can enable the SMTP Handler with the `dsconfig` command to send notifications to designated email addresses.

Account Status Notification Types

The handlers send alerts when one of the account status events described in the following table occurs during password policy processing.

Table 65: Account Status Notification Types

Account Status Notification Types	Description
account-disabled	Generates a notification whenever a user account is disabled by an administrator.
account-enabled	Generates a notification whenever a user account is enabled by an administrator.
account-expired	Generates a notification whenever a user authentication attempt fails because the account has expired.
account-idle-locked	Generates a notification whenever a user authentication attempt fails because the account has been locked after idling for too long.
account-permanently-locked	Generates a notification whenever a user account is permanently locked (requiring administrative action to unlock the account) after too many failed attempts.
account-reset-locked	Generates a notification whenever an authentication attempt fails because the user account is locked because the user failed to change a password within the required interval that was reset by an administrator.
account-temporarily-locked	Generates a notification whenever a user account is temporarily locked after too many failed attempts.
account-unlocked	Generates a notification whenever a user account is unlocked by an administrator.
password-changed	Generates a notification whenever a user changes his or her own password.
password-expired	Generates a notification whenever a user authentication fails because the password has expired.
password-expiring	Generates a notification the first time that a password expiration warning is encountered for a user password.
password-reset	Generates a notification whenever a user's password is reset by an administrator.

Working with the Error Log Account Status Notification Handler

The Error Log Account Status Notification Handler is enabled by default and sends alerts when one of the account status events occur.

To Disable the Error Log Account Status Notification Handler

- Use the `dsconfig` tool to disable the Error Log Handler. You can view the log at `logs/error`.

```
$ bin/dsconfig set-account-status-notification-handler-prop \
  ---handler-name "Error Log Handler" --set enabled:false
```

To Remove a Notification Type from the Error Log Handler

- While not recommended, if you want to remove an account status notification type, use the `dsconfig` tool with the `--remove` option.

```
$ bin/dsconfig set-account-status-notification-handler-prop \
  --handler-name "Error Log Handler" \
  --remove account-status-notification-type: password-reset
```

Working with the SMTP Account Status Notification Handler

You can enable account status notifications to be sent to designated email addresses of end users, administrators, or both through an outgoing SMTP server. The email message is automatically generated from template files that contain the text to use in the message body. For example, the message subject for the account-disabled event is:

```
account-disabled: Your directory account has been disabled.
```

The message templates are located in the `config/messages` directory. The typical message body template is as follows:

```
Your directory account has been disabled.

For further assistance, please contact a server administrator.
```

By default, the sender address is notifications@example.com, but you can configure your own address.

Before you enable the SMTP Account Status Notification Handler, you must configure the Data Store to use at least one mail server as shown below. You can configure an SMTP server using `dsconfig` and the `set-global-configuration-prop` option.

To Configure the SMTP Server

1. Use `dsconfig` to configure a simple mail server.

```
$ bin/dsconfig create-external-server --server-name smtp1 \
  --type smtp --set server-host-name:smtp.example.com
```

2. Use `dsconfig` to configure an SMTP server. This command adds the server to the global list of mail servers that the Data Store can use.

```
$ bin/dsconfig set-global-configuration-prop \
  --set smtp-server:smtp1
```

To Configure a StartTLS Connection to the SMTP Server

1. Use `dsconfig` to configure a StartTLS connection to the server.

```
$ bin/dsconfig create-external-server \
  --server-name myTLSServer --type smtp \
  --set server-host-name:tls.smtp.example.com \
  --set server-port:587 \
  --set smtp-security:starttls \
  --set user-name:MyAccountName \
  --set "password:"password:AAD5yZ+DjvwiYkBSMer6GQ6B3szQ6gSSBjA="
```

2. Use `dsconfig` to configure a newly-created SMTP server. This command adds the server to the global list of mail servers that the Data Store can use.

```
$ bin/dsconfig set-global-configuration-prop \
  -set smtp-server:myTLSServer
```

To Configure an SSL Connection to the SMTP Server

1. Use `dsconfig` to create an external SMTP server using SSL.

```
$ bin/dsconfig create-external-server \
  --server-name ssl.smtp.example.com \
  --type smtp --set server-host-name:stmp.gmail.com \
  --set server-port:465 \
  --set smtp-security:ssl \
  --set ’username:my.name@example.com’ \
  --set password:xxxxxx --set "smtp-timeout:10s"
```

2. Use `dsconfig` to configure an SMTP server. This command adds the server to the global list of mail servers that the Data Store can use.

```
$ bin/dsconfig set-global-configuration-prop \
  --set smtp-server:ssl.smtp.example.com
```

To Enable the SMTP Account Status Notification Handler

- Use `dsconfig` to enable the SMTP account status notification handler.

```
$ bin/dsconfig set-account-status-notification-handler-prop \
  --handler-name "SMTP Server" --set enabled:true \
  --set "recipient-address:admin@example.com" \
  --set "sender-address:acct-status-notifications@example.com
```

To View the Account Status Notification Handlers

- After you have enabled the SMTP server, view the list of account status notification handlers using `dsconfig`.

```
$ bin/dsconfig list-account-status-notification-handlers
```

```
Account Status Notification Handler : Type      : enabled
------------------------------------:-----------:--------
Error Log Handler                   : error-log : true
SMTP Handler                        : smtp      : true
```

Associating Account Status Notification Handlers with Password Policies

To generate notifications whenever appropriate password policy state changes occur in the server, the password policy that governs the entry being updated must be configured to use one or more account status notification handlers. By default, password policies are not configured with any such handlers, and therefore, no account status notifications will be generated.

The set of account status notification handlers that should be in use for a password policy is controlled by the `account-status-notification-handler` property for that password policy. It can be configured using `dsconfig` or the web administration console. For example, the following change updates the default password policy, so that the error log account status notification handler will be invoked for any appropriate password policy state changes for entries governed by the default password policy:

```
$ bin/dsconfig set-password-policy-prop \
  --policy-name "Default Password Policy" \
  --set "account-status-notification-handler:Error Log Handler"
```

Working with Administrative Alert Handlers

The UnboundID Data Store provides mechanisms to send alert notifications to administrators when significant problems or events occur during processing, such as problems during server startup or shutdown. The Data Store provides a number of alert handler implementations, including:

- **Error Log Alert Handler**. Sends administrative alerts to the configured server error logger(s).
- **Exec Alert Handler**. Executes a specified command on the local system if an administrative alert matching the criteria for this alert handler is generated by the Data Store. Information about the administrative alert will be made available to the executed application as arguments provided by the command.
- **Groovy Scripted Alert Handler**. Provides alert handler implementations defined in a dynamically-loaded Groovy script that implements the `ScriptedAlertHandler` class defined in the Server SDK.

- **JMX Alert Handler**. Sends administrative alerts to clients using the Java Management Extensions (JMX) protocol. UnboundID uses JMX for monitoring entries and requires that the JMX connection handler be enabled.
- **SMTP Alert Handler**. Sends administrative alerts to clients via email using the Simple Mail Transfer Protocol (SMTP). The server requires that one or more SMTP servers be defined in the global configuration.
- **SNMP Alert Handler**. Sends administrative alerts to clients using the Simple Network Monitoring Protocol (SNMP). The server must have an SNMP agent capable of communicating via SNMP 2c.
- **SNMP Subagent Alert Handler**. Sends SNMP traps to a master agent in response to administrative alerts generated within the server.
- **Third Party Alert Handler**. Provides alert handler implementations created in third-party code using the Server SDK.

Administrative Alert Types

If enabled, the Data Store can generate administrative alerts when the events occur. A full listing of system alerts and their severity is available in `<server-root>/docs/admin-alerts-list.csv`

Configuring the JMX Connection Handler and Alert Handler

You can configure the JMX connection handler and alert handler respectively using the `dsconfig` tool. Any user allowed to receive JMX notifications must have the `jmx-read` and `jmx-notify` privileges. By default, these privileges are not granted to any users (including root users or global administrators). For security reasons, we recommend that you create a separate user account that does not have any other privileges but these. Although not shown in this section, you can configure the JMX connection handler and alert handler using `dsconfig` in interactive command-line mode, which is visible on the "Standard" object menu.

To Configure the JMX Connection Handler

1. Use `dsconfig` to enable the JMX Connection Handler.

```
$ bin/dsconfig set-connection-handler-prop \
  --handler-name "JMX Connection Handler" \
  --set enabled:true \
  --set listen-port:1689
```

2. Add a new non-root user account with the `jmx-read` and `jmx-notify` privileges. This account can be added using the `ldapmodify` tool using an LDIF representation like:

```
dn: cn=JMX User,cn=Root DNs,cn=config
changetype: add
objectClass: top
```

```
objectClass: person
objectClass: organizationalPerson
objectClass: inetOrgPerson
objectClass: ds-cfg-root-dn-user
givenName: JMX
sn: User
cn: JMX User
userPassword: password
ds-cfg-inherit-default-root-privileges: false
ds-cfg-alternate-bind-dn: cn=JMX User
ds-privilege-name: jmx-read
ds-privilege-name: jmx-notify
```

To Configure the JMX Alert Handler

- Use `dsconfig` to configure the JMX Alert Handler.

```
$ bin/dsconfig set-alert-handler-prop --handler-name "JMX Alert Handler" \
  --set enabled:true
```

Configuring the SMTP Alert Handler

By default, there is no configuration entry for an SMTP alert handler. To create a new instance of an SMTP alert handler, use the `dsconfig` tool.

Configuring the SMTP Alert Handler

- Use the `dsconfig` tool to configure the SMTP Alert Handler.

```
$ bin/dsconfig create-alert-handler \
  --handler-name "SMTP Alert Handler" \
  --type smtp \
  --set enabled:true \
  --set "sender-address:alerts@example.com" \
  --set "recipient-address:administrators@example.com" \
  --set "message-subject:Directory Admin Alert \%\%alert-type\%\%" \
  --set "message-body:Administrative alert:\\n\%\%alert-message\%\%"
```

Configuring the SNMP Subagent Alert Handler

You can configure the SNMP Subagent alert handler using the `dsconfig` tool, which is visible at the "Standard" object menu. Before you begin, you need an SNMP Subagent capable of communicating via SNMP2c. For more information on SNMP, see Monitoring Using SNMP.

To Configure the SNMP Subagent Alert Handler

- Use `dsconfig` to configure the SNMP subagent alert handler. The `server-host-name` is the address of the system running the SNMP subagent. The `server-port` is the port number on which the subagent is running. The `community-name` is the name of the SNMP community that is used for the traps.

The Data Store also supports a SNMP Alert Handler, which is used in deployments that do not enable an SNMP subagent.

```
$ bin/dsconfig set-alert-handler-prop \
  --handler-name "SNMP Subagent Alert Handler" \
  --set enabled:true \
  --set server-host-name:host2 \
  --set server-port:162 \
  --set community-name:public
```

Working with the Alerts Backend

The Data Store stores recently generated admin alerts in an Alerts Backend under the `cn=alerts` branch. The backend makes it possible to obtain admin alert information over LDAP for use with remote monitoring. The backend's primary job is to process search operations for alerts. It does not support add, modify, or modify DN operations of entries in the `cn=alerts` backend.

The alerts persist on disk in the `config/alerts.ldif` file so that they can survive server restarts. By default, the alerts remain on disk for seven days before being removed. However, administrators can configure the number of days for alert retention using the `dsconfig` tool. The administrative alerts of Warning level or worse that have occurred in the last 48 hours are viewable from the output of the status command-line tool and in the Management Console.

To View Information in the Alerts Backend

- The following uses `ldapsearch` to view the admin alerts.

```
$ bin/ldapsearch --port 1389 --bindDN "cn=Directory Manager" \
  --bindPassword secret --baseDN cn=alerts "(objectclass=ds-admin-alert)"
```

```
dn: ds-alert-id=3d1857a2-e8cf-4e80-ac0e-ba933be59eca,cn=alerts
objectClass: top
objectClass: ds-admin-alert
ds-alert-id: 3d1857a2-e8cf-4e80-ac0e-ba933be59eca
ds-alert-type: server-started
ds-alert-severity: info
ds-alert-type-oid: 1.3.6.1.4.1.32473.2.11.33
ds-alert-time: 20110126041442.622Z
ds-alert-generator: com.unboundid.directory.server.core.directory.server
ds-alert-message: The Data Store has started successfully
```

To Modify the Alert Retention Time

1. Use `dsconfig` to change the maximum time information about generated admin alerts is retained in the Alerts backend. After this time, the information gets purged from the Data Store. The minimum retention time is 0 milliseconds, which immediately purges the alert information.

```
$ bin/dsconfig set-backend-prop --backend-name "alerts" \
  --set "alert-retention-time: 2 weeks"
```

2. View the property using `dsconfig`.

```
$ bin/dsconfig get-backend-prop --backend-name "alerts" \
  --property alert-retention-time
```

```
Property : Value(s)
--------------------:---------
alert-retention-time : 2 w
```

To Configure Duplicate Alert Suppression

- Use `dsconfig` to configure the maximum number of times an alert is generated within a particular timeframe for the same condition. The `duplicate-alert-time-limit` property specifies the length of time that must pass before duplicate messages are sent over the administrative alert framework. The `duplicate-alert-limit` property specifies the maximum number of duplicate alert messages should be sent over the administrative alert framework in the time limit specified in the `duplicate-alert-time-limit` property.

```
$ bin/dsconfig set-global-configuration-prop \
  --set duplicate-alert-limit:2 \
  --set "duplicate-alert-time-limit:3 minutes"
```

Working with Alarms, Alerts, and Gauges

An alarm represents a stateful condition of the server or a resource that may indicate a problem, such as low disk space or external server unavailability. A gauge defines a set of threshold values with a specified severity that, when crossed, cause the server to enter or exit an alarm state. Gauges are used for monitoring continuous values like CPU load or free disk space (Numeric Gauge), or an enumerated set of values such as 'server unavailable' or ‘server unavailable’ (Indicator Gauge). Gauges generate alarms, when the gauge’s severity changes due to changes in the monitored value. Like alerts, alarms have severity (NORMAL, WARNING, MINOR, MAJOR, CRITICAL), name, and message. Alarms will always have a Condition property, and may have a Specific Problem or Resource property. If surfaced through SNMP, a Probable Cause property and Alarm Type property are also listed. Alarms can be configured to generate alerts when the alarm's severity changes. The Alarm Manager, which governs the actions performed when an alarm state is entered, is configurable through the `dsconfig` tool and Management Console. A complete listing of system alerts, alarms, and their severity is available in `<server-root>/docs/admin-alerts-list.csv`.

There are two alert types supported by the server - standard and alarm-specific. The server constantly monitors for conditions that may need attention by administrators, such as low disk space. For this condition, the standard alert is `low-disk-space-warning`, and the alarm-specific alert is `alarm-warning`. The server can be configured to generate alarm-specific alerts instead of, or in addition to, standard alerts. By default, standard alerts are generated for conditions internally monitored by the server. However, gauges can only generate alarm-alerts.

The Data Store installs a set of gauges that are specific to the product and that can be cloned or configured through the `dsconfig` tool. Existing gauges can be tailored to fit each environment by adjusting the update interval and threshold values. Configuration of system gauges determines the criteria by which alarms are triggered. The Stats Logger can be used to view historical information about the value and severity of all system gauges.

The Data Store is compliant with the International Telecommunication Union CCITT Recommendation X.733 (1992) standard for generating and clearing alarms. If configured, entering or exiting an alarm state can result in one or more alerts. An alarm state is exited when the condition no longer applies. An `alarm_cleared` alert type is generated by the system when an alarm's severity changes from a non-normal severity to any other severity. An `alarm_cleared` alert will correlate to a previous alarm when the Condition and Resource properties are the same. The Condition corresponds to the Summary column in the `admin-alerts-list.csv` file.

Like the Alerts Backend, which stores information in `cn=alerts`, the Alarm Backend stores information within the `cn=alarms` backend. Unlike alerts, alarm thresholds have a state over time that can change in severity and be cleared when a monitored value returns to normal. Alarms can be viewed with the `status` tool. As with other alert types, alert handlers can be configured to manage the alerts generated by alarms.

To View Information in the Alarms Backend

- The following uses `ldapsearch` to view alarms. The following displays the listing for the CPU usage alarm.

```
$ bin/ldapsearch --port 1389 --bindDN "cn=Directory Manager" \
  --bindPassword secret --baseDN cn=alarms "(objectclass=ds-admin-alarm)"
```

```
dn: ds-alarm-id=CPU Usage (Percent)-Host System,cn=alarms
dn: ds-alarm-id=CPU Usage (Percent)-Host System,cn=alarms
objectClass: top
objectClass: ds-admin-alarm
ds-alarm-id: CPU Usage (Percent)-Host System
ds-alarm-condition: CPU Usage (Percent)
ds-alarm-specific-resource: Host System
ds-alarm-severity: CRITICAL
ds-alarm-previous-severity: CRITICAL
ds-alarm-details: Gauge CPU Usage (Percent) for Host System
       has value 99, having had a value of 83.13 in the
       previous interval. The severity is critical, having
       assumed this severity Thu Sep 25 10:24:20 CDT 2014
       when the value crossed threshold 80
ds-alarm-additional-text: If CPU use is high, check the server's current workload
       and other processes on this system and make any needed adjustments. Reducing
       the load on the system will lead to better response times
ds-alarm-start-time: 20140925152420.004Z
ds-alarm-critical-last-time: 20140925152420.004Z
ds-alarm-critical-total-duration-millis: 0
```

Testing Alerts and Alarms

After alarms and alert handlers are configured, verify that the server takes the appropriate action when an alarm state changes by manually increasing the severity of a gauge. Alarms and alerts can be verified with the `status` tool.

To Test Alarms and Alerts

1. Configure a gauge with `dsconfig` and set the `override-severity` property to critical. The following example uses the CPU Usage (Percent) gauge.

```
$ dsconfig set-gauge-prop \
  --gauge-name "CPU Usage (Percent)" \
  --set override-severity:critical
```

2. Run the `status` tool to verify that an alarm was generated with corresponding alerts. The `status` tool provides a summary of the server's current state with key metrics and a list of recent alerts and alarms. The sample output has been shortened to show just the alarms and alerts information.

```
$ bin/status

                        --- Administrative Alerts ---
 Severity : Time            : Message
 ---------:-----------------:--------------------------------------------------
 Info     : 11/Aug/2014     : A configuration change has been made in the
          : 15:48:46 -0500  : Data Store:
          :                 : [11/Aug/2014:15:48:46.054 -0500]
          :                 : conn=17 op=73 dn='cn=Directory Manager,cn=Root
          :                 : DNs,cn=config' authtype=[Simple] from=127.0.0.1
          :                 : to=127.0.0.1 command='dsconfig set-gauge-prop
          :                 :  --gauge-name 'Cleaner Backlog (Number Of Files)'
          :                 : --set warning-value:-1'
 Info     : 11/Aug/2014     : A configuration change has been made in the
          :  15:47:32 -0500 : Data Store: [11/Aug/2014:15:47:32.547 -0500]
          :                 : conn=4 op=196 dn='cn=Directory Manager,cn=Root
          :                 : DNs,cn=config' authtype=[Simple] from=127.0.0.1
          :                 : to=127.0.0.1 command='dsconfig set-gauge-prop
          :                 : --gauge-name 'Cleaner Backlog (Number Of Files)'
          :                 :  --set warning-value:0'
 Error    : 11/Aug/2014     : Alarm [CPU Usage (Percent). Gauge CPU Usage (Percent)
          :  15:41:00 -0500 : for Host System has
          :                 : a current value of '18.583333333333332'.
          :                 : The severity is currently OVERRIDDEN in the
          :                 : Gauge's configuration to 'CRITICAL'.
          :                 : The actual severity is: The severity is
          :                 : currently 'NORMAL', having assumed this severity
          :                 : Mon Aug 11 15:41:00 CDT 2014. If CPU use is high,
          :                 : check the server's current workload and make any
          :                 : needed adjustments. Reducing the load on the system
          :                 : will lead to better response times.
          :                 : Resource='Host System']
          :                 : raised with critical severity
Shown are alerts of severity [Info,Warning,Error,Fatal] from the past 48 hours
 Use the --maxAlerts and/or --alertSeverity options to filter this list
```

```
                         --- Alarms ---
 Severity : Severity Start : Condition : Resource     : Details
          : Time           :           :              :
 ---------:----------------:-----------:--------------:------------------------------
 Critical : 11/Aug/2014    : CPU Usage : Host System  : Gauge CPU Usage (Percent) for
          : 15:41:00 -0500 : (Percent) :              : Host System
          :                :           :              : has a current value of
          :                :           :              : '18.785714285714285'.
          :                :           :              : The severity is currently
          :                :           :              : 'CRITICAL', having assumed
          :                :           :              : this severity Mon Aug 11
          :                :           :              : 15:49:00 CDT 2014. If CPU use
          :                :           :              : is high, check the server's
          :                :           :              : current workload and make any
          :                :           :              : needed adjustments. Reducing
          :                :           :              : the load on the system will
          :                :           :              : lead to better response times
 Warning  : 11/Aug/2014    : Work Queue: Work Queue   : Gauge Work Queue Size (Number
          : 15:39:40 -0500 : Size      :              : of Requests) for Work Queue
          :                : (Number of:              : has a current value of '27'.
          :                : Requests) :              : The severity is currently
          :                :           :              : 'WARNING' having assumed this
          :                :           :              : severity Mon Aug 11 15:48:50
          :                :           :              : CDT 2014. If all worker
          :                :           :              : threads are busy processing
          :                :           :              : other client requests, then
          :                :           :              : new requests that arrive will
          :                :           :              : be forced to wait in the work
          :                :           :              : queue until a worker thread
          :                :           :              : becomes available
```

```
Shown are alarms of severity [Warning,Minor,Major,Critical]
Use the --alarmSeverity option to filter this list
```

Indeterminate Alarms

Indeterminate alarms are raised for a server condition for which a severity cannot be determined. In most cases these alarms are benign and do not issue alerts nor appear in the output of the `status` tool or Web Console by default. These alarms are usually caused by an enabled gauge that is intended to measure an aspect of the server that is not currently enabled. For example, gauges intended to monitor metrics related to replication may produce indeterminate alarms if a Data Store is not currently replicating data. The gauge can be disabled if needed.

For more information about indeterminate alarms, view the gauge's associated monitor entry. There may be messages that can help determine the issue. The following is sample output from the `status` tool run with the –`alarmSeverity=indeterminate` option:

```
                         --- Alarms ---
Severity     : Severity Start : Condition      : Resource   : Details
             : Time           :                :            :
-------------:----------------:----------------:------------:------------------------
Normal       : 26/Aug/2014    : Startup Begun  : cn=config  : The Data Store
             : 14:16:29 -0500 :                :            : is starting.
             :                :                :            :
Indeterminate: 26/Aug/2014    : Replication    : not        : The value of gauge
             : 14:16:40 -0500 : Latency        : available  : Replication Latency
             :                : (Milliseconds) :            : (Milliseconds) could not
             :                :                :            : be determined. The
             :                :                :            : severity is INDETERMINATE,
             :                :                :            : having assumed this
             :                :                :            : severity Tue Aug 26
             :                :                :            : 14:17:10 CDT 2014.
```

The following is an indeterminate alarm for the Replication Latency (Milliseconds) gauge. The following is a sample search of the monitor backend for this gauge’s entry. The result is an error message may explain the indeterminate severity:

```
# ldapsearch -w password --baseDN "cn=monitor"  \
-D"cn=directory manager" gauge-name="Replication Latency (Milliseconds)"

dn: cn=Gauge Replication Latency (Milliseconds),cn=monitor
objectClass: top
objectClass: ds-monitor-entry
objectClass: ds-numeric-gauge-monitor-entry
objectClass: ds-gauge-monitor-entry
objectClass: extensibleObject
cn:          Gauge Replication Latency (Milliseconds)
gauge-name:  Replication Latency (Milliseconds)
resource:
severity:    indeterminate
summary:     The value of gauge Replication Latency (Milliseconds) could not
             be determined. The severity is INDETERMINATE, having assumed
             this severity Tue Aug 26 15:42:40 CDT 2014
error-message: No entries were found under cn=monitor having object
               class ds-replica-monitor-entry
              …
```

Chapter 24 Managing the SCIM Servlet Extension

The UnboundID Data Store provides a System for Cross-domain Identity Management (SCIM) servlet extension to facilitate moving users to, from, and between cloud-based Software-as-a-Service (SaaS) applications in a secure, fast, and simple way. SCIM is an alternative to LDAP, allowing identity data provisioning between cloud-based applications over HTTPS.

This section describes fundamental SCIM concepts and provides information on configuring SCIM on your server.

Topics:

Overview of SCIM Fundamentals

Understanding the basic concepts of SCIM can help you use the SCIM extension to meet the your deployment needs. SCIM allows you to:

- **Provision identities.** Through the API, you have access to the basic create, read, update, and delete functions, as well as other special functions.
- **Provision groups.** SCIM also allows you to manage groups.
- **Interoperate using a common schema.** SCIM provides a well-defined, platform-neutral user and group schema, as well as a simple mechanism to extend it.

The SCIM extension implements the 1.1 version of the SCIM specification. Familiarize yourself with this specification to help you understand and make efficient use of the SCIM extension and the SCIM SDK. The SCIM specifications are located on the Simplecloud website.

Summary of SCIM Protocol Support

UnboundID implements all required features of the SCIM protocol and most optional features. The following table describes SCIM features and whether they are supported by UnboundID.

Table 66: SCIM Protocol Support

SCIM Feature	Supported
JSON	Yes
XML*	Yes
Authentication/Authorization	Yes, via HTTP basic authentication or OAuth 2.0 bearer tokens
Service Provider Configuration	Yes
Schema	Yes
User resources	Yes
Group resources	Yes
User-defined resources	Yes
Resource retrieval via GET	Yes
List/query resources	Yes
Query filtering*	Yes
Query result sorting*	Yes
Query result pagination*	Yes (Data Store, not Proxy Server)
Resource updates via PUT	Yes
Partial resource updates via PATCH*	Yes
Resource deletes via DELETE	Yes
Resource versioning*	Yes (requires configuration for updated servers)
Bulk*	Yes
HTTP method overloading	Yes
Raw LDAP Endpoints**	Yes

* denotes an optional feature of the SCIM protocol.

** denotes an UnboundID extension to the basic SCIM functionality.

About the Identity Access API

The UnboundID Data Store, UnboundID Proxy Server, and UnboundID Data Sync Server support an extension to the SCIM standard called the Identity Access API. The Identity Access API provides an alternative to LDAP by supporting CRUD (create, read, update, and delete) operations to access data store data over an HTTP connection.

SCIM and the Identity Access API are provided as a unified service through the SCIM HTTP Servlet Extension. The SCIM HTTP Servlet Extension can be configured to only enable core SCIM resources (e.g., 'Users' and 'Groups'), only LDAP object classes (e.g., `top`, `domain`, `inetOrgPerson`, or `groupOfUniqueNames`), or both. Because SCIM and the Identity Access API have different schemas, if both are enabled, there may be two representations with different schemas for any resources defined in the `scim-resources.xml` file: the SCIM representation and the raw LDAP representation. Likewise, because resources are exposed by an LDAP object class, and because these are hierarchical (e.g., `top` --> `person` --> `organizationalPerson` --> `inetOrgPerson`, etc.), a client application can access an entry in multiple ways due to the different paths/URIs to a given resource.

This chapter provides information on configuring the SCIM and the Identity Access API services on the UnboundID Data Store.

Configuring SCIM

This section discusses details about the UnboundID implementation of the SCIM protocol. Before reading this chapter, familiarize yourself with the SCIM Protocol specification, available on the Simplecloud website.

Creating Your Own SCIM Application

The System for Cross-domain Identity Management (SCIM) is an open initiative designed to make moving identity data to, from, and between clouds standard, secure, fast, and easy. UnboundID provides an open source SCIM SDK and Reference Implementation with which you can build a SCIM application.

The SCIM SDK is a pre-packaged collection of libraries and extensible classes that provides developers with a simple, concrete API to interact with a SCIM service provider. The reference implementation uses the UnboundID SCIM SDK, UnboundID LDAP SDK for Java, and other open source libraries.

The UnboundID SCIM Reference Implementation is an easy-to-use, self-contained implementation of a SCIM Service Provider (server) and consumer (client). The server is built on the UnboundID In-Memory Data Store and allows for custom mappings between LDAP and

SCIM data models. The reference implementation supports all required aspects of the SCIM API, schema, and schema extension model.

The SCIM SDK is available for download at www.unboundid.com/resources/scim.

Note: The value of a read-only SCIM attribute can be set by a POST operation if the SCIM attribute is a custom attribute in the `scim-resource.xml` config file, but not if the SCIM attribute is a core SCIM attribute.

Configuring the SCIM Servlet Extension

The Data Store provides a default SCIM HTTP Servlet Extension that can be enabled and configured using a `dsconfig` batch script located in the `config` directory. The script runs a series of commands that enables an HTTPS Connection Handler, increases the level of detail logged by the HTTP Detailed Access log publisher, and adds access controls to allow access to LDAP controls used by the SCIM Servlet Extension. There are additional optional configurations (e.g., changing the log format, enable `entryDN` virtual attribute and using VLV indexes) that you can make by altering the `dsconfig` batch script.

The SCIM resource mappings are defined by the `scim-resources.xml` file located in the `config` directory. This file defines the SCIM schema and maps it to the LDAP schema. This file can be customized to define and expose deployment specific resources. See *Managing the SCIM Schema* for more information.

The following procedures show how to configure SCIM on the server. The first example procedure shows the steps to manually configure SCIM without using the script. The second example procedure uses the `dsconfig` batch script to configure SCIM.

To Configure SCIM Manually

The following example procedure assumes that you have configured the Data Store using the default settings, which means that SSL and the HTTPS Connection Handler have not been configured. The example also shows the `dsconfig` non-interactive commands. You can easily use the `dsconfig` interactive commands, which uses a menu-driven interface. If you use the `dsconfig` interactive, you must change to the Standard or Advanced object menu to access many of these configuration settings.

1. Set up your certificates. Follow the examples shown in the section *Managing Certificates*. You should have a keystore and truststore set up in the `config` directory. Make sure that the keystore.pin and truststore.pin are set.

2. Enable the key manager provider. The key manager provider accesses the certificate during the SSL handshaking process. If running `dsconfig` interactive, open the configuration console main menu, select "Key Manager Provider" -> "View and edit an existing Key Manager Provider" -> "JKS" (or the type of certificate you are working with) -> "enabled" and then set the value to "true". Click "finish" to save the setting.

```
$ bin/dsconfig create-key-manager-provider --provider-name JKS \
  --type file-based --set enabled:true --set key-store-file:config/keystore \
  --set key-store-type:JKS --set key-store-pin-file:config/keystore.pin
```

3. Enable the trust manager provider. The trust manager provider determines if a presented certificate can be trusted. If running `dsconfig` interactive, open the configuration console main menu, select "Trust Manager Provider" -> "View and edit an existing Trust Manager Provider" -> "JKS" (or the type of certificate you are working with) -> "enabled" and then set the value to "true". Click "finish" to save the setting.

```
$ bin/dsconfig create-trust-manager-provider --provider-name JKS \
  --type file-based --set enabled:true --set trust-store-file:config/truststore \
  --set trust-store-type:JKS --set trust-store-pin-file:config/truststore.pin
```

4. Configure the HTTPS Connection Handler. The command enables the connection handler, specifies the SCIM HTTP servlet extension and sets the listen port to a port of your choice, in this example, use 8443. The command also specifies the type of key manager and trust manager providers and sets the log publisher to "HTTP Detailed Access." If running `dsconfig` interactive, open the configuration console main menu, select "Connection Handler" -> "View and edit an existing Connection Handler" -> "HTTPS Connection Handler". Change the parameters to match your setup, and then, click "finish" to save the setting.

```
$ bin/dsconfig create-connection-handler \
  --handler-name "HTTPS Connection Handler" \
  --type http --set enabled:true \
  --set listen-port:8443 \
  --set use-ssl:true \
  --set http-servlet-extension:SCIM \
  --set "http-operation-log-publisher:HTTP Detailed Access" \
  --set key-manager-provider:JKS --set trust-manager-provider:JKS
```

5. Add access controls to allow access to LDAP controls used by the SCIM Servlet Extension. These controls are the Post-Read Request Control (1.3.6.1.1.13.2), Server-Side Sort Request Control (1.2.840.113556.1.4.473), Simple Paged Results Control (1.2.840.113556.1.4.319), and Virtual List View Request Control (2.16.840.1.113730.3.4.9). We recommend using the following command to add access control instructions, rather than its `dsconfig` interactive equivalent.

```
$ bin/dsconfig set-access-control-handler-prop \
  --add 'global-aci:(targetcontrol="1.3.6.1.1.13.2 || 1.2.840.113556.1.4.473 ||
 1.2.840.113556.1.4.319 || 2.16.840.1.113730.3.4.9")
    (version 3.0;acl "Authenticated access to controls used by the SCIM servlet
     extension"; allow (all) userdn="ldap:///all";)'
```

6. Add access controls to allow read access to operational attributes used by the SCIM Servlet Extension. We recommend using the following non-interactive command to add access control instructions, rather than its `dsconfig` interactive equivalent.

```
$ bin/dsconfig set-access-control-handler-prop \
  --add 'global-aci:(targetattr="entryUUID || entryDN || ds-entry-unique-id ||
    createTimestamp || modifyTimestamp")
    (version 3.0;acl "Authenticated read access to operational attributes \
    used by the SCIM servlet extension"; allow (read,search,compare)
    userdn="ldap:///all";)'
```

7. Optional. The SCIM HTTP Connection Handler automatically uses a detailed HTTP log publisher, which is implemented in a proprietary format. If you need a standard W3C common log format publisher, enter the following command. If running `dsconfig` interactive, open the configuration console main menu, select "Log Publisher" -> "Create

a new Log Publisher" -> "new Log Publisher created from scratch" -> "File Based Access Log Publisher", enter the parameters to match your setup, and then, click "finish" to save the setting. Go back to the main menu, select "Connection Handler" -> "HTTPS Connection Handler", and then add "HTTP Common Access" to the `http-operation-log-publisher` property. Click "finish" to save the setting.

```
$ bin/dsconfig create-log-publisher \
  --publisher-name "HTTP Common Access" \
  --type common-log-file-http-operation --set enabled:true \
  --set log-file:logs/http-common-access \
  --set "rotation-policy:24 Hours Time Limit Rotation Policy" \
  --set "rotation-policy:Size Limit Rotation Policy" \
  --set "retention-policy:File Count Retention Policy" \
  --set "retention-policy:Free Disk Space Retention Policy"

$ bin/dsconfig set-connection-handler-prop \
  --handler-name "HTTPS Connection Handler" \
  --add "http-operation-log-publisher:HTTP Common Access"
```

8. Optional. To support searching or filtering by DN using the Identity Access API, you can enable the entryDN virtual attribute. If running `dsconfig` interactive, open the configuration console main menu, select "Virtual Attribute" -> "View and edit an existing Virtual Attribute" -> "Entry DN", and then change the enabled property to "true". Click "finish" to save the setting.

```
$ bin/dsconfig set-virtual-attribute-prop --name entryDN --set enabled:true
```

9. Optional. To support pagination, create some Virtual List View indexes. If running `dsconfig` interactive, open the configuration console main menu, select "Local DB VLV Index" -> "Create a new Local DB VLV Index" and then enter the properties needed for your setup. Click "finish" to save the setting. Repeat again for the "ascending-sn" index. Then, run the `rebuild-index` command to let the VLV Indexes take effect.

```
$ bin/dsconfig create-local-db-vlv-index --backend-name userRoot \
--index-name ascending-uid --set base-dn:dc=example,dc=com \
--set scope:whole-subtree --set "filter:(objectclass=inetorgperson)" \
--set "sort-order:+uid"

$ bin/dsconfig create-local-db-vlv-index --backend-name userRoot \
--index-name ascending-sn --set base-dn:dc=example,dc=com \
--set scope:whole-subtree --set "filter:(objectclass=inetorgperson)" \
--set "sort-order:+sn"

$ bin/rebuild-index --baseDN dc=example,dc=com --index vlv.ascending-uid \
--index vlv.ascending-sn
```

To Enable Resource Versioning

Resource versioning is enabled by default in new installations. Upgraded servers that had SCIM enabled need additional configuration to enable resource versioning.

1. Enable the `ds-entry-checksum` virtual attribute.

```
$ bin/dsconfig set-virtual-attribute-prop \
    --name ds-entry-checksum \
    --set enabled:true
```

2. Remove any existing access controls required by SCIM for read access to operational attributes:

```
$ bin/dsconfig set-access-control-handler-prop \
    --remove 'global-aci:(targetattr="entryUUID || entryDN || ds-entry-unique-id ||
 createTimestamp || ds-create-time || modifyTimestamp || ds-update-time")(version
 3.0;acl "Authenticated read access to operational attributes used by the SCIM
 servlet extension"; allow (read,search,compare) userdn="ldap:///all"'
```

3. Add new access controls required by SCIM for read access to operational attributes with the addition of the `ds-entry-checksum`:

```
$ bin/dsconfig set-access-control-handler-prop \
    --add  'global-aci:(targetattr="entryUUID || entryDN || ds-entry-unique-id ||
 createTimestamp || ds-create-time || modifyTimestamp || ds-update-time || ds-entry-
checksum")(version 3.0;acl "Authenticated read access to operational attributes used
 by the SCIM servlet extension"; allow (read,search,compare) userdn="ldap:///all"'
```

4. Enable SCIM resource versioning using the entry checksum virtual attribute:

```
$ bin/dsconfig set-http-servlet-extension-prop \
    --extension-name SCIM \
    --set entity-tag-ldap-attribute:ds-entry-checksum
```

To Configure the SCIM Servlet Extension using the Batch Script

The following example procedure assumes that you have set up your certificates, keystore, and truststore

1. Open the `<server-root>/config/scim-config-ds.dsconfig` script in a text editor.

2. For the optional elements (W3C common log, filtering by DN, and VLV Indexes, remove the comment (#) symbol on the `dsconfig` commands. Save the file when finished editing.

3. To enable the SCIM servlet extension, run the `dsconfig` batch file. Remember to include the bind parameters.

```
$ bin/dsconfig --batch-file config/scim-config-ds.dsconfig
```

SCIM Servlet Extension Authentication

The SCIM servlet supports authentication using either the HTTP Basic authentication scheme, or OAuth 2.0 bearer tokens. When authenticating using HTTP Basic authentication, the SCIM servlet attempts to correlate the username component of the Authorization header to a DN in the Data Store. If the username value cannot be parsed directly as a DN, it is correlated to a DN using an Identity Mapper. The DN is then used in a simple bind request to verify the password.

In deployments that use an OAuth authorization server, the SCIM extension can be configured to authenticate requests using OAuth bearer tokens. The SCIM extension supports authentication with OAuth 2.0 bearer tokens (per RFC 6750) using an OAuth Token Handler Server SDK Extension. Because the OAuth 2.0 specification does not specify how contents of a bearer token are formatted, UnboundID provides the token handler API to decode incoming bearer tokens and extract or correlate associated authorization DNs.

Neither HTTP Basic authentication nor OAuth 2.0 bearer token authentication are secure unless SSL is used to encrypt the HTTP traffic.

To Configure Basic Authentication Using an Identity Mapper

By default, the SCIM servlet is configured to use the Exact Match Identity Mapper, which matches against the `uid` attribute. In this example, an alternate Identity Mapper is created so that clients can authenticate using `cn` values.

1. Create a new Identity Mapper that uses a match attribute of cn.

```
$ bin/dsconfig create-identity-mapper \
  --mapper-name "CN Identity Mapper" \
  --type exact-match \
  --set enabled:true \
  --set match-attribute:cn
```

2. Configure the SCIM servlet to use the new Identity Mapper.

```
$ bin/dsconfig set-http-servlet-extension-prop \
  --extension-name SCIM \
  --set "identity-mapper:CN Identity Mapper"
```

To Enable OAuth Authentication

To enable OAuth authentication, you need to create an implementation of the `OAuthTokenHandler` using the API provided in the Server SDK. For details on creating an `OAuthTokenHandler` extension, see the UnboundID Server SDK documentation.

1. Install your OAuth token handler on the server using `dsconfig`.

```
$ bin/dsconfig create-oauth-token-handler \
  --handler-name ExampleOAuthTokenHandler \
  --type third-party \
  --set extension-class:com.unboundid.directory.sdk.examples.ExampleOAuthTokenHandler
```

2. Configure the SCIM servlet extension to use it as follows:

```
$ bin/dsconfig set-http-servlet-extension-prop \
  --extension-name SCIM \
  --set oauth-token-handler:ExampleOAuthTokenHandler
```

Verifying the SCIM Servlet Extension Configuration

You can verify the configuration of the SCIM extension by navigating to a SCIM resource URL via the command line or through a browser window.

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You can verify the configuration of the SCIM extension by navigating to a SCIM resource URL via the command line or through a browser window.

- Run `curl` to verify that the SCIM extension is running. The `-k` (or `--insecure`) option is used to turn off curl's verification of the server certificate, since the example Data Store is using a self-signed certificate.

```
$ curl -u "cn=Directory Manager:password" \
-k "https://localhost:8443/scim/ServiceProviderConfigs"

{"schemas":["urn:scim:schemas:core:1.0"],"id":"urn:scim:schemas:core:1.0",
"patch":{"supported":true},"bulk":{"supported":true,"maxOperations":10000,
"maxPayloadSize":10485760},"filter":{"supported":true,"maxResults":100},
"changePassword":{"supported":true},"sort":{"supported":true},
"etag":{"supported":false},"authenticationSchemes":[{"name":"HttpBasic",
"description":"The HTTP Basic Access Authentication scheme. This scheme is
not considered to be a secure method of user authentication (unless used in
conjunction with some external secure system such as SSL), as the user
name and password are passed over the network as cleartext.","specUrl":
"http://www.ietf.org/rfc/rfc2617","documentationUrl":
"http://en.wikipedia.org/wiki/Basic_access_authentication"}]}
```

- If the user ID is a valid DN (such as `cn=Directory Manager`), the SCIM extension authenticates by binding to the Data Store as that user. If the user ID is not a valid DN, the SCIM extension searches for an entry with that `uid` value, and binds to the server as that user. To verify authentication to the server as the user with the `uid` of `user.0`, run the following command:

```
$ curl -u "user.0:password" \
  -k "https://localhost:8443/scim/ServiceProviderConfigs"
```

Configuring Advanced SCIM Extension Features

The following sections show how to configure advanced SCIM servlet extension features, such as bulk operation implementation, mapping SCIM resource IDs, and transformations.

Managing the SCIM Schema

This section describes the SCIM schema and provides information on how to map LDAP schema to the SCIM resource schema.

About SCIM Schema

SCIM provides a common user schema and extension model, making it easier to interoperate with multiple Service Providers. The core SCIM schema defines a concrete schema for user and group resources that encompasses common attributes found in many existing schemas.

Each attribute is defined as either a single attribute, allowing only one instance per resource, or a multi-valued attribute, in which case several instances may be present for each resource. Attributes may be defined as simple, name-value pairs or as complex structures that define sub-attributes.

While the SCIM schema follows an object extension model similar to object classes in LDAP, it does not have an inheritance model. Instead, all extensions are additive, similar to LDAP Auxiliary Object Classes.

Mapping LDAP Schema to SCIM Resource Schema

The resources configuration file is an XML file that is used to define the SCIM resource schema and its mapping to LDAP schema. The default configuration of the `scim-resources.xml` file provides definitions for the standard SCIM Users and Groups resources, and mappings to the standard LDAP `inetOrgPerson` and `groupOfUniqueNames` object classes.

The default configuration may be customized by adding extension attributes to the Users and Groups resources, or by adding new extension resources. The resources file is composed of a single `<resources>` element, containing one or more `<resource>` elements.

For any given SCIM resource endpoint, only one `<LDAPAdd>` template can be defined, and only one `<LDAPSearch>` element can be referenced. If entries of the same object class can be located under different subtrees or base DNs of the Data Store, then a distinct SCIM resource must be defined for each unique entry location in the Directory Information Tree. This can be implemented in many ways. For example:

- Create multiple SCIM servlets, each with a unique `scim-resources.xml` configuration, and each running under a unique HTTP connection handler.
- Create multiple SCIM servlets, each with a unique `scim-resources.xml` configuration, each running under a single, shared HTTP connection handler, but each with a unique context path.

Note that LDAP attributes are allowed to contain characters that are invalid in XML (because not all valid UTF-8 characters are valid XML characters). The easiest and most-correct way to handle this is to make sure that any attributes that may contain binary data are declared using "dataType=binary" in the `scim-resources.xml` file. Likewise, when using the Identity Access API make sure that the underlying LDAP schema uses the Binary or Octet String attribute syntax for attributes which may contain binary data. This will cause the server to automatically base64-encode the data before returning it to clients and will also make it predictable for clients because they can assume the data will always be base64-encoded.

However, it is still possible that attributes that are not declared as binary in the schema may contain binary data (or just data that is invalid in XML), and the server will always check for this before returning them to the client. If the client has set the content-type to XML, then the server may choose to base64-encode any values which are found to include invalid XML characters. When this is done, a special attribute is added to the XML element to alert the client that the value is base64-encoded. For example:

```
<scim:value base64Encoded="true">AAABPB0EBZc=</scim:value>
```

The remainder of this section describes the mapping elements available in the `scim-resources.xml` file.

About the <resource> Element

A `resource` element has the following XML attributes:

- `schema`: a required attribute specifying the SCIM schema URN for the resource. Standard SCIM resources already have URNs assigned for them, such as `urn:scim:schemas:core:1.0`. A new URN must be obtained for custom resources using any of the standard URN assignment methods.

- `name`: a required attribute specifying the name of the resource used to access it through the SCIM REST API.
- `mapping`: a custom Java class that provides the logic for the resource mapper. This class must extend the `com.unboundid.scim.ldap.ResourceMapper` class.

A resource element contains the following XML elements in sequence:

- `description`: a required element describing the resource.
- `endpoint`: a required element specifying the endpoint to access the resource using the SCIM REST API.
- `LDAPSearchRef`: a mandatory element that points to an `LDAPSearch` element. The `LDAPSearch` element allows a SCIM query for the resource to be handled by an LDAP service and also specifies how the SCIM resource ID is mapped to the LDAP server.
- `LDAPAdd`: an optional element specifying information to allow a new SCIM resource to be added through an LDAP service. If the element is not provided then new resources cannot be created through the SCIM service.
- `attribute`: one or more elements specifying the SCIM attributes for the resource.

About the <attribute> Element

An `attribute` element has the following XML attributes:

- `schema`: a required attribute specifying the schema URN for the SCIM attribute. If omitted, the schema URN is assumed to be the same as that of the enclosing resource, so this only needs to be provided for SCIM extension attributes. Standard SCIM attributes already have URNs assigned for them, such as urn:scim:schemas:core:1.0. A new URN must be obtained for custom SCIM attributes using any of the standard URN assignment methods.
- `name`: a required attribute specifying the name of the SCIM attribute.
- `readOnly`: an optional attribute indicating whether the SCIM sub-attribute is not allowed to be updated by the SCIM service consumer. The default value is false.
- `required`: an optional attribute indicating whether the SCIM attribute is required to be present in the resource. The default value is false.

An attribute element contains the following XML elements in sequence:

- `description`: a required element describing the attribute. Then just one of the following elements:
    - ➢ `simple`: specifies a simple, singular SCIM attribute.
    - ➢ `complex`: specifies a complex, singular SCIM attribute.
    - ➢ `simpleMultiValued`: specifies a simple, multi-valued SCIM attribute.
    - ➢ `complexMultiValued`: specifies a complex, multi-valued SCIM attribute.

About the <simple> Element

A `simple` element has the following XML attributes:

- `dataType`: a required attribute specifying the simple data type for the SCIM attribute. The following values are permitted: binary, boolean, dateTime, decimal, integer, string.
- `caseExact`: an optional attribute that is only applicable for string data types. It indicates whether comparisons between two string values use a case-exact match or a case-ignore match. The default value is false.

A simple element contains the following XML element:

- `mapping`: an optional element specifying a mapping between the SCIM attribute and an LDAP attribute. If this element is omitted, then the SCIM attribute has no mapping and the SCIM service ignores any values provided for the SCIM attribute.

About the <complex> Element

The `complex` element does not have any XML attributes. It contains the following XML element:

- `subAttribute`: one or more elements specifying the sub-attributes of the complex SCIM attribute, and an optional mapping to LDAP. The standard `type`, `primary`, and `display` sub-attributes do not need to be specified.

About the <simpleMultivalued> Element

A `simpleMultiValued` element has the following XML attributes:

- `childName`: a required attribute specifying the name of the tag that is used to encode values of the SCIM attribute in XML in the REST API protocol. For example, the tag for the standard emails SCIM attribute is email.
- `dataType`: a required attribute specifying the simple data type for the plural SCIM attribute (i.e. the data type for the value sub-attribute). The following values are permitted: `binary`, `boolean`, `dateTime`, `integer`, `string`.
- `caseExact`: an optional attribute that is only applicable for string data types. It indicates whether comparisons between two string values use a case-exact match or a case-ignore match. The default value is false.

A simpleMultiValued element contains the following XML elements in sequence:

- `canonicalValue`: specifies the values of the type sub-attribute that is used to label each individual value, and an optional mapping to LDAP.
- `mapping`: an optional element specifying a default mapping between the SCIM attribute and an LDAP attribute.

About the <complexMultiValued> Element

A `complexMultiValued` element has the following XML attribute:

- `tag`: a required attribute specifying the name of the tag that is used to encode values of the SCIM attribute in XML in the REST API protocol. For example, the tag for the standard addresses SCIM attribute is address.

A `complexMultiValued` element contains the following XML elements in sequence:

- `subAttribute`: one or more elements specifying the sub-attributes of the complex SCIM attribute. The standard type, primary, and display sub-attributes do not need to be specified.
- `canonicalValue`: specifies the values of the type sub-attribute that is used to label each individual value, and an optional mapping to LDAP.

About the <subAttribute> Element

A `subAttribute` element has the following XML attributes:

- `name`: a required element specifying the name of the sub-attribute.
- `readOnly`: an optional attribute indicating whether the SCIM sub-attribute is not allowed to be updated by the SCIM service consumer. The default value is false.
- `required`: an optional attribute indicating whether the SCIM sub-attribute is required to be present in the SCIM attribute. The default value is false.
- `dataType`: a required attribute specifying the simple data type for the SCIM sub-attribute. The following values are permitted: binary, boolean, dateTime, integer, string.
- `caseExact`: an optional attribute that is only applicable for string data types. It indicates whether comparisons between two string values use a case-exact match or a case-ignore match. The default value is false.

A `subAttribute` element contains the following XML elements in sequence:

- `description`: a required element describing the sub-attribute.
- `mapping`: an optional element specifying a mapping between the SCIM sub-attribute and an LDAP attribute. This element is not applicable within the complexMultiValued element.

About the <canonicalValue> Element

A `canonicalValue` element has the following XML attribute:

- `name`: specifies the value of the type sub-attribute. For example, work is the value for emails, phone numbers and addresses intended for business purposes.

A `canonicalValue` element contains the following XML element:

- `subMapping`: an optional element specifying mappings for one or more of the sub-attributes. Any sub-attributes that have no mappings will be ignored by the mapping service.

About the <mapping> Element

A `mapping` element has the following XML attributes:

- `ldapAttribute`: A required element specifying the name of the LDAP attribute to which the SCIM attribute or sub-attribute map.

- `transform`: An optional element specifying a transformation to apply when mapping an attribute value from SCIM to LDAP and vice-versa. The available transformations are described in the *Mapping LDAP Entries to SCIM Using the SCIM-LDAP API* section.

About the <subMapping> Element

A `subMapping` element has the following XML attributes:

- `name`: a required element specifying the name of the sub-attribute that is mapped.
- `ldapAttribute`: a required element specifying the name of the LDAP attribute to which the SCIM sub-attribute maps.
- `transform`: an optional element specifying a transformation to apply when mapping an attribute value from SCIM to LDAP and vice-versa. The available transformations are described later. The available transformations are described in *Mapping LDAP Entries to SCIM Using the SCIM-LDAP API*.

About the <LDAPSearch> Element

An `LDAPSearch` element contains the following XML elements in sequence:

- `baseDN`: a required element specifying one or more LDAP search base DNs to be used when querying for the SCIM resource.
- `filter`: a required element specifying an LDAP filter that matches entries representing the SCIM resource. This filter is typically an equality filter on the LDAP object class.
- `resourceIDMapping`: an optional element specifying a mapping from the SCIM resource ID to an LDAP attribute. When the element is omitted, the resource ID maps to the LDAP entry DN. Note The `LDAPSearch` element can be added as a top-level element outside of any <Resource> elements, and then referenced within them via an ID attribute.

Note: The `LDAPSearch` element can be added as a top-level element outside of any <Resource> elements, and then referenced within them via an ID attribute.

About the <resourceIDMapping> Element

The `resourceIDMapping` element has the following XML attributes:

- `ldapAttribute`: a required element specifying the name of the LDAP attribute to which the SCIM resource ID maps.
- `createdBy`: a required element specifying the source of the resource ID value when a new resource is created by the SCIM consumer using a POST operation. Allowable values for this element include `scim-consumer`, meaning that a value must be present in the initial resource content provided by the SCIM consumer, or Data Store, meaning that a value is automatically provided by the Data Store (as would be the case if the mapped LDAP attribute is entryUUID).

The following example illustrates an `LDAPSearch` element that contains a `resourceIDMapping` element:

```
<LDAPSearch id="userSearchParams">
  <baseDN>ou=people,dc=example,dc=com</baseDN>
  <filter>(objectClass=inetOrgPerson)</filter>
  <resourceIDMapping ldapAttribute="entryUUID" createdBy="directory"/>
</LDAPSearch>
```

About the <LDAPAdd> Element

An LDAPAdd element contains the following XML elements in sequence:

- `DNTemplate`: a required element specifying a template that is used to construct the DN of an entry representing a SCIM resource when it is created. The template may reference values of the entry after it has been mapped using `{ldapAttr}`, where `ldapAttr` is the name of an LDAP attribute.
- `fixedAttribute`: zero or more elements specifying fixed LDAP values to be inserted into the entry after it has been mapped from the SCIM resource.

About the <fixedAttribute> Element

A `fixedAttribute` element has the following XML attributes:

- `ldapAttribute`: a required attribute specifying the name of the LDAP attribute for the fixed values.
- `onConflict`: an optional attribute specifying the behavior when the LDAP entry already contains the specified LDAP attribute. The value merge indicates that the fixed values should be merged with the existing values. The value overwrite indicates that the existing values are to be overwritten by the fixed values. The value preserve indicates that no changes should be made. The default value is merge.

A `fixedAttribute` element contains one or more `fixedValue` XML element, which specify the fixed LDAP values.

Validating Updated SCIM Schema

The UnboundID SCIM extension is bundled with an XML Schema document, `resources.xsd`, which describes the structure of a `scim-resources.xml` resource configuration file. After updating the resource configuration file, you should confirm that its contents are well-formed and valid using a tool such as `xmllint`.

For example, you could validate your updated file as follows:

```
$ xmllint --noout --schema resources.xsd scim-resources.xml
scim-resources.xml validates
```

Mapping SCIM Resource IDs

The default `scim-resources.xml` configuration maps the SCIM resource ID to the LDAP `entryUUID` attribute. The `entryUUID` attribute, whose read-only value is assigned by the Data Store, meets the requirements of the SCIM specification regarding resource ID immutability.

However, configuring a mapping to the attribute may result in inefficient group processing, since LDAP groups use the entry DN as the basis of group membership. The resource configuration allows the SCIM resource ID to be mapped to the LDAP entry DN. However, the entry DN does not meet the requirements of the SCIM specification regarding resource ID immutability. LDAP permits entries to be renamed or moved, thus modifying the DN. Likewise, you can use the Identity Access API to change the value of an entry's RDN attribute, thereby triggering a MODDN operation.

A resource may also be configured such that its SCIM resource ID is provided by an arbitrary attribute in the request body during POST operations. This SCIM attribute must be mapped to an LDAP attribute so that the SCIM resource ID may be stored in the Data Store. By default, it is the responsibility of the SCIM client to guarantee ID uniqueness. However, the UID Unique Attribute Plugin may be used by the Data Store to enforce attribute value uniqueness. For information about the UID Unique Attribute Plugin, see "Working with the UID Unique Attribute Plug-in" in the UnboundID Data Store Administration Guide.

Note: Resource IDs may not be mapped to virtual attributes. For more information about configuring SCIM Resource IDs, see "About the `<resourceIDMapping>` Element".

Using Pre-defined Transformations

Transformations are required to change SCIM data types to LDAP syntax values. The following pre-defined transformations may be referenced by the transform XML attribute:

- `com.unboundid.scim.ldap.BooleanTransformation`. Transforms SCIM boolean data type values to LDAP Boolean syntax values and vice-versa.
- `com.unboundid.scim.ldap.GeneralizedTimeTransformation`. Transforms SCIM dateTime data type values to LDAP Generalized Time syntax values and vice-versa.
- `com.unboundid.scim.ldap.PostalAddressTransformation`. Transforms SCIM formatted address values to LDAP Postal Address syntax values and vice-versa. SCIM formatted physical mailing addresses are represented as strings with embedded new lines, whereas LDAP uses the $ character to separate address lines. This transformation interprets new lines in SCIM values as address line separators.
- `com.unboundid.scim.ldap.TelephoneNumberTransformation`. Transforms LDAP Telephone Number syntax (E.123) to RFC3966 format and vice-versa.

You can also write your own transformations using the SCIM API described in the following section.

Mapping LDAP Entries to SCIM Using the SCIM-LDAP API

In addition to the SCIM SDK, UnboundID provides a library called SCIM-LDAP, which provides facilities for writing custom transformations and more advanced mapping. This API is provided with the SCIM Reference Implementation. It is also available via the Maven Central public repository on the Maven website.

You can add the SCIM-LDAP library to your project using the following dependency:

```
<dependency>
    <groupId>com.unboundid.product.scim</groupId>
    <artifactId>scim-ldap</artifactId>
    <version>1.5.0</version>
</dependency>
```

Create your custom transformation by extending the `com.unboundid.scim.ldap.Transformation` class. Place your custom transformation class in a jar file in the server's `lib` directory.

Note: The Identity Access API automatically maps LDAP attribute syntaxes to the appropriate SCIM attribute types. For example, an LDAP DirectoryString is automatically mapped to a SCIM string.

SCIM Authentication

SCIM requests to the LDAP endpoints will support HTTP Basic Authentication and OAuth2 Authentication using a bearer token. There is existing support for this feature in the Data Store and the Proxy Server using the OAuthTokenHandler API (i.e., via a Server SDK extension, which requires some technical work to implement).

Note that our implementation only supports the HTTP Authorization header for this purpose; we do not support the form-encoded body parameter or URI query parameter mechanisms for specifying the credentials or bearer token.

SCIM Logging

The Data Store already provides a detailed HTTP log publisher to capture the SCIM and HTTP request details. To be able to correlate this data to the internal LDAP operations that are invoked behind the scenes, the Access Log Publisher will use "`origin=scim`" in access log messages that are generated by the SCIM servlet.

For example, you will see a message for operations invoked by replication:

```
[30/Oct/2012:18:45:10.490 -0500] MODIFY REQUEST conn=-3 op=190 msgID=191
origin="replication" dn="uid=user.3,ou=people,dc=example,dc=com"
```

Likewise for SCIM messages, you will see a message like this:

```
[30/Oct/2012:18:45:10.490 -0500] MODFIY REQUEST conn=-3 op=190 msgID=191
origin="scim" dn="uid=user.3,ou=people,dc=example,dc=com"
```

SCIM Monitoring

There are two facilities that can be used to monitor the SCIM activity in the server.

- **HTTPConnectionHandlerStatisticsMonitorProvider --** Provides statistics straight about total and average active connections, requests per connection, connection duration, processing time, invocation count, etc.
- **SCIMServletMonitorProvider --** Provides high level statistics about request methods (POST, PUT, GET, etc.), content types (JSON, XML), and response codes, for example, "`user-patch-404:26`".

The LDAP object class endpoints are treated as their own resource types, so that for requests using the Identity Access API, there will be statistics, such as `person-get-200` and `inetorgperson-post-401`.

Configuring the Identity Access API

Once you have run the `<server-root>/config/scim-config-ds.dsconfig` script, the resources defined in the `scim-resources.xml` will be available as well as the Identity Access API. However, to allow SCIM access to the raw LDAP data, you must set a combination of configuration properties on the SCIM Servlet Extenstion using the `dsconfig` tool.

- **include-ldap-objectclass**. Specifies a multi-valued property that lists the object classes for entries that will be exposed. The object class used here will be the one that clients need to use when referencing Identity Access API resources. This property allows the special value "*" to allow all object classes. If "*" is used, then the SCIM servlet uses the same case used in the Data Store LDAP Schema.
- **exclude-ldap-objectclass**. Specifies a multi-valued property that lists the object classes for entries that will not be exposed. When this property is specified, all object classes will be exposed except those in this list.
- **include-ldap-base-dn**. Specifies a multi-valued property that lists the base DNs that will be exposed. If specified, only entries under these base DNs will be accessible. No parent-child relationships in the DNs are allowed here.
- **exclude-ldap-base-dn**. Specifies a multi-valued property that lists the base DNs that will not be exposed. If specified, entries under these base DNs will not be accessible. No parent-child relationships in the DNs are allowed here.

Using a combination of these properties, SCIM endpoints will be available for all included object clases, just as if they were SCIM Resources defined in the `scim-resources.xml` file.

To Configure the Identity Access API

1. Ensure that you have run the `scim-config-ds.dsconfig` script to configure the SCIM interface. Be sure to enable the entryDN virtual attribute. See the Configure SCIM section for more information.
2. Set a combination of properties to allow the SCIM clients access to the raw LDAP data: `include-ldap-objectclass`, `exclude-ldap-objectclass`, `include-ldap-base-dn`, or `exclude-ldap-base-dn`.

```
$ bin/dsconfig set-http-servlet-extension-prop \
  --extension-name SCIM --set 'include-ldap-objectclass:*' \
  --set include-ldap-base-dn:ou=People,dc=example,dc=com
```

The SCIM clients now have access to the raw LDAP data via LDAP object class-based resources as well as core SCIM resources as defined in the `scim.resource.xml` file.

To Disable Core SCIM Resources

1. Open the `config/scim-resources.xml` file, and comment out or remove the `<resource>` elements that you would like to disable.

2. Disable and re-enable the HTTP Connection Handler, or restart the server to make the changes take effect. In general, changing the `scim-resources.xml` file requires a HTTP Connection Handler restart or server restart.

Note: When making other changes to the SCIM configuration by modifying the SCIM HTTP Servlet Extension using `dsconfig`, the changes take effect immediately without any restart required.

To Verify the Identity Access API Configuration

- Perform a curl request to verify the Identity Access API configuration.

```
$ curl -k -u "cn=directory manager:password" \
  -H "Accept: application/json" \
  "https://example.com/top/56c9fd6b-f870-35ef-9959-691c783b7318?
     attributes=entryDN,uid,givenName,sn,entryUUID"
     {"schemas":["urn:scim:schemas:core:1.0","urn:unboundid:schemas:scim:ldap:1.0"],
      "id":"56c9fd6b-f870-35ef-9959-691c783b7318",
      "meta":{"lastModified":"2013-01-11T23:38:26.489Z",
      "location":"https://example.com:443/v1/top/56c9fd6b-
f870-35ef-9959-691c783b7318"},
      "urn:unboundid:schemas:scim:ldap:1.0":{"givenName":["Rufus"],"uid":["user.1"],
      "sn":["Firefly"],"entryUUID":["56c9fd6b-f870-35ef-9959-691c783b7318"],
      "entrydn":"uid=user.1,ou=people,dc=example,dc=com"}}
```

Monitoring the SCIM Servlet Extension

The SCIM reference implementation provides a command-line tool, `scim-query-rate`, that measures the SCIM query performance for your extension. The SCIM extension also exposes monitoring information for each SCIM resource, such as the number of successful operations per request, the number of failed operations per request, the number of operations with XML or JSON to and from the client. Finally, the Data Store automatically logs SCIM-initiated LDAP operations to the default File-based Access Logger. These operations will have an `origin='scim'` attribute to distinguish them from operations initiated by LDAP clients. You can also create custom logger or request criteria objects that can track incoming HTTP requests, which the SCIM extension rewrites as internal LDAP operations.

Testing SCIM Query Performance

You can use the `scim-query-rate` tool, provided in the SCIM Reference Implementation, to test query performance, by performing repeated resource queries against the SCIM server. You should be aware that this tool is bundled with the SCIM Reference Implementation, and not the SCIM extension.

The `scim-query-rate` tool performs searches using a query filter or can request resources by ID. For example, you can test performance by using a filter to query randomly across a set of one million users with eight concurrent threads. The user resources returned to the client in this example is in XML format and includes the `userName` and `name` attributes.

```
scim-query-rate --hostname server.example.com --port 80 \
--authID admin --authPassword password --xml \
--filter 'userName eq "user.[1-1000000]"' --attribute userName \
--attribute name --numThreads 8
```

You can request resources by specifying a resource ID pattern using the `--resourceID` argument as follows:

```
scim-query-rate --hostname server.example.com --port 443 \
--authID admin --authPassword password --useSSL --trustAll\
--resourceName User \
--resourceID 'uid=user.[1-150000],ou=people,dc=example,dc=com'
```

The `scim-query-rate` tool reports the error `"java.net.SocketException: Too many open files"` if the open file limit is too low. You can increase the open file limit to increase the number of file descriptors.

Monitoring Resources Using the SCIM Extension

The monitor provider exposes the following information for each resource:

- Number of successful operations per request type (such as GET, PUT, and POST).
- Number of failed operations and their error codes per request type.
- Number of operations with XML or JSON from client.
- Number of operations that sent XML or JSON to client.

In addition to the information about the user-defined resources, monitoring information is also generated for the schema, service provider configuration, and monitor resources. The attributes of the monitor entry are formatted as follows:

```
{resource name}-resource-{request type}-{successful or error status code}
```

You can search for one of these monitor providers using an `ldapsearch` such as the following:

```
$ bin/ldapsearch --port 1389 bindDN uid=admin,dc=example,dc=com \
  --bindPassword password --baseDN cn=monitor \
  --searchScope sub "(objectclass=scim-servlet-monitor-entry)"
```

For example, the following monitor output was produced by a test environment with three distinct SCIM servlet instances, Aleph, Beth, and Gimel. Note that the first instance has a custom resource type called host.

```
$ bin/ldapsearch --baseDN cn=monitor \
  '(objectClass=scim-servlet-monitor-entry)'
dn: cn=SCIM Servlet (SCIM HTTP Connection Handler),cn=monitor
objectClass: top
objectClass: ds-monitor-entry
objectClass: scim-servlet-monitor-entry
objectClass: extensibleObject
cn: SCIM Servlet (SCIM HTTPS Connection Handler) [from
  ThirdPartyHTTPServletExtension:SCIM (Aleph)]
ds-extension-monitor-name: SCIM Servlet (SCIM HTTPS Connection Handler)
ds-extension-type: ThirdPartyHTTPServletExtension
ds-extension-name: SCIM (Aleph)
version: 1.2.0
build: 20120105174457Z
revision: 820
schema-resource-query-successful: 8
schema-resource-query-401: 8
schema-resource-query-response-json: 16
user-resource-delete-successful: 1
user-resource-put-content-xml: 27
user-resource-query-response-json: 3229836
user-resource-put-403: 5
user-resource-put-content-json: 2
user-resource-get-401: 1
user-resource-put-response-json: 23
user-resource-get-response-json: 5
user-resource-get-response-xml: 7
user-resource-put-400: 2
user-resource-query-401: 1141028
user-resource-post-content-json: 1
user-resource-put-successful: 22
user-resource-post-successful: 1
user-resource-delete-404: 1
user-resource-query-successful: 2088808
user-resource-get-successful: 10
user-resource-put-response-xml: 6
user-resource-get-404: 1
user-resource-delete-401: 1
user-resource-post-response-json: 1
host-resource-query-successful: 5773268
host-resource-query-response-json: 11576313
host-resource-query-400: 3
host-resource-query-response-xml: 5
host-resource-query-401: 5788152
dn: cn=SCIM Servlet (SCIM HTTP Connection Handler),cn=monitor
objectClass: top
objectClass: ds-monitor-entry
objectClass: scim-servlet-monitor-entry
objectClass: extensibleObject
cn: SCIM Servlet (SCIM HTTPS Connection Handler) [from
  ThirdPartyHTTPServletExtension:SCIM (Beth)]
ds-extension-monitor-name: SCIM Servlet (SCIM HTTPS Connection
  Handler)
ds-extension-type: ThirdPartyHTTPServletExtension
ds-extension-name: SCIM (Beth)
version: 1.2.0
build: 20120105174457Z
revision: 820
serviceproviderconfig-resource-get-successful: 3
serviceproviderconfig-resource-get-response-json: 2
serviceproviderconfig-resource-get-response-xml: 1
schema-resource-query-successful: 8
schema-resource-query-401: 8
schema-resource-query-response-json: 16
group-resource-query-successful: 245214
group-resource-query-response-json: 517841
group-resource-query-400: 13711
group-resource-query-401: 258916
user-resource-query-response-json: 107876
user-resource-query-400: 8288
user-resource-get-400: 33
user-resource-get-response-json: 1041
user-resource-get-successful: 2011
user-resource-query-successful: 45650
user-resource-get-response-xml: 1003
user-resource-query-401: 53938
dn: cn=SCIM Servlet (SCIM HTTP Connection Handler),cn=monitor
objectClass: top
```

```
objectClass: ds-monitor-entry
objectClass: scim-servlet-monitor-entry
objectClass: extensibleObject
cn: SCIM Servlet (SCIM HTTPS Connection Handler) [from
  ThirdPartyHTTPServletExtension:SCIM (Gimel)]
ds-extension-monitor-name: SCIM Servlet (SCIM HTTPS Connection
  Handler)
ds-extension-type: ThirdPartyHTTPServletExtension
ds-extension-name: SCIM (Gimel)
version: 1.2.0
build: 20120105174457Z
revision: 820
schema-resource-query-successful: 1
schema-resource-query-401: 1
schema-resource-query-response-json: 2
user-resource-query-successful: 65
user-resource-get-successful: 4
user-resource-get-response-json: 6
user-resource-query-response-json: 132
user-resource-get-404: 2
user-resource-query-401: 67
```

About the HTTP Log Publishers

HTTP operations may be logged using either a Common Log File HTTP Operation Log Publisher or a Detailed HTTP Operation Log Publisher. The Common Log File HTTP Operation Log Publisher is a built-in log publisher that records HTTP operation information to a file using the W3C common log format. Because the W3C common log format is used, logs produced by this log publisher can be parsed by many existing web analysis tools.

Log messages are formatted as follows:

- IP address of the client.
- RFC 1413 identification protocol. The Ident Protocol is used to format information about the client.
- The user ID provided by the client in an Authorization header, which is typically available server-side in the REMOTE_USER environment variable. A dash appears in this field if this information is not available.
- A timestamp, formatted as "'['dd/MM/yyyy:HH:mm:ss Z']'"
- Request information, with the HTTP method followed by the request path and HTTP protocol version.
- The HTTP status code value.
- The content size of the response body in bytes. This number does not include the size of the response headers.

The HTTP Detailed Access Log Publisher provides more information than the common log format in a format that is familiar to administrators who use the File-Based Access Log Publisher.

The HTTP Detailed Access Log Publisher generates log messages such as the following. The lines have been wrapped for readability.

```
[15/Feb/2012:21:17:04 -0600] RESULT requestID=10834128
from="10.2.1.114:57555" method="PUT"
url="https://10.2.1.129:443/Aleph/Users/6272c691-
```

```
38c6-012f-d227-0dfae261c79e" authorizationType="Basic"
requestContentType="application/json" statusCode=200
etime=3.544 responseContentLength=1063
redirectURI="https://server1.example.com:443/Aleph/Users/6272c691-38c6-012f-
d227-0dfae261c79e"
responseContentType="application/json"
```

In this example, only default log publisher properties are used. Though this message is for a RESULT, it contains information about the request, such as the client address, the request method, the request URL, the authentication method used, and the Content-Type requested. For the response, it includes the response length, the redirect URI, the Content-Type, and the HTTP status code.

You can modify the information logged, including adding request parameters, cookies, and specific request and response headers. For more information, refer to the `dsconfig` command-line tool help.

Chapter 25 Managing Server SDK Extensions

The UnboundID Data Store provides support for any custom extensions that you create using the UnboundID® Server SDK. This chapter summarizes the various features and extensions that can be developed using the Server SDK.

Topics:

About the Server SDK

You can create extensions that use the Server SDK to extend the functionality of your Data Store. Extension bundles are installed from a .zip archive or a file system directory. You can use the `manage-extension` tool to install or update any extension that is packaged using the extension bundle format. It opens and loads the extension bundle, confirms the correct extension to install, stops the server if necessary, copies the bundle to the server install root, and then restarts the server.

Note: The `manage-extension` tool may only be used with Java extensions packaged using the extension bundle format. Groovy extensions do not use the extension bundle format. For more information, see the "Building and Deploying Java-Based Extensions" section of the Server SDK documentation, which describes the extension bundle format and how to build an extension.

Available Types of Extensions

The UnboundID Server SDK provides support for creating a number of different types of extensions for UnboundID Server Products, including the UnboundID Data Store, UnboundID Proxy Server, and UnboundID Data Sync Server. Some of those extensions include:

Cross-Product Extensions

- Access Loggers
- Alert Handlers
- Error Loggers
- Key Manager Providers
- Monitor Providers
- Trust Manager Providers
- OAuth Token Handlers
- Manage Extension Plugins

UnboundID Data Store Extensions

- Certificate Mappers
- Change Subscription Handlers
- Extended Operation Handlers
- Identity Mappers
- Password Generators
- Password Storage Schemes
- Password Validators
- Plugins
- Tasks

- Virtual Attribute Providers

UnboundID Proxy Server Extensions

- LDAP Health Checks
- Placement Algorithms
- Proxy Transformations

UnboundID Data Sync Server Extensions

- JDBC Sync Sources
- JDBC Sync Destinations
- LDAP Sync Source Plugins
- LDAP Sync Destination Plugins
- Sync SourcesSync Destinations
- Sync Pipe Plugins

For more information on the UnboundID Server SDK, see the documentation available in the SDK build.

Chapter 26 Troubleshooting the Server

The UnboundID Data Store provides a highly-reliable service that satisfies your company's objectives. However, if problems do arise (whether from issues in the Data Store itself or a supporting component, like the JVM, operating system, or hardware), then it is essential to be able to diagnose the problem quickly to determine the underlying cause and the best course of action to take towards resolving it.

This chapter provides information about how to perform this analysis to help ensure that the problem is resolved as quickly as possible. It targets cases in which the Data Store is running on Sun Solaris or Linux systems, but much of the information can be useful on other platforms as well. This chapter presents the following information:

Topics:

Working with the Collect Support Data Tool

The Data Store provides a significant amount of information about its current state including any problems that it has encountered during processing. If a problem occurs, the first step is to run the `collect-support-data` tool in the `bin` directory. The tool aggregates all relevant support files into a zip file that administrators can send to your authorized support provider for analysis. The tool also runs data collector utilities, such as `jps`, `jstack`, and `jstat` plus other diagnostic tools for Solaris and Linux machines, and bundles the results in the zip file.

The tool may only archive portions of certain log files to conserve space, so that the resulting support archive does not exceed the typical size limits associated with e-mail attachments.

The data collected by the `collect-support-data` tool varies between systems. For example, on Solaris Zone, configuration information is gathered using commands like `zonename` and `zoneadm`. However, the tool always tries to get the same information across all systems for the target Data Store. The data collected includes the configuration directory, summaries and snippets from the `logs` directory, an LDIF of the monitor and RootDSE entries, and a list of all files in the server root.

Server Commands Used in the Collect Support Data Tool

The following presents a summary of the data collectors that the `collect-support-data` tool archives in zip format. If an error occurs during processing, you can re-run the specific data collector command and send the results to your authorized support provider.

Table 67: Directory Server Commands Used in the Collect-Support-Data Tool

Data Collector	Description
status	Runs `status -F` to show the full version information of the Data Store (Unix, Windows).
server-state	Runs `server-state` to show the current state of the Data Store process (Unix, Windows).
dsreplication status	Runs `dsreplication status` to show the status of the replicated topology (Unix, Windows). If the `--noReplicationStatus` option is used, the replication status information is not collected.

JDK Commands Used in the Collect-Support-Data Tool

Table 68: JDK Commands Used in the Collect-Support-Data Tool

Data Collector	Description
jps	Java Virtual Machine Process status tool. Reports information on the JVM (Solaris, Linux, Windows, Mac OS).
jstack	Java Virtual Machine Stack Trace. Prints the stack traces of threads for the Java process (Solaris, Linux, Windows, Mac OS).
jstat	Java Virtual Machine Statistics Monitoring Tool. Displays performance statistics for the JVM (Solaris, Linux, Windows, Mac OS).

Data Collector	Description
jinfo	Displays the Java configuration information for the Java process (Solaris, Linux, Windows, Mac OS).

Linux Commands Used in the collect-support-data Tool

Table 69: Linux Commands Used in the Collect-Support-Data Tool

Data Collector	Description
tail	Displays the last few lines of a file. Tails the `/var/logs/messages` directory.
uname	Prints system, machine, and operating system information.
ps	Prints a snapshot of the current active processes.
df	Prints the amount of available disk space for filesystems in 1024-byte units.
cat	Concatenates the following files and prints to standard output: ➢ /proc/cpuinfo ➢ /proc/meminfo ➢ /etc/hosts ➢ /etc/nsswitch.conf ➢ /etc/resolv.conf
netstat	Prints the state of network interfaces, protocols, and the kernal routing table.
ifconfig	Prints information on all interfaces.
uptime	Prints the time the server has been up and active.
dmesg	Prints the message buffer of the kernel.
vmstat	Prints information about virtual memory statistics.
iostat	Prints disk I/O and CPU utilization information.
mpstat	Prints performance statistics for all logical processors.
pstack	Prints an execution stack trace on an active processed specified by the pid.
top	Prints a list of active processes and how much CPU and memory each process is using.

Solaris Commands Used in the collect-support-data Tool

Table 70: Solaris Commands Used in the Collect-Support-Data Tool

Data Collector	Description
uname	Prints system, machine, and operating system information.
ps	Prints a snapshot of the current active processes.
zonename	Prints the name of the current zone.
zoneadm	Prints the name of the current configured in verbose mode.
df	Prints the amount of available disk space for filesystems in 1024-byte units.
zfs	Prints basic ZFS information: dataset pool names, and their used, available, referenced, and mountpoint properties.
zpool	Print a zpool's status.
fmdump	Prints the log files managed by the Solaris Fault Manager.
prtconf	Prints the system configuration information.
iostat	Prints disk I/O and CPU utilization information.
prtdiag	Prints the system diagnostic information.
cat	Concatenates the following files and prints to standard output: ➢ /proc/cpuinfo ➢ /proc/meminfo

Data Collector	Description
	➢ /etc/hosts ➢ /etc/nsswitch.conf ➢ /etc/resolv.conf
tail	Displays the last few lines of a file. Tails the `/var/logs/messages` directory and the `/var/log/system.log` directory.
netstat	Prints the state of network interfaces, protocols, and the kernal routing table.
ifconfig	Prints information on all interfaces.
uptime	Prints the time the server has been up and active.
dmesg	Prints the message buffer of the kernel.
patchadd	Prints the patches added to the system if any (Solaris, not OpenSolaris).
vmstat	Prints information about virtual memory statistics.
iostat	Prints disk I/O and CPU utilization information.
mpstat	Prints performance statistics for all logical processors.
pstack	Prints an execution stack trace on an active processed specified by the pid.
prstat	Prints resource usage.

AIX Commands Used in the collect-support-data Tool

Table 71: AIX Commands Used in the Collect-Support-Data Tool

Data Collector	Description
ulimit	Defines user and system resources.
uptime	Prints the time the server has been up and active.
ps	Prints a snapshot of the current active processes.
zonename	Prints the name of the current zone.
cat	Concatenates the following files and prints to standard output: ➢ /proc/cpuinfo ➢ /proc/meminfo ➢ /etc/hosts ➢ /etc/nsswitch.conf ➢ /etc/resolv.conf
vmstat	Prints information about virtual memory statistics.
alog	Prints the contents of the boot log file.
netstat	Prints the state of network interfaces, protocols, and the kernal routing table.
ifconfig	Prints information on all interfaces.
df	Prints the amount of available disk space for filesystems in 1024-byte units.
sar	Print the local activity of the server.
lparstat	Prints logical partition information and statistics.
vmo	Prints the characteristics of one or more tunable parameters.
iostat	Prints disk I/O and CPU utilization information.
mpstat	Prints performance statistics for all logical processors.

MacOS Commands Used in the Collect Support Data Tool

Table 72: MacOS Commands Used in the Collect-Support-Data Tool

Data Collector	Description
uname	Prints system, machine, and operating system information.
uptime	Prints the time the server has been up and active.

Data Collector	Description
ps	Prints a snapshot of the current active processes.
system_profiler	Prints system hardware and software configuration.
vm_stat	Prints machine virtual memory statistics.
tail	Displays the last few lines of a file. Tails the `/var/log/system.log` directory.
netstat	Prints the state of network interfaces, protocols, and the kernal routing table.
ifconfig	Prints information on all interfaces.
df	Prints the amount of available disk space for filesystems in 1024-byte units.
sample	Profiles a process during an interval.

Available Tool Options

The `collect-support-data` tool has some important options that you should be aware of:

- **--noLdap**. Specifies that no effort should be made to collect any information over LDAP. This option should only be used if the server is completely unresponsive or will not start and only as a last resort.
- **--pid {pid}**. Specifies the ID of an additional process from which information is to be collected. This option is useful for troubleshooting external server tools and can be specified multiple times for each external server, respectively.
- **--sequential**. Use this option to diagnose “Out of Memory” errors. The tool collects data in parallel to minimize the collection time necessary for some analysis utilities. This option specifies that data collection should be run sequentially as opposed to in parallel. This action has the effect of reducing the initial memory footprint of this tool at a cost of taking longer to complete.
- **--reportCount {count}**. Specifies the number of reports generated for commands that supports sampling (for example, `vmstat`, `iostat`, or `mpstat`). A value of 0 (zero) indicates that no reports will be generated for these commands. If this option is not specified, it defaults to 10.
- **--reportInterval {interval}**. Specifies the number of seconds between reports for commands that support sampling (for example, `mpstat`). This option must have a value greater than 0 (zero). If this option is not specified, it default to 1.
- **--maxJstacks {number}**. Specifies the number of jstack samples to collect. If not specified, the default number of samples collected is 10.
- **--collectExpensiveData**. Specifies that data on expensive or long running processes be collected. These processes are not collected by default, because they may impact the performance of a running server.
- **--comment {comment}**. Provides the ability to submit any additional information about the collected data set. The comment will be added to the generated archive as a README file.
- **--includeBinaryFiles**. Specifies that binary files be included in the archive collection. By default, all binary files are automatically excluded in data collection.
- **--adminPassword {adminPassword}**. Specifies the global administrator password used to obtain `dsreplication status` information.
- **--adminPasswordFile {adminPasswordFile}**. Specifies the file containing the password of the global administrator used to obtain `dsreplication status` information.

To Run the Collect Support Data Tool

1. Go to the server root directory.

2. Use the `collect-support-data` tool. Make sure to include the host, port number, bind DN, and bind password.

```
$ bin/collect-support-data --hostname 127.0.0.1 --port 389 \
  --bindDN "cn=Directory Manager" --bindPassword secret \
  --serverRoot /opt/UnboundID-DS --pid 1234
```

3. Email the zip file to your Authorized Support Provider.

Data Store Troubleshooting Information

The Data Store has a comprehensive default set of log files and monitor entries that are useful when troubleshooting a particular server problem.

Error Log

By default, this log file is available at `logs/errors` below the server install root and it provides information about warnings, errors, and other significant events that occur within the server. A number of messages are written to this file on startup and shutdown, but while the server is running there is normally little information written to it. In the event that a problem does occur, however, the server writes information about that problem to this file.

The following is an example of a message that might be written to the error log:

```
[11/Apr/2011:10:31:53.783 -0500] category=CORE severity=NOTICE msgID=458887 msg="The
 Directory Server has started successfully"
```

The category field provides information about the area of the server from which the message was generated. Available categories include:

ACCESS_CONTROL, ADMIN, ADMIN_TOOL, BACKEND, CONFIG, CORE, DSCONFIG, EXTENSIONS, PROTOCOL, SCHEMA, JEB, SYNC, LOG, PLUGIN, PROXY, QUICKSETUP, REPLICATION, RUNTIME_INFORMATION, TASK, THIRD_PARTY, TOOLS, USER_DEFINED, UTIL, VERSION.

The severity field provides information about how severe the server considers the problem to be. Available severities include:

- **DEBUG** – Used for messages that provide verbose debugging information and do not indicate any kind of problem. Note that this severity level is rarely used for error logging, as the Data Store provides a separate debug logging facility as described below.

- **INFORMATION** – Used for informational messages that can be useful from time to time but are not normally something that administrators need to see.

- **MILD_WARNING** – Used for problems that the server detects, which can indicate something unusual occurred, but the warning does not prevent the server from completing the task it was working on. These warnings are not normally something that should be of concern to administrators.
- **MILD_ERROR** – Used for problems detected by the server that prevented it from completing some processing normally but that are not considered to be a significant problem requiring administrative action.
- **NOTICE** – Used for information messages about significant events that occur within the server and are considered important enough to warrant making available to administrators under normal conditions.
- **SEVERE_WARNING** – Used for problems that the server detects that might lead to bigger problems in the future and should be addressed by administrators.
- **SEVERE_ERROR** – Used for significant problems that have prevented the server from successfully completing processing and are considered important.
- **FATAL_ERROR** – Used for critical problems that arise which might leave the server unable to continue processing operations normally.

The messages written to the error log may be filtered based on their severities in two ways. First, the error log publisher has a `default-severity` property, which may be used to specify the severity of messages logged regardless of their category. By default, this includes the NOTICE, SEVERE_WARNING, SEVERE_ERROR, and FATAL_ERROR severities.

You can override these severities on a per-category basis using the `override-severity` property. If this property is used, then each value should consist of a category name followed by an equal sign and a comma-delimited set of severities that should be logged for messages in that category. For example, the following override severity would enable logging at all severity levels in the PROTOCOL category:

```
protocol=debug,information,mild-warning,mild-error,notice,severe-warning,severe-
error,fatal-error
```

Note that for the purposes of this configuration property, any underscores in category or severity names should be replaced with dashes. Also, severities are not inherently hierarchical, so enabling the DEBUG severity for a category will not automatically enable logging at the INFORMATION, MILD_WARNING, or MILD_ERROR severities.

The error log configuration may be altered on the fly using tools like `dsconfig`, the web administration console, or the LDIF connection handler, and changes will take effect immediately. You can configure multiple error logs that are active in the server at the same time, writing to different log files with different configurations. For example, a new error logger may be activated with a different set of default severities to debug a short-term problem, and then that logger may be removed once the problem is resolved, so that the normal error log does not contain any of the more verbose information.

server.out Log

The `server.out` file holds any information written to standard output or standard error while the server is running. Normally, it includes a number of messages written at startup and shutdown, as well as information about any administrative alerts generated while the server is running. In most cases, this information is also written to the error log. The `server.out` file can also contain output generated by the JVM. For example, if garbage collection debugging is enabled, or if a stack trace is requested via "kill -QUIT" as described in a later section, then output is written to this file.

Debug Log

The debug log provides a means of obtaining information that can be used for troubleshooting problems but is not necessary or desirable to have available while the server is functioning normally. As a result, the debug log is disabled by default, but it can be enabled and configured at any time.

Some of the most notable configuration properties for the debug log publisher include:

- **enabled** – Indicates whether debug logging is enabled. By default, it is disabled.
- **log-file** – Specifies the path to the file to be written. By default, debug messages are written to the `logs/debug` file.
- **default-debug-level** – Specifies the minimum log level for debug messages that should be written. The default value is “error,” which only provides information about errors that occur during processing (for example, exception stack traces). Other supported debug levels include warning, info, and verbose. Note that unlike error log severities, the debug log levels are hierarchical. Configuring a specified debug level enables any debugging at any higher levels. For example, configuring the info debug level automatically enables the warning and error levels.
- **default-debug-category** – Specifies the categories for debug messages that should be written. Some of the most useful categories include caught (provides information and stack traces for any exceptions caught during processing), database-access (provides information about operations performed in the underlying database), protocol (provides information about ASN.1 and LDAP communication performed by the server), and data (provides information about raw data read from or written to clients).

As with the error and access logs, multiple debug loggers can be active in the server at any time with different configurations and log files to help isolate information that might be relevant to a particular problem.

Note: Enabling one or more debug loggers can have a significant impact on server performance. We recommend that debug loggers be enabled only when necessary, and then be scoped so that only pertinent debug information is recorded.

Debug targets can be used to further pare down the set of messages generated. For example, you can specify that the debug logs be generated only within a specific class or package. If you need to enable the debug logger, you should work with your authorized support provider to best configure the debug target and interpret the output.

Replication Repair Log

The replication repair log is written to `logs/replication` by default and records information about processing performed by the replication repair service. This log is used to resolve replication conflicts that can arise. For example, if the same entry is modified at the same time on two different systems, or if an attempt is made to create entries with the same DN at the same time on two different systems, the Data Store records these events.

Config Audit Log and the Configuration Archive

The configuration audit log provides a record of any changes made to the server configuration while the server is online. This information is written to the `logs/config-audit.log` file and provides information about the configuration change in the form that may be used to perform the operation in a non-interactive manner with the `dsconfig` command. Other information written for each change includes:

- Time that the configuration change was made.
- Connection ID and operation ID for the corresponding change, which can be used to correlate it with information in the access log.
- DN of the user requesting the configuration change and the method by which that user authenticated to the server.
- Source and destination addresses of the client connection.
- Command that can be used to undo the change and revert to the previous configuration for the associated configuration object.

In addition to information about the individual changes that are made to the configuration, the Data Store maintains complete copies of all previous configurations. These configurations are provided in the `config/archived-configs` directory and are gzip-compressed copies of the `config/config.ldif` file in use before the configuration change was made. The filenames contain time stamps that indicate when that configuration was first used.

Access and Audit Log

The access log provides information about operations processed within the server. The default access log file is written to `logs/access`, but multiple access loggers can be active at the same time, each writing to different log files and using different configurations.

By default, a single access log message is generated, which combines the elements of request, forward, and result messages. If an error is encountered while attempting to process the request, then one or more forward-failed messages may also be generated.

```
[01/Jun/2011:11:10:19.692 -0500] CONNECT conn=49 from="127.0.0.1" to="127.0.0.1"
  protocol="LDAP+TLS" clientConnectionPolicy="default"
[01/Jun/2011:11:10:19.764 -0500] BIND RESULT conn=49 op=0 msgID=1 version="3"
  dn="cn=Directory Manager" authType="SIMPLE" resultCode=0 etime=0.401
  authDN="cn=Directory Manager,cn=Root DNs,cn=config" clientConnectionPolicy="default"
```

```
[01/Jun/2011:11:10:19.769 -0500] SEARCH RESULT conn=49 op=1 msgID=2
  base="ou=People,dc=example,dc=com" scope=2 filter="(uid=1)" attrs="ALL"
  resultCode=0 etime=0.549 entriesReturned=1
[01/Jun/2011:11:10:19.788 -0500] DISCONNECT conn=49 reason="Client Unbind"
```

Each log message includes a timestamp indicating when it was written, followed by the operation type, the connection ID (which is used for all operations processed on the same client connection), the operation ID (which can be used to correlate the request and response log messages for the operation), and the message ID used in LDAP messages for this operation.

The remaining content for access log messages varies based on the type of operation being processed, and whether it is a request or a result message. Request messages generally include the most pertinent information from the request, but generally omit information that is sensitive or not useful.

Result messages include a `resultCode` element that indicates whether the operation was successful or if failed and an `etime` element that indicates the length of time in milliseconds that the server spent processing the operation. Other elements that might be present include the following:

- **origin=replication** – Operation that was processed as a result of data synchronization (for example, replication) rather than a request received directly from a client.
- **message** – Text that was included in the `diagnosticMessage` field of the response sent to the client.
- **additionalInfo** – Additional information about the operation that was not included in the response sent back to the client.
- **authDN – DN** of the user that authenticated to the server (typically only included in bind result messages).
- **authzDN – DN** of an alternate authorization identify used when processing the operation (for example, if the proxied authorization control was included in the request).
- **authFailureID** – Unique identifier associated with the authentication failure reason (only included in non-successful bind result messages).
- **authFailureReason** – Information about the reason that a bind operation failed that might be useful to administrators but was not included in the response to the client for security reasons.
- **responseOID** – OID included in an extended response returned to the client.
- **entriesReturned** – Number of matching entries returned to the client for a search operation.
- **unindexed=true** – Indicates that the associated search operation could not be sufficiently processed using server indexes and a significant traversal through the database was required.

Note that this is not an exhaustive list, and elements that are not listed here may also be present in access log messages. The Commercial Edition of the LDAP SDK provides an API for parsing access log messages and provides access to all elements that they may contain.

The Data Store provides a second access log implementation called the *audit log*, which is used to provide detailed information about write operations (add, delete, modify, and modify DN) processed within the server. If the audit log is enabled, the entire content of the change is written to the audit log file (which defaults to `logs/audit`) in LDIF form.

The UnboundID Data Store also provides a very rich classification system that can be used to filter the content for access log files. This can be helpful when debugging problems with client applications, because it can restrict log information to operations processed only by a particular application (for example, based on IP address and/or authentication DN), only failed operations, or only operations taking a long time to complete, etc.

Setup Log

The `setup` tool writes a log file providing information about the processing that it performs. By default, this log file is written to `logs/setup.log` although a different name may be used if a file with that name already exists, because the `setup` tool has already been run. The full path to the setup log file is provided when the `setup` tool has completed.

Tool Log

Many of the administrative tools provided with the Data Store (for example, `import-ldif`, `export-ldif`, `backup`, `restore`, etc.) can take a significant length of time to complete write information to standard output or standard error or both while the tool is running. They also write additional output to files in the `logs/tools` directory (for example, **logs/tools/ import-ldif.log**). The information written to these log files can be useful for diagnosing problems encountered while they were running. When running via the server tasks interface, log messages generated while the task is running may alternately be written to the server error log file.

je.info and je.config Files

The primary data store used by the Data Store is the Oracle Berkeley DB Java Edition (JE). The Data Store provides two primary sources of information about processing within the database.

The first is logging performed by the JE code itself, and is written into the `je.info.0` file in the server containing the database files (for example, `db/userRoot/je.info.0`). In the event of a problem within JE itself, useful information about the nature of the problem may be written to this log. The level of information written to this log file is controlled by the `db-logging-level` property in the backend configuration object. It uses the standard Java logging framework for logging messages, so the standard SEVERE, WARNING, INFO, CONFIG, FINE, FINER, and FINEST levels are available.

The second is configuration information used when opening the database environment. When the backend database environment is opened, then the Data Store will also write a file named `je.config` in the server containing the database files (for example, `db/userRoot/je.config`) with information about the configuration used.

LDAP SDK Debug Log

This log can be used to help examine the communication between the Data Store and the Proxy Server. It contains information about exceptions that occur during processing, problems establishing and terminating network connections, and problems that occur during the reading and writing of LDAP messages and LDIF entries. You can configure the types of debugging that should be enabled, the debug level that should be used, and whether debug messages should include stack traces. As for other file-based loggers, you can also specify the rotation and retention policies.

About the Monitor Entries

While the Data Store is running, it generates a significant amount of information available through monitor entries. Monitor entries are available over LDAP in the `cn=monitor` subtree. The types of monitor entries that are available include:

- **General Monitor Entry (cn=monitor)** – Provides a basic set of general information about the server.
- **Active Operations Monitor Entry (cn=Active Operations,cn=monitor)** – Provides information about all operations currently in progress in the server.
- **Backend Monitor Entries (cn={id} Backend,cn=monitor)** – Provides information about the backend, including the number of entries, the base DN(s), and whether it is private.
- **Client Connections Monitor Entry (cn=Client Connections,cn=monitor)** – Provides information about all connections currently established to the server.
- **Connection Handler Monitor Entry (cn={name},cn=monitor)** – Provides information about the configuration of each connection handler and the client connections established to it.
- **Database Environment Monitor Entries (cn={id} Database Environment,cn=monitor)** – Provides statistics and other data from the Oracle Berkeley DB Java Edition database environment used by the associated backend.
- **Disk Space Usage Monitor Entry (cn=Disk Space Usage,cn=monitor)** – Provides information about the amount of usable disk space available to server components.
- **JVM Memory Usage Monitor Entry (cn=JVM Memory Usage,cn=monitor)** – Provides information about garbage collection activity, the amount of memory available to the server, and the amount of memory consumed by various server components.
- **JVM Stack Trace Monitor Entry (cn=JVM Stack Trace,cn=monitor)** – Provides a stack trace of all threads in the JVM.
- **LDAP Statistics Monitor Entries (cn={name} Statistics,cn=monitor)** – Provides information about the number of each type of operation requested and bytes transferred over the connection handler.

- **Processing Time Histogram Monitor Entry (cn=Processing Time Histogram,cn=monitor)** – Provides information about the number of percent of operations that completed in various response time categories.
- **System Information Monitor Entry (cn=System Information,cn=monitor)** – Provides information about the underlying JVM and system.
- **Version Monitor Entry (cn=Version,cn=monitor)** – Provides information about the Data Store version.
- **Work Queue Monitor Entry (cn=Work Queue,cn=monitor)** – Provides information about the state of the Data Store work queue, including the number of operations waiting on worker threads and the number of operations that have been rejected because the queue became full.

Data Store Troubleshooting Tools

The UnboundID Data Store provides a set of tools that can also be used to obtain information for diagnosing and solving problems.

Server Version Information

If it becomes necessary to contact your authorized support provider, then it will be important to provide precise information about the version of the Data Store software that is in use. If the server is running, then this information can be obtained from the "`cn=Version,cn=monitor`" entry. It can also be obtained using the command:

```
$ bin/status --fullVersion
```

This command outputs a number of important pieces of information, including:

- Major, minor, point and patch version numbers for the server.
- Source revision number from which the server was built.
- Build information including build ID with time stamp, OS, user, Java and JVM version for the build.
- Auxiliary software versions: Jetty, JZlib, SNMP4j (SNMP4J, Agent, Agentx), Groovy, UnboundID LDAP SDK for Java, and UnboundID Server SDK.

LDIF Connection Handler

The Data Store provides an LDIF connection handler that provides a way to request operations that do not require any network communication with the server. This can be particularly helpful if a configuration problem or bug in the server has left a connection handler unusable, or if all worker threads are busy processing operations.

The LDIF connection handler is enabled by default and looks for LDIF files to be placed in the `config/auto-process-ldif` directory. This Data Store does not exist by default, but if it is created and an LDIF file is placed in it that contains one or more changes to be processed, then those changes will be applied.

Any changes that can be made over LDAP can be applied through the LDIF connection handler. It is primarily intended for administrative operations like updating the server configuration or scheduling tasks, although other types of changes (including changes to data contained in the server) can be processed. As the LDIF file is processed, a new file is written with comments for each change providing information about the result of processing that change.

dbtest Tool

The `dbtest` tool provides a utility that can be used to obtain general information about the data in a backend database. The tool dumps information about entries or keys, and raw data from the database. It can also find keys that have exceeded the entry limit.

For example, the following command can be used to dump a list of all keys in the `objectClass.equality` that have exceeded the entry threshold:

```
$ bin/dbtest dump-database-container \
  --backendID userRoot \
  --baseDN "dc=example,dc=com" \
  --databaseName objectClass.equality \
  --onlyExceedingLimit
```

On a large database, many `dbtest` operations may take a long time to complete, since every record in the associated database is examined. Use the database name option to list a specific database. The following command displays information about the uid.equality database in the `dc=example,dc=com` entry container in the userRoot backend.

```
$ bin/dbtest list-database-containers -n userRoot -b "dc=example,dc=com" -d uid.equality
```

Index Key Entry Limit

Indexes have keys that maintain a list of matching entries, up to the index entry limit. When that limit is reached, the key will not contain or maintain that list, and will just maintain a count of matching entries. To determine if index keys are approaching their limit, use either the `dbtest` tool or the `verify-index` tool.

While the `dbtest` tool can be used to gather general imformation, the `verify-index` tool provides statistical data about the percent of entries covered by the keys.

For example, the following command can be used to retrieve a list of keys that have exceeded the entry threshold:

```
$ bin/verify-index \
  --baseDN dc=example,dc=com \
  --listKeysExceedingIndexEntryLimit
```

The following is a sample of the data returned:

```
 [12:06:05]  Checked 6003 entries and found 0 error(s) in 2 seconds (average rate
 2453.2/sec)
 [12:06:05]  Statistics for records that have exceeded the entry limit:
 [12:06:05]  The st.equality index has 48 such record(s) limit=100 min=103 max=152
 median=118
 [12:06:05]  1. or (152 entries / 2.53% of all entries)
```

```
[12:06:05]  2. ma (132 entries / 2.20% of all entries)
 .....
[12:06:05]  The id2subtree index has 2 such record(s) limit=4000 min=6000 max=6002
median=6001
[12:06:05]  1. 1 => dc=example,dc=com (6002 entries / 99.98% of all entries)
 .....
[12:06:05]  The id2children index has 1 such record(s) limit=4000 min=6000 max=6000
median=6000
[12:06:05]  1. 2 => ou=People,dc=example,dc=com (6000 entries / 99.95% of all entries)
[12:06:05]  The objectClass.equality index has 4 such record(s) limit=4000 min=6001
max=6003 median=6001
[12:06:05]  1. top (6003 entries / 100.00% of all entries)
 .....
```

Embedded Profiler

If the Data Store appears to be running slowly, then it is helpful to know what operations are being processed in the server. The JVM Stack Trace monitor entry can be used to obtain a point-in-time snapshot of what the server is doing, but in many cases, it might be useful to have information collected over a period of time.

The embedded profiler is configured so that it is always available but is not active by default so that it has no impact on the performance of the running server. Even when it is running, it has a relatively small impact on performance, but it is recommended that it remain inactive when it is not needed. It can be controlled using the `dsconfig` tool or the web administration console by managing the "Profiler" configuration object in the "Plugin" object type, available at the standard object level. The `profile-action` property for this configuration object can have one of the following values:

- **start** – Indicates that the embedded profiler should start capturing data in the background.
- **stop** – Indicates that the embedded profiler should stop capturing data and write the information that it has collected to a `logs/profile{timestamp}` file.
- **cancel** – Indicates that the embedded profiler should stop capturing data and discard any information that it has collected.

Any profiling data that has been captured can be examined using the `profiler-viewer` tool. This tool can operate in either a text-based mode, in which case it dumps a formatted text representation of the profile data to standard output, or it can be used in a graphical mode that allows the information to be more easily understood.

To Invoke the Profile Viewer in Text-based Mode

- Run the `profile-viewer` command and specify the captured log file using the `--fileName` option.

```
$ bin/profile-viewer --fileName logs/profile.20110101000000Z
```

To Invoke the Profile Viewer in GUI Mode

- Run the `profile-viewer` command and specify the captured log file using the `--fileName` option. To invoke GUI mode, add the option `--useGUI`.

```
$ bin/profile-viewer --fileName logs/profile.20110101000000Z --useGUI
```

Oracle Berkeley DB Java Edition Utilities

The Oracle Berkeley DB Java Edition (JE) itself provides a number of utilities that can be used for performing various types of low-level debugging in the database environment. These utilities should generally not be used unless you are advised to do so by your authorized support provider, but they provide access to information about the underlying database environment that is not available through any other means.

Troubleshooting Resources for Java Applications

Because the UnboundID Data Store is written entirely in Java, it is possible to use standard Java debugging and instrumentation tools when troubleshooting problems with the Data Store. In many cases, obtaining the full benefit of these tools requires access to the Data Store source code. These Java tools should be used under the advisement of your authorized support provider.

Java Troubleshooting Tools

The Java Development Kit provides a number of very useful tools to obtain information about Java applications and diagnosing problems. These tools are not included with the Java Runtime Environment (JRE), so the full Java Development Environment (JDK) should always be installed and used to run the UnboundID Data Store.

jps

The `jps` tool is a Java-specific version of the UNIX `ps` tool. It can be used to obtain a list of all Java processes currently running and their respective process identifiers. When invoked by a non-root user, it will list only Java processes running as that user. When invoked by a root user, then it lists all Java processes on the system.

This tool can be used to see if the Data Store is running and if a process ID has been assigned to it. This process ID can be used in conjunction with other tools to perform further analysis.

This tool can be run without any arguments, but some of the more useful arguments that include:

- **-v** – Includes the arguments passed to the JVM for the processes that are listed.
- **-m** – Includes the arguments passed to the main method for the processes that are listed.
- **-l** – (lowercase L). Include the fully qualified name for the main class rather than only the base class name.

jstack

The `jstack` tool is used to obtain a stack trace of a running Java process, or optionally from a core file generated if the JVM happens to crash. A stack trace can be extremely valuable when trying to debug a problem, because it provides information about all threads running and exactly what each is doing at the point in time that the stack trace was obtained.

Stack traces are helpful when diagnosing problems in which the server appears to be hung or behaving slowly. Java stack traces are generally more helpful than native stack traces, because Java threads can have user-friendly names (as do the threads used by the UnboundID Data Store), and the frame of the stack trace may include the line number of the source file to which it corresponds. This is useful when diagnosing problems and often allows them to be identified and resolved quickly.

To obtain a stack trace from a running JVM, use the command:

```
jstack {processID}
```

where {processID} is the process ID of the target JVM as returned by the `jps` command. To obtain a stack trace from a core file from a Java process, use the command:

```
jstack {pathToJava} {pathToCore}
```

where `{pathToJava}` is the path to the java command from which the core file was created, and `{pathToCore}` is the path to the core file to examine. In either case, the stack trace is written to standard output and includes the names and call stacks for each of the threads that were active in the JVM.

In many cases, no additional options are necessary. The "`-l`" option can be added to obtain a long listing, which includes additional information about locks owned by the threads. The “`-m`” option can be used to include native frames in the stack trace.

jmap

The `jmap` tool is used to obtain information about the memory consumed by the JVM. It is very similar to the native `pmap` tool provided by many operating systems. As with the `jstack` tool, `jmap` can be invoked against a running Java process by providing the process ID, or against a core file, like:

```
jmap {processID}
jmap {pathToJava} {pathToCore}
```

Some of the additional arguments include:

- **-dump:live,format=b,file=filename** – Dump the live heap data to a file that can be examined by the `jhat` tool
- **-heap** – Provides a summary of the memory used in the Java heap, along with information about the garbage collection algorithm in use.

- **-histo:live** – Provides a count of the number of objects of each type contained in the heap. If the "`:live`" portion is included, then only live objects are included; otherwise, the count include objects that are no longer in use and are garbage collected.

jhat

The `jhat` (Java Heap Analysis Tool) utility provides the ability to analyze the contents of the Java heap. It can be used to analyze a heap dump file, which is generated if the Data Store encounters an out of memory error (as a result of the "`-XX:+HeapDumpOnOutOfMemoryError`" JVM option) or from the use of the `jmap` command with the "`-dump`" option.

The `jhat` tool acts as a web server that can be accessed by a browser in order to query the contents of the heap. Several predefined queries are available to help determine the types of objects consuming significant amounts of heap space, and it also provides a custom query language (OQL, the Object Query Language) for performing more advanced types of analysis.

The `jhat` tool can be launched with the path to the heap dump file, like:

```
jhat /path/to/heap.dump
```

This command causes the `jhat` web server to begin listening on port 7000. It can be accessed in a browser at `http://localhost:7000` (or `http://address:7000` from a remote system). An alternate port number can be specified using the "`-port`" option, like:

```
jhat -port 1234 /path/to/heap.dump
```

To issue custom OQL searches, access the web interface using the URL `http://localhost:7000/oql/` (the trailing slash must be provided). Additional information about the OQL syntax may be obtained in the web interface at `http://localhost:7000/oqlhelp/`.

jstat

The `jstat` tool is used to obtain a variety of statistical information from the JVM, much like the `vmstat` utility that can be used to obtain CPU utilization information from the operating system. The general manner to invoke it is as follows:

```
jstat {type} {processID} {interval}
```

The `{interval}` option specifies the length of time in milliseconds between lines of output. The `{processID}` option specifies the process ID of the JVM used to run the Data Store, which can be obtained by running `jps` as mentioned previously. The `{type}` option specifies the type of output that should be provided. Some of the most useful types include:

- **-class** – Provides information about class loading and unloading.
- **-compile** – Provides information about the activity of the JIT complex.
- **-printcompilation** – Provides information about JIT method compilation.
- **-gc** – Provides information about the activity of the garbage collector.
- **-gccapacity** – Provides information about memory region capacities.

Java Diagnostic Information

In addition to the tools listed in the previous section, the JVM can provide additional diagnostic information in response to certain events.

JVM Crash Diagnostic Information

If the JVM itself should happen to crash for some reason, then it generates a fatal error log with information about the state of the JVM at the time of the crash. By default, this file is named `hs_err_pid{processID}.log` and is written into the base directory of the Data Store installation. This file includes information on the underlying cause of the JVM crash, information about the threads running and Java heap at the time of the crash, the options provided to the JVM, environment variables that were set, and information about the underlying system.

Java Troubleshooting Tools (IBM JDK)

The UnboundID Data Store can be run on machines using the IBM JDK. IBM provides Java monitoring and diagnostic tools that can assess JVM performance and troubleshoot any Java application failures. The following tools are available for the IBM JDK. For more detailed information, see the IBM Developers web-site for a description of each tool:

- **Health Center Version 1.3**. Monitors Java applications running on the JDK. The tool provides profiling information for performance, memory usage, system environment, object allocations and other areas.
- **Memory Analyzer Version 1.1**. Analyzes Java heap memory using a system or heap dump snapshot of a Java process.
- **Garbage Collection and Memory Visualizer Version 2.6**. Fine-tunes Java performance by optimizing garbage collection performance, provides Java heap recommendations based on peak and average memory usage, and detects memory leaks and heap exhaustion.
- **Dump Analyzer Version 2.2**. Helps troubleshoot the cause of any application failure using an operating system dump. The tool detects any potential problems based on state, thread, stack information and error messages that were generated when the application failed.
- **Diagnostics Collector Version 1.0**. Collects diagnostic and context information during Java runtime processes that failed. The tool verifies your Java diagnostic configuration to ensure that disabled diagnostic analyzers are enabled to troubleshoot a problem.
- **IBM Diagnostic Tool Framework for Java Version 1.5**. Runs on dump data extracted by the `jextract` tool. The tool checks memory locations, Java threads, Java objects and other important diagnostic areas when the system dump was produced.

Troubleshooting Resources in the Operating System

The underlying operating system also provides a significant amount of information that can help diagnose issues that impact the performance and the stability of the Data Store. In some cases, problems with the underlying system can be directly responsible for the issues seen with the Data Store, and in others system, tools can help narrow down the cause of the problem.

Identifying Problems with the Underlying System

If the underlying system itself is experiencing problems, it can adversely impact the function of applications running on it. Places to look for problems in the underlying system include:

- The system log file (`/var/adm/messages` on Solaris and `/var/log/messages` on Linux). Information about faulted or degraded devices or other unusual system conditions are written there.
- On Solaris systems, if the fault management system has detected a problem with a system component, information about that problem is obtain by running the `fmdump` command.
- If the ZFS filesystem is in use, then the `zpool` status command provides information about read errors, write errors, or data checksum errors.

Examining CPU Utilization

Observing CPU utilization for the Data Store process and the system as a whole provides clues as to the nature of the problem.

System-Wide CPU Utilization

To investigate CPU consumption of the system as a whole, use the `vmstat` command with a time interval in seconds, like:

```
vmstat 5
```

The specific output of this command varies between different operating systems, but it includes the percentage of the time the CPU was spent executing user-space code (user time), the percentage of time spent executing kernel-space code (system time), and the percentage of time not executing any code (idle time).

If the CPUs are spending most of their time executing user-space code, the available processors are being well-utilized. If performance is poor or the server is unresponsive, it can indicate that the Data Store is not optimally tuned. If there is a high system time, it can indicate that the system is performing excessive disk and/or network I/O, or in some cases, there can be some other system-wide problem like an interrupt storm. If the system is mostly idle but the Data Store is performing poorly or is unresponsive, there can be a resource constraint elsewhere (for example, waiting on disk or memory access, or excessive lock contention), or the JVM can be performing other tasks like stop-the-world garbage collection that cannot be run heavily in parallel.

Per-CPU Utilization

To investigate CPU consumption on a per-CPU basis, use the `mpstat` command with a time interval in seconds, like:

```
mpstat 5
```

On Linux systems, it might be necessary to add "`-P ALL`" to the command, like:

```
mpstat -P ALL 5
```

Among other things, this shows the percentage of time each CPU has spent in user time, system time, and idle time. If the overall CPU utilization is relatively low but `mpstat` reports that one CPU has a much higher utilization than the others, there might be a significant bottleneck within the server or the JVM might be performing certain types of garbage collection which cannot be run in parallel. On the other hand, if CPU utilization is relatively even across all CPUs, there is likely no such bottleneck and the issue might be elsewhere.

Per-Process Utilization

To investigate CPU consumption on a per-process basis, use the `prstat` tool on Solaris or the `top` utility on Linux. If a process other than the Java process used to run the Data Store is consuming a significant amount of available CPU, it might be interfering with the ability of the Data Store to run effectively.

If the `mpstat` command showed that one CPU was much more heavily utilized than the others, it might be useful to identify the thread with the highest CPU utilization as it is likely the one that is a bottleneck preventing other threads from processing. On Solaris, this can be achieved by using the `prstat` command with the "`-L`" option, like:

```
prstat -L -p {processID}
```

This command will cause each thread to be displayed on a separate line, with the LWPID (lightweight process identifier) displayed as the last item on each line, separated from the process name by a slash. The thread that is currently consuming the largest amount of CPU will be displayed at the top of the list, and the `pstack` command can be used to identify which thread is responsible.

Examining Disk Utilization

If the underlying system has a very high disk utilization, it can adversely impact Data Store performance. It could delay the ability to read or write database files or write log files. It could also raise concerns for server stability if excessive disk I/O inhibits the ability of the cleaner threads to keep the database size under control.

The `iostat` tool may be used to obtain information about the disk activity on the system. On Solaris systems, this should be invoked using the "`-x`" and "`-n`" arguments, like:

```
iostat -x -n 5
```

On Linux systems, `iostat` should be invoked with the "`-x`" argument, like:

```
iostat -x 5
```

A number of different types of information will be displayed, but to obtain an initial feel for how busy the underlying disks are, look at the "%b" column on Solaris and the "%util" column on Linux. Both of these fields show the percentage of the time that the underlying disks are actively servicing I/O requests. A system with a high disk utilization likely exhibits poor Data Store performance.

If the high disk utilization is on one or more disks that are used to provide swap space for the system, the system might not have enough free memory to process requests. As a result, it might have started swapping blocks of memory that have not been used recently to disk. This can cause very poor server performance. It is important to ensure that the server is configured appropriately to avoid this condition. If this problem occurs on a regular basis, then the server is likely configured to use too much memory. If swapping is not normally a problem but it does arise, then check to see if there are any other processes running, which are consuming a significant amount of memory, and check for other potential causes of significant memory consumption (for example, large files in a `tmpfs` filesystem).

On Solaris systems using ZFS, you can use the `zpool iostat {interval}` command to obtain information about I/O activity on a per-pool basis. While this command provides a useful display of the number of read and write operations and the amount of data being read from and written to the disks, it does not actually show how busy the underlying disks. As a result, the `zpool iostat` command is generally not as useful as the traditional `iostat` command for identifying potential I/O bottlenecks.

Examining Process Details

There are a number of tools provided by the operating system that can help examine a process in detail.

ps

The standard `ps` tool can be used to provide a range of information about a particular process. For example, the command can be used to display the state of the process, the name of the user running the process, its process ID and parent process ID, the priority and nice value, resident and virtual memory sizes, the start time, the execution time, and the process name with arguments:

```
ps -fly -p {processID}
```

Note that for a process with a large number of arguments, the standard `ps` command displays only a limited set of the arguments based on available space in the terminal window. In that case, the BSD version of the `ps` command (available on Solaris as `/usr/ucb/ps`) can be used to obtain the full command with all arguments, like:

```
/usr/ucb/ps auxwww {processID}
```

pstack

The `pstack` command can be used to obtain a native stack trace of all threads in a process. While a native stack trace might not be as user-friendly as a Java stack trace obtained using `jstack`, it includes threads that are not available in a Java stack trace. For example, the command displays those threads used to perform garbage collection and other housekeeping tasks. The general usage for the `pstack` command is:

```
pstack {processID}
```

dbx / gdb

A process debugger provides the ability to examine a process in detail. Like `pstack`, a debugger can obtain a stack trace for all threads in the process, but it also provides the ability to examine a process (or core file) in much greater detail, including observing the contents of memory at a specified address and the values of CPU registers in different frames of execution. The GNU debugger `gdb` is widely-used on Linux systems and is available on Solaris, but the Sun Studio debugger `dbx` is generally preferred over `gdb` on Solaris.

Note that using a debugger against a live process interrupts that process and suspends its execution until it detaches from the process. In addition, when running against a live process, a debugger has the ability to actually alter the contents of the memory associated with that process, which can have adverse effects. As a result, it is recommended that the use of a process debugger be restricted to core files and only used to examine live processes under the direction of your authorized support provider.

pfiles / lsof

To examine the set of files that a process is using (including special types of files, like sockets) on Solaris, you can use the `pfiles` command, like:

```
pfiles {processID}
```

On Linux systems, the `lsof` tool can be used, like:

```
lsof -p {processID}
```

Tracing Process Execution

If a process is unresponsive but is consuming a nontrivial amount of CPU time, or if a process is consuming significantly more CPU time than is expected, it might be useful to examine the activity of that process in more detail than can be obtained using a point-in-time snapshot like you can get with `pstack` or a debugger. For example, if a process is performing a significant amount of disk reads and/or writes, it can be useful to see which files are being accessed. Similarly, if a process is consistently exiting abnormally, then beginning tracing for that process just before it exits can help provide additional information that cannot be captured in a core file (and if the process is exiting rather than being terminated for an illegal operation, then no core file may be available).

On Solaris systems, the `dtrace` tool provides an unmatched mechanism for tracing the execution of a process in extremely powerful and flexible ways, but it is also relatively complex and describing its use is beyond the scope of this document. In many cases, however, observing the system calls made by a process can reveal a great deal about what it is doing. This can be accomplished using the `truss` utility on Solaris or the `strace` tool on Linux.

The `truss` utility is very powerful and has a lot of options, but two of the most useful forms in which it may be invoked are:

- **truss -f -p {processID}** – Provides a basic overview of all system calls being made by the specified process (and any subprocesses that it creates) and their associated return values.
- **truss -fear all -p {processID}** – Provides an extremely verbose trace of all system call activity, including details about data being read from or written to files and sockets.

In both cases, the output may be written to a file instead of the terminal window by adding the `-o {path}` option. Further, rather than observing an already-running process, it is possible to have `truss` launch the process and trace execution over its entire life span by replacing `-p {processID}` with name and arguments for the command to invoke.

On Linux systems, the basic equivalent of the first truss variant above is:

```
strace -f -p {processID}
```

Consult the `strace` manual page for additional information about using it to trace process execution on Linux.

Examining Network Communication

Because the UnboundID Data Store is a network-based application, it can be valuable to observe the network communication that it has with clients. The Data Store itself can provide details about its interaction with clients by enabling debugging for the protocol or data debug categories, but there may be a number of cases in which it is useful to view information at a much lower level. A network sniffer, like the `snoop` tool on Solaris or the *tcpdump* tool on Linux, can be used to accomplish this.

There are many options that can be used with these tools, and their corresponding manual pages will provide a more thorough explanation of their use. However, to perform basic tracing to show the full details of the packets received for communication on port 389 with remote host 1.2.3.4, the following commands can be used on Solaris and Linux, respectively:

```
snoop -d {interface} -r -x 0 host 1.2.3.4 port 389
tcpdump -i {interface} -n -XX -s 0 host 1.2.3.4 and port 389
```

On Solaris systems, the `snoop` command provides enhanced support for parsing LDAP communication (but only when the Data Store is listening on the default port of 389). By adding the "`-v`" argument to the `snoop` command line, a verbose breakdown of each packet will be displayed, including protocol-level information. It does not appear that the `tcpdump` tool provides support for LDAP parsing. However, in either case it is possible to write capture data to a file rather than displaying information on the terminal (using "`-o {path}`" with `snoop`, or "`-w {path}`" with `tcpdump`), so that information can be later analyzed with a graphical tool like Wireshark, which provides the ability to interpret LDAP communication on any port.

Note that enabling network tracing generally requires privileges that are not available to normal users and therefore may require root access. On Solaris systems, granting the `net_rawaccess` privilege to a user should be sufficient to allow that user to run the `snoop` utility.

Common Problems and Potential Solutions

This section describes a number of different types of problems that can occur and common potential causes for them.

General Methodology to Troubleshoot a Problem

When a problem is detected, UnboundID recommends using the following general methodology to isolate the problem:

1. Run the `bin/status` tool or look at the server status in the web console. The `status` tool provides a summary of the server's current state with key metrics and a list of recent alerts.
2. Look in the server logs. In particular, view the following logs:
   - logs/errors
   - logs/failed-ops
   - logs/expensive-ops
3. Use system commands, such as `vmstat` and `iostat` to determine if the server is bottle-necked on a system resource like CPU or disk throughput.
4. For performance problem (especially intermittent ones like spikes in response time), enabling the `periodic-stats-logger` can help to isolate problems, because it stores important server performance information on a per-second basis. The `periodic-stats-logger` can save the information in a csv-formatted file that can be loaded into a spreadsheet. The information this logger makes available is very configurable. You can create multiple loggers for different types of information or a different frequency of logging (for example, hourly data in addition to per-second data). For more information, see "Profiling Server Performance Using the Periodic Stats Logger".
5. For replication problem, run `dsreplication status` and look at the `logs/replication` file.
6. For more advanced users, run the `collect-support-data` tool on the system, unzip the archive somewhere, and look through the collected information. This is often useful when administrators most familiar with the UnboundID Platform do not have direct access to the systems where the production servers are running. They can examine the `collect-support-data` archive on a different server. For more information, see Using the Collect Support Data Tool.

Important: Run the `collect-support-data` tool whenever there is a problem whose cause is not easily identified, so that this information can be passed back to your authorized support provider before corrective action can be taken.

The Server Will Not Run Setup

If the `setup` tool does not run properly, some of the most common reasons include the following:

A Suitable Java Environment Is Not Available

The UnboundID Data Store requires that Java be installed on the system and made available to the server, and it must be installed prior to running `setup`. If the `setup` tool does not detect that a suitable Java environment is available, it will refuse to run.

To ensure that this does not happen, the `setup` tool should be invoked with an explicitly-defined value for the *JAVA_HOME* environment variable that specifies the path to the Java installation that should be used. For example:

```
env JAVA_HOME=/ds/java ./setup
```

If this still does not work for some reason, then it can be that the value specified in the provided *JAVA_HOME* environment variable can be overridden by another environment variable. If that occurs, try the following command, which should override any other environment variables that can be set:

```
env UNBOUNDID_JAVA_HOME="/ds/java" UNBOUNDID_JAVA_BIN="" ./setup
```

Oracle Berkeley DB Java Edition Is Not Available

If the version of the Data Store that you are using was not provided with the Oracle Berkeley DB Java Edition library, then it must be manually downloaded and the appropriate JAR file placed in the `lib` directory before running setup. See the `lib/downloading-je.txt` file for instructions on obtaining the appropriate library.

Unexpected Arguments Provided to the JVM

If the `setup` script attempts to launch the java command with an invalid set of Java arguments, it might prevent the JVM from starting. By default, no special options are provided to the JVM when running setup, but this might not be the case if either the *JAVA_ARGS* or *UNBOUNDID_JAVA_ARGS* environment variable is set. If the `setup` tool displays an error message that indicates that the Java environment could not be started with the provided set of arguments, then invoke the following command before trying to re-run `setup`:

```
unset JAVA_ARGS UNBOUNDID_JAVA_ARGS
```

The Server Has Already Been Configured or Used

The `setup` tool is only intended to provide the initial configuration for the Data Store. It refuses to run if it detects that the `setup` tool has already been run, or if an attempt has been made to start the Data Store prior to running the `setup` tool. This protects an existing Data

Store installation from being inadvertently updated in a manner that could harm an existing configuration or data set.

If the Data Store has been previously used and if you want to perform a fresh installation, it is recommended that you first remove the existing installation, create a new one and run `setup` in that new installation. However, if you are confident that there is nothing of value in the existing installation (for example, if a previous attempt to run `setup` failed to complete successfully for some reason but it will refuse to run again), the following steps can be used to allow the `setup` program to run:

- Remove the `config/config.ldif` file and replace it with the `config/update/config.ldif.{revision}` file containing the initial configuration.
- If there are any files or subdirectories below the `db` directory, then remove them.
- If a `config/java.properties` file exists, then remove it.
- If a `lib/setup-java-home` script (or `lib\set-java-home.bat` file on Microsoft Windows) exists, then remove it.

The Server Will Not Start

If the Data Store does not start, then there are a number of potential causes.

The Server or Other Administrative Tool Is Already Running

Only a single instance of the Data Store can run at any time from the same installation root. If an instance is already running, then subsequent attempts to start the server will fail. Similarly, some other administrative operations can also prevent the server from being started. In such cases, the attempt to start the server should fail with a message like:

```
The Data Store could not acquire an exclusive lock on file
/ds/UnboundID-DS/locks/server.lock: The exclusive lock requested for file
/ds/UnboundID-DS/locks/ server.lock was not granted, which indicates
that another process already holds a shared or exclusive lock on that
file. This generally means that another instance of this server is already
running
```

If the Data Store is not running (and is not in the process of starting up or shutting down) and there are no other tools running that could prevent the server from being started, and the server still believes that it is running, then it is possible that a previously-held lock was not properly released. In that case, you can try removing all of the files in the `locks` directory before attempting to start the server.

If you wish to have multiple instances running at the same time on the same system, then you should create a completely separate installation in another location on the filesystem.

There Is Not Enough Memory Available

When the Data Store is started, the JVM attempts to allocate all memory that it has been configured to use. If there is not enough free memory available on the system, then the Data Store generates an error message that indicates that the server could not be started with the specified set of arguments. Note that it is possible that an invalid option was provided to the JVM (as described below), but if that same set of JVM arguments has already been used successfully to run the server, then it is more likely that the system does not have enough memory available.

There are a number of potential causes for this:

- If the amount of memory in the underlying system has changed (for example, system memory has been removed, or if the Data Store is running in a zone or other type of virtualized container and a change has been made to the amount of memory that container will be allowed to use), then the Data Store might need to be re-configured to use a smaller amount of memory than had been previously configured.
- Another process running on the system is consuming a significant amount of memory so that there is not enough free memory available to start the server. If this is the case, then either terminate the other process to make more memory available for the Data Store, or reconfigure the Data Store to reduce the amount of memory that it attempts to use.
- The Data Store was just shut down and an attempt was made to immediately restart it. In some cases, if the server is configured to use a significant amount of memory, then it can take a few seconds for all of the memory that had been in use by the server, when it was previously running, to be released back to the operating system. In that case, run the `vmstat` command and wait until the amount of free memory stops growing before attempting to restart the server.
- For Solaris-based systems only, if the system has one or more ZFS filesystems (even if the Data Store itself is not installed on a ZFS filesystem), but it has not been configured to limit the amount of memory that ZFS can use for caching, then it is possible that ZFS caching is holding onto a significant amount of memory and cannot release it quickly enough when it is needed by the Data Store. In that case, the system should be re-configured to limit the amount of memory that ZFS is allowed to use as described in the Using the Collect Support Data Tool.
- If the system is configured with one or more memory-backed filesystems, for example, `tmpfs` used for `/tmp` for Solaris), then look to see if there are any large files that can be consuming a significant amount of memory in any of those locations. If so, then remove them or relocate them to a disk-based filesystem.
- For Linux systems only, if there is a mismatch between the huge pages setting for the JVM and the huge pages reserved in the operating system.

If nothing else works and there is still not enough free memory to allow the JVM to start, then as a last resort, try rebooting the system.

An Invalid Java Environment or JVM Option Was Used

If an attempt to start the Data Store fails with an error message indicating that no valid Java environment could be found, or indicates that the Java environment could not be started with the configured set of options, then you should first ensure that enough memory is available on the system as described above. If there is a sufficient amount of memory available, then other causes for this error can include the following:

- The Java installation that was previously used to run the server no longer exists (for example, an updated Java environment was installed and the old installation was removed). In that case, update the `config/java.properties` file to reference to path to the new Java installation and run the `bin/dsjavaproperties` command to apply that change.
- The Java installation used to run the server has been updated and the server is trying to use the correct Java installation but one or more of the options that had worked with the previous Java version no longer work with the new version. In that case, it is recommended that the server be re-configured to use the previous Java version, so that it can be run while investigating which options should be used with the new installation.
- If an *UNBOUNDID_JAVA_HOME* or *UNBOUNDID_JAVA_BIN* environment variable is set, then its value may override the path to the Java installation used to run the server as defined in the `config/java.properties` file. Similarly, if an *UNBOUNDID_JAVA_ARGS* environment variable is set, then its value might override the arguments provided to the JVM. If this is the case, then explicitly unset the *UNBOUNDID_JAVA_HOME*, *UNBOUNDID_JAVA_BIN*, and *UNBOUNDID_JAVA_ARGS* environment variables before trying to start the server.

Note that any time the `config/java.properties` file is updated, the `bin/dsjavaproperties` tool must be run to apply the new configuration. If a problem with the previous Java configuration prevents the `bin/dsjavaproperties` tool from running properly, then it can be necessary to remove the `lib/set-java-home` script (or `lib\set-java-home.bat` file on Microsoft Windows) and invoke the `bin/dsjavaproperties` tool with an explicitly-defined path to the Java environment, like:

```
env UNBOUNDID_JAVA_HOME=/ds/java bin/dsjavaproperties
```

An Invalid Command-Line Option Was Provided

There are a small number of arguments that are provided when running the `bin/start-ds` command, but in most cases, none are required. If one or more command-line arguments were provided for the `bin/start-ds` command and any of them is not recognized, then the server provides an error message indicating that an argument was not recognized and displays version information. In that case, correct or remove the invalid argument and try to start the server again.

The Server Has an Invalid Configuration

If a change is made to the Data Store configuration using an officially-supported tool like `dsconfig` or the Management Console, the server should validate that configuration change before applying it. However, it is possible that a configuration change can appear to be valid at the time that it is applied, but does not work as expected when the server is restarted. Alternately, a change in the underlying system can cause a previously-valid configuration to become invalid.

In most cases involving an invalid configuration, the Data Store displays (and writes to the error log) a message that explains the problem, and this can be sufficient to identify the problem and understand what action needs to be taken to correct it. If for some reason the startup failure does not provide enough information to identify the problem with the configuration, then look in the `logs/config-audit.log` file to see what recent configuration changes have been made with the server online, or in the `config/archived-configs` directory to see if there might have been a recent configuration change resulting from a direct change to the configuration file itself that was not made through a supported configuration interface.

If the server does not start as a result of a recent invalid configuration change, then it can be possible to start the server using the configuration that was in place the last time that the server started successfully (for example, the "last known good" configuration). This can be achieved using the `--useLastKnownGoodConfig` option:

```
$ bin/start-ds --useLastKnownGoodConfig
```

Note that if it has been a long time since the last time the server was started and a number of configuration changes have been made since that time, then the last known good configuration can be significantly out of date. In such cases, it can be preferable to manually repair the configuration.

If there is no last known good configuration, if the server no longer starts with the last known good configuration, or if the last known good configuration is significantly out of date, then manually update the configuration by editing the `config/config.ldif` file. In that case, you should make sure that the server is offline and that you have made a copy of the existing configuration before beginning. You might wish to discuss the change with your authorized support representative before applying it to ensure that you understand the correct change that needs to be made.

Note: In addition to manually-editing the config file, you can look at previous achived configurations to see if the most recent one works. You can also use the `ldif-diff` tool to compare the configurations in the archive to the current configuration to see what is different.

You Do Not Have Sufficient Permissions

The Data Store should only be started by the user or role used to initially install the server. In most cases, if an attempt is made to start the server as a user or role other than the one used to create the initial configuration, then the server will fail to start, because the user will not have sufficient permissions to access files owned by the other user, such as database and log files. However, if the server was initially installed as a non-root user and then the server is started by the root account, then it can no longer be possible to start the server as a non-root user because new files that are created would be owned by root and could not be written by other users.

If the server was inadvertently started by root when it is intended to be run by a non-root user, or if you wish to change the user account that should be used to run the server, then it should be sufficient to simply change ownership on all files in the Data Store installation, so that they are owned by the user or role under which the server should run. For example, if the Data Store should be run as the "ds" user in the "other" group, then the following command can be used to accomplish this (invoked by the root user):

```
chown -R ds:other /ds/UnboundID-DS
```

The Server Has Crashed or Shut Itself Down

You can first check the current server state by using the `bin/server-state` command. If the Data Store was previously running but is no longer active, then the potential reasons include the following:

- The Data Store was shut down by an administrator. Unless the server was forcefully terminated (for example, using "kill -9"), then messages are written to the `error` and `server.out` logs explaining the reason for the shutdown.
- The Data Store was shut down when the underlying system crashed or was rebooted. If this is the case, then running the `uptime` command on the underlying system shows that it was recently booted.
- The Data Store process was terminated by the underlying operating system for some reason (for example, the out of memory killer on Linux). If this happens, then a message will be written to the system error log.
- The Data Store decided to shut itself down in response to a serious problem that had arisen. At present, this should only occur if the server has detected that the amount of usable disk space has become critically low, or if significant errors have been encountered during processing that left the server without any remaining worker threads to process operations. If this happens, then messages are written to the `error` and `server.out` logs (if disk space is available) to provide the reason for the shutdown.
- The JVM in which the Data Store was running crashed. If this happens, then the JVM should dump a fatal error log (a `hs_err_pid{processID}.log` file) and potentially a core file.

In the event that the operating system itself crashed or terminated the process, then you should work with your operating system vendor to diagnose the underlying problem. If the JVM crashed or the server shut itself down for a reason that is not clear, then contact your authorized support provider for further assistance.

The Server Will Not Accept Client Connections

You can first check the current server state by using the `bin/server-state` command. If the Data Store does not appear to be accepting connections from clients, then potential reasons include the following:

- The Data Store is not running.
- The underlying system on which the Data Store is installed is not running.
- The Data Store is running but is not reachable as a result of a network or firewall configuration problem. If that is the case, then connection attempts should time out rather than be rejected.
- If the Data Store is configured to allow secure communication via SSL or StartTLS, then a problem with the key manager and/or trust manager configuration can cause connections to

be rejected. If that is the case, then messages should be written to the server access log for each failed connection attempt.

- If the Data Store has been configured with a maximum allowed number of connections, then it can be that the maximum number of allowed client connections are already established. If that is the case, then messages should be written to the server access log for each rejected connection attempt.
- If the Data Store is configured to restrict access based on the address of the client, then messages should be written to the server access log for each rejected connection attempt.
- If a connection handler encounters a significant error, then it can stop listening for new requests. If this occurs, then a message should be written to the server error log with information about the problem. Another solution is to restart the server. A third option is to restart the connection handler using the LDIF connection handler to make it available again. To do this, create an LDIF file that disables and then re-enables the connection handler, create the `config/auto-process-ldif` directory if it does not already exist, and then copy the LDIF file into it.

The Server is Unresponsive

You can first check the current server state by using the `bin/server-state` command. If the Data Store process is running and appears to be accepting connections but does not respond to requests received on those connections, then potential reasons for this behavior include:

- If all worker threads are busy processing other client requests, then new requests that arrive will be forced to wait in the work queue until a worker thread becomes available. If this is the case, then a stack trace obtained using the `jstack` command shows that all of the worker threads are busy and none of them are waiting for new requests to process.

  A dedicated thread pool can be used for processing administrative operations. This thread pool enables diagnosis and corrective action if all other worker threads are processing operations. To request that operations use the administrative thread pool, using the `ldapsearch` command for example, use the `--useAdministrativeSession` option. The requester must have the `use-admin-session` privilege (included for root users). By default, eight threads are available for this purpose. This can be changed with the `num-administrative-session-worker-threads` property in the work queue configuration.

  Note: If all of the worker threads are tied up processing the same operation for a long time, the server will also issue an alert that it might be deadlocked, which may not actually be the case. All threads might be tied up processing unindexed searches.

- If a request handler is stuck performing some expensive processing for a client connection, then other requests sent to the server on connections associated with that request handler is forced to wait until the request handler is able to read data on those connections. If this is the case, then only some of the connections can experience this behavior (unless there is only a single request handler, in which it will impact all connections), and stack traces obtained using the `jstack` command shows that a request handler thread is continuously blocked rather than waiting for new requests to arrive. Note that this scenario is a theoretical problem and one that has not appeared in production.

- If the JVM in which the Data Store is running is not properly configured, then it can be forced to spend a significant length of time performing garbage collection, and in severe cases, could cause significant interruptions in the execution of Java code. In such cases, a stack trace obtained from a `pstack` of the native process should show that most threads are idle but at least one thread performing garbage collection is active. It is also likely that one or a small number of CPUs is 100% busy while all other CPUs are mostly idle. The server will also issue an alert after detecting a long JVM pause (due to garbage collection). The alert will include details of the pause.
- If the JVM in which the Data Store is running has hung for some reason, then the `pstack` utility should show that one or more threads are blocked and unable to make progress. In such cases, the system CPUs should be mostly idle.
- If a network or firewall configuration problem arises, then attempts to communicate with the server cannot be received by the server. In that case, a network sniffer like `snoop` or `tcpdump` should show that packets sent to the system on which the Data Store is running are not receiving TCP acknowledgement.
- If the system on which the Data Store is running has become hung or lost power with a graceful shutdown, then the behavior is often similar to that of a network or firewall configuration problem.

If it appears that the problem is with the Data Store software or the JVM in which it is running, then you need to work with your authorized support provider to fully diagnose the problem and determine the best course of action to correct it.

The Server is Slow to Respond to Client Requests

If the Data Store is running and does respond to clients, but clients take a long time to receive responses, then the problem can be attributable to a number of potential problems. In these cases, use the Periodic Stats Logger, which is a valuable tool to get per-second monitoring information on the Data Store. The Periodic Stats Logger can save the information in csv format for easy viewing in a spreadsheet. For more information, see "Profiling Server Performance Using the Periodic Stats Logger". The potential problems that cause slow responses to client requests are as follows:

- The server is not optimally configured for the type of requests being processed, or clients are requesting inefficient operations. If this is the case, then the access log should show that operations are taking a long time to complete and they will likely be unindexed. In that case, updating the server configuration to better suit the requests, or altering the requests to make them more efficient, could help alleviate the problem. In this case, view the expensive operations access log in `logs/expensive-ops`, which by default logs operations that take longer than 1 second. You can also run the `bin/status` command or view the status in the web console to see the Data Store's Work Queue information (also see the next bullet point).
- The server is overwhelmed with client requests and has amassed a large backlog of requests in the work queue. This can be the result of a configuration problem (for example, too few worker thread configured), or it can be necessary to provision more systems on which to

run the Data Store software. Symptoms of this problem appear similar to those experienced when the server is asked to process inefficient requests, but looking at the details of the requests in the access log show that they are not necessarily inefficient requests. Run the `bin/status` command to view the Work Queue information. If everything is performing well, you should not see a large queue size or a server that is near 100% busy. The %Busy statistic is calculated as the percentage of worker threads that are busy processing operations.

```
           --- Work Queue ---
           : Recent : Average : Maximum
-----------:--------:---------:--------
Queue Size : 10  : 1       : 10
% Busy     : 17     : 14      : 100
```

You can also view the expensive operations access log in `logs/expensive-ops`, which by default logs operations that take longer than 1 second.

- The server is not configured to fully cache all of the data in the server, or the cache is not yet primed. In this case, `iostat` reports a very high disk utilization. This can be resolved by configuring the server to fully cache all data, and to load database contents into memory on startup. If the underlying system does not have enough memory to fully cache the entire data set, then it might not be possible to achieve optimal performance for operations that need data which is not contained in the cache. For more information, see Disk-Bound Deployments.
- If the JVM is not properly configured, then it will need to perform frequent garbage collection and periodically pause execution of the Java code that it is running. In that case, the server error log should report that the server has detected a number of pauses and can include tuning recommendations to help alleviate the problem.
- If the Data Store is configured to use a large percentage of the memory in the system, then it is possible that the system has gotten low on available memory and has begun swapping. In this case, `iostat` should report very high utilization for disks used to hold swap space, and commands like `swap -l` on Solaris or `cat /proc/meminfo` on Linux can report a large amount of swap memory in use. Another cause of swapping is if swappiness is not set to 0 on Linux. For more information, see Disable File System Swapping (Linux).
- If another process on the system is consuming a significant amount of CPU time, then it can adversely impact the ability of the Data Store to process requests efficiently. Isolating the processes (for example, using processor sets) or separating them onto different systems can help eliminate this problem.

The Server Returns Error Responses to Client Requests

If a large number of client requests are receiving error responses, then view the `logs/failed-ops` log, which is an access log for only failed operations. The potential reasons for the error responses include the following:

- If clients are requesting operations that legitimately should fail (for example, they are targeting entries that do not exist, are attempting to update entries in a way that would violate the server schema, or are performing some other type of inappropriate operation), then the problem is likely with the client and not the server.
- If a portion of the Data Store data is unavailable (for example, because an online LDIF import or restore is in progress), then operations targeting that data will fail. Those problems

will be resolved when the backend containing that data is brought back online. During the outage, it might be desirable to update proxies or load balancers or both to route requests away from the affected server. As of Data Store version 3.1 or later, the Data Store will indicate that it is in a degraded status and the Proxy Server will route around it.

- If the Data Store work queue is configured with a maximum capacity and that capacity has been reached, then the server begins rejecting all new requests until space is available in the work queue. In this case, it might be necessary to alter the server configuration or the client requests or both, so that they can be processed more efficiently, or it might be necessary to add additional server instances to handle some of the workload.
- If an internal error occurs within the server while processing a client request, then the server terminates the connection to the client and logs a message about the problem that occurred. This should not happen under normal circumstances, so you will need to work with your authorized support provider to diagnose and correct the problem.
- If a problem is encountered while interacting with the underlying database (for example, an attempt to read from or write to disk failed because of a disk problem or lack of available disk space), then it can begin returning errors for all attempts to interact with the database until the backend is closed and re-opened and the database has been given a change to recover itself. In these cases, the `je.info.*` file in the database directory should provide information about the nature of the problem.

The Server Must Disconnect a Client Connection

If a client connection must be disconnected due to the expense of the client's request, such as an unindexed search across a very large database, perform the following:

- Find the client's connection ID by looking in the `cn=Active Operations,cn=monitor monitor` entry.

```
$ bin/ldapsearch -baseDN cn=monitor "cn=active operations" \
  --bindDN "cn=directory manager"  \
  --bindPassword password
```

- The monitor entry will contain attribute values for `operation-in-progress`, which look like an access log message. Look for the value of `conn` in the client request that should be disconnected. In the following example, the client to be disconnected is requesting a search for `(description=expensive)`, which is on connection 6.

```
dn: cn=Active Operations,cn=monitor
objectClass: top
objectClass: ds-monitor-entry
objectClass: ds-active-operations-monitor-entry
objectClass: extensibleObject
cn: Active Operations
num-operations-in-progress: 2
operation-in-progress: [15/Dec/2014:10:55:35 -0600] SEARCH conn=6 op=3 msgID=4
     clientIP="10.8.4.21" authDN="cn=app1,ou=applications,dc=example,dc=com" base="dc
     =example,dc=com" scope=wholeSubtree filter="(description=expensive)" attrs="A
     LL" unindexed=true
operation-in-progress: [15/Dec/2014:10:56:11 -0600] SEARCH conn=7 op=1 msgID=2
     clientIP="127.0.0.1" authDN="cn=Directory Manager,cn=Root DNs,cn=config" base="c
     n=monitor" scope=wholeSubtree filter="(cn=active operations)" attrs="ALL"
     num-persistent-searches-in-progress: 0
```

- With the connection ID value, create a file with the following contents, named `disconnect6.ldif`.

```
dn: ds-task-id=disconnect6,cn=scheduled Tasks,cn=tasks
objectClass: top
objectClass: ds-task
objectClass: ds-task-disconnect
ds-task-disconnect-connection-id: 6
ds-task-id: disconnect6
ds-task-class-name: com.unboundid.directory.server.tasks.DisconnectClientTask
```

- This LDIF file represents a task entry. The connection ID value 6 is assigned to `ds-task-disconnect-connection-id`. The value for `ds-task-id` value does not follow a specific convention. It must be unique among other task entries currently cached by the server.
- Disconnect the client and cancel the associated operation by adding the task entry to the server:

```
$ bin/ldapmodify --filename disconnect6.ldif  \
  --defaultAdd --bindDN "cn=directory manager" \
  --bindPassword password
```

The Server is experiencing problems with replication

If replication does not appear to be functioning properly, then first check the `dsreplication status` command, which shows all of the servers that are replicating and whether they are back-logged or not. Next, you can check the server error log, replication repair log, and replication monitor entries may provide information about the nature of the underlying problem. Potential reasons that replication may not be functioning as expected include the following:

- Replication has not yet been configured between systems or has been disabled.
- If a server has been offline for a period of time or has fallen far enough behind such that it is missing changes, which are no longer present in any of the replication databases, then that server must be re-initialized with an up-to-date copy of the data from another server.
- If the environment is comprised of a heterogeneous set of systems, then it is possible that some of the systems might not be able to keep up with the maximum throughput achieved by other servers in the topology. In such cases, the slower servers might not be fast enough to remain in sync with the other servers in the environment.
- If the environment contains systems in multiple data centers and the network links between the data centers are insufficient for the volume of changes that must be processed, then servers might not be able to remain in sync under a high volume of changes.
- A network or firewall configuration problem has arisen, which prevents or interferes with communication between servers.
- An internal problem within the server has caused replication to stop functioning properly. The Data Store logs the event in the error log in this case. Run the `collect-support-data` tool, so that the details of the problems can be passed to your authorized support provider. Then, try restarting the Data Store.

How to Regenerate the Server ads-certificate

At setup time, the server generates a private key and certificate for use when secure communication between servers is required. This certificate, `ads-certificate`, is stored in `config/ads-truststore` and should typically remain unchanged for the life of the server deployment. If the need arises for a new ads-certificate to be created, say because the server-root has been copied to a new host, then the private key and certificate will be recreated by the startup process if the `config/ads-truststore` and `config/ads-truststore.pin` files are first manually removed while the server is offline. Note that if replication is enabled, the server must have replication disabled before regeneration of the ads-certificate.

For example, the Data Store allows easy copying of its installation, which can then be used to install another server instance. If a server (ldap1.example.com:389) is enabled with its own copy (ldap2.example.com:389), `dsreplication` will exit with the following error message:

```
Replication cannot be enabled between servers ldap1.example.com:389 and ldap2.example.com:389
because they are using the same instance key.
```

The solution is to stop the server, remove `config/adstruststore` and `config/adstruststore.pin` and re-start the server. Upon startup, a new `adstruststore`, containing the server's instance key, will be generated. Then, you can re-run `dsreplication enable` to set up replication between the two servers.

The Server behaves differently from Sun/Oracle

After migrating from a Sun/Oracle configuration to an UnboundID Data Store, follow the tuning procedures in *Sun/Oracle Compatibility* if the Data Store behaves differently from the Sun/Oracle server.

Troubleshooting ACI Evaluation

The Data Store provides the ability to collect debug information related to ACI evaluation for any operation by enabling the Debug ACI Logger. The Debug ACI Logger is highly configurable and can be scoped to trace very specific request operations in order to narrow on any ACI issue that may arise in the field. Parameters for non-request operations, such as `log-connects`, `log-disconnects`, `log-security-negotiation`, `log-results`, `log-assuance-completed`, `log-search-entries`, `log-search-references`, `log-intermediate-responses` are set to `false` by default and should remain so.

Here is an example to enable the Debug ACI Logger:

```
$ bin/dsconfig set-log-publisher-prop \
--publisher-name "Debug ACI Logger" \
--set enabled:true
```

Once you have enabled the logger, all matching operations begin writing ACI evaluation traces to the log file. The amount of information is quite large for each evaluation that is done. However, this information is useful if there is an ACI issue that is difficult to resolve. Most operations result in multiple "ACI DEBUG" traces in the log, since it usually requires multiple ACI rights to perform an operation, each of which requires a separate evaluation. In particular, you can expect a lot of debug tracing when dealing with ACIs for controls, extended operations, and proxied authorization.

The ACI DEBUG traces contain the following pieces of information:

- **Operation**. Specifies a dump of the operation object that you can use to correlate to the original request operation.
- **ACI Container**. Specifies the context of the ACI evaluation being performed.
    - ➢ **Client Entry**. Specifies an LDIF dump of the client request access.
    - ➢ **Resource Entry**. Specifies an LDIF dump of the target resource.
    - ➢ **isProxiedAuth**. Specifies if the client is attempting to proxy as another user.
    - ➢ **Original Auth**. Specifies the original client DN if authorization is currently via the proxy.
    - ➢ **Rights**. Specifies a list of the ACI rights being requested on the resource entry.
    - ➢ **Control**. Specifies the OIDs when evaluating ACIs for a control.
    - ➢ **ExtOp**. Specifies the OIDs when evaluating ACIs for an extended operation.
- **ACI Canidates**. Specifies a list of all the ACIs known to this operation, sorted by origin.
- **Applicable ACIs**. Specifies a list of ACIs relevant to the current evaluation. These ACIs are separated by type into "Denies" and "Allows".
- **Deny ACI Evaluations**. Specifies the results of evaluating each "deny" ACI. If any of these evaluate to TRUE, then the operation will be denied.
- **Allow ACI Evaluations**. Specifies the results of evaluating each "allow" ACI. At least one of these must evaluate to "TRUE" or the operation will be denied.

For users with the `bypass-acl` privilege, the Debug ACI Logger will not provide any ACI debug tracing since evaluations are not done for those operations. However, you will see the following trace if you have ACI debugging enabled (i.e., `debug-aci-enabled` is set to TRUE) for those operations:

```
Bypassing ACL Evaluation for Operation
```

To avoid unnecessary tracing of these operations, the "Debug ACI Logger" uses a "Client Connection Criteria" called "Clients subject to Access Control" that excludes requests from users with the `bypass-acl` privilege. It is recommended that you create and use your own criteria which specifically targets the clients that you are trying to debug in order to make analyzing the tracing output easier.

```
$ bin/dsconfig create-connection-criteria \
  --criteria-name "Restricted Clients" \
  --type simple \
  --set none-included-user-privilege:bypass-acl
```

Problems with the Management Console

If a problem arises when trying to use the Management Console, then potential reasons for the problem may include the following:

- The web application container used to host the console is not running. If an error occurs while trying to start it, then consult the logs for the web application container.

- If a problem occurs while trying to authenticate to the web application container, then make sure that the target Data Store is online. If it is online, then the access log may provide information about the reasons for the authentication failure.
- If a problem occurs while attempting to interact with the Proxy Server instance using the Management Console, then the access and error logs for that Data Store instance might provide additional information about the underlying problem.

Problems with the Management Console: JVM Memory Issues

Console runs out of memory (PermGen). If you are running a Management Console for a UnboundID Data Store while also running a console for the UnboundID Proxy Server Management Console and an UnboundID Data Sync Server Management Console, you may see a Java PermGen error as follows:

```
Exception in thread "http-bio-8080-exec-7" java.lang.OutOfMemoryError: PermGen Space
```

For a servlet container, such as Tomcat, you can specify additional arguments to pass to the JVM by creating a `bin/setenv.sh` file (or `setenv.bat` for Windows) that sets the CATALINA_OPTS variable. The `startup.sh` script will automatically pick this up. For example:

```
#!/bin/bash
# The following may be modified to change JVM memory arguments.
MAX_HEAP_SIZE=512m
MIN_HEAP_SIZE=$MAX_HEAP_SIZE
MAX_PERM_SIZE=256m

CATALINA_OPTS="-Xmx${MAX_HEAP_SIZE} -Xms${MIN_HEAP_SIZE} -XX:MaxPermSize=
${MAX_PERM_SIZE}"
```

Problems with the HTTP Connection Handler

When problems with the HTTP Connection Handler occur, first look at the HTTP connection handler log to diagnose the issue. The following section shows HTTP log examples when various errors occur.

- **Failed Request Due to a Non-Existent Resource**. The server receives a status code 404, which indicates the server could not match the URI.

  ```
  [15/Mar/2012:17:39:39 -0500] RESULT requestID=0 from="10.2.1.113:52958"
  method="GET" url="https://10.2.1.113:443/Aleph/Users/uid=user.1,ou=people,
  dc=example,dc=com" requestHeader="Host: x2270-11.example.lab"
  requestHeader="Accept: */*" requestHeader="User-Agent: curl/7.21.6
  (i386-pc-solaris2.10) libcurl/7.21.6 OpenSSL/1.0.0d zlib/1.2.5 libidn/1.22
  libssh2/1.2.7" authorizationType="Basic" statusCode=404 etime=81.484
  responseContentLength=103 responseHeader="Access-Control-Allow-Credentials:true"
  responseContentType="application/json"
  ```

- **Failed Request due to a Malformed Request Body**. The server receives a status code 400, which indicates that the request had a malformed syntax in its request body.

  ```
  [15/Mar/2012:17:47:23-0500] RESULT requestID=10 from="10.2.1.113:55284"
  method="POST" url="https://10.2.1.113:443/Aleph/Users" requestHeader="Host:
  x2270-11.example.lab" requestHeader="Expect: 100-continue"
  requestHeader="Accept: */*" requestHeader="Content-Type: application/json"
  requestHeader="User-Agent: curl/ 7.21.6 (i386-pc-solaris2.10) libcurl/7.21.6
  OpenSSL/1.0.0d zlib/1.2.5 libidn/1.22 libssh2/1.2.7" authorizationType="Basic"
  ```

```
requestContentType="application/json" requestContentLength=5564 statusCode=400
etime=15.272 responseContentLength=133 responseContentType="application/json"
```

- **Failed Request due to an unsupported HTTP method**. The server receives a status code 405, which indicates that the specified method (e.g., "PATCH") in the request line is not allowed for the resource identified in the URI.

```
[15/Mar/2012:17:48:59-0500] RESULT requestID=11 from="10.2.1.113:55763"
method="PATCH" url="https://10.2.1.113:443/Aleph/Users" requestHeader="Host:
x2270-11.example.lab" requestHeader="Accept: */*" requestHeader="Content-Type:
application/json" requestHeader="User-Agent: curl/7.21.6 (i386-pc-solaris2.10)
libcurl/7.21.6 OpenSSL/1.0.0d zlib/1.2.5 libidn/1.22 libssh2/1.2.7"
authorization-Type="Basic" requestContentType="application/json" statusCode=405
etime=6.807 responseContentLength=0 responseHeader="Allow: POST, GET, OPTIONS, HEAD"
```

- **Failed Request due to an Unsupported Media Type**. The server receives a status code 415, which indicates that the request entity is in a format that is not supported by the requested resource.

```
[15/Mar/2012:17:44:45-0500] RESULT requestID=4 from="10.2.1.113:54493"
method="POST" url="https://10.2.1.113:443/Aleph/Users" requestHeader="Host:
x2270-11.example.lab" requestHeader="Accept: */*" requestHeader="Content-Type:
application/atom+xml" requestHeader="User-Agent: curl/7.21.6 (i386-pc-solaris2.10)
libcurl/7.21.6 OpenSSL/1.0.0d zlib/1.2.5 libidn/1.22 libssh2/1.2.7"
authorizationType="Basic" requestContentType="application/atom+xml"
requestContentLength=3 statusCode=415 etime=6.222 responseContentLength=1402
responseHeader="Cache-Control: must-revalidate,no-cache,no-store"
responseContentType="text/html;charset=ISO-8859-1"
```

- **Failed Request due to an Authentication Error**. The server receives a status code 401, which indicates that the request requires user authentication.

```
[15/Mar/2012:17:46:06-0500] RESULT requestID=8 from="10.2.1.113:54899"
method="GET" url="https://10.2.1.113:443/Aleph/Schemas" requestHeader="Host:
x2270-11.example.lab" requestHeader="Accept: */*" requestHeader="User-Agent:
curl/7.21.6 (i386-pc-solaris2.10) libcurl/7.21.6 OpenSSL/1.0.0d zlib/1.2.5
libidn/1.22 libssh2/ 1.2.7" authorizationType="Basic" statusCode=401
etime=2.751 responseContentLength=63 responseHeader="WWW-Authenticate: Basic
realm=SCIM" responseHeader="Access-Control-Allow-Credentials: true"
responseContentType="application/json"
```

Virtual Process Size on RHEL6 Linux is Much Larger than the Heap

Red Hat Linux introduced a change in glib 2.11 that creates larger per-thread address spaces aligned at 64MB. This change results in a virtual process size much larger than those seen in previous versions of `glibc`. This is not considered a bug by RedHat, as noted in *https://bugzilla.redhat.com/show_bug.cgi?id=640286*, and does not affect the physical memory needed by the server process. To see the version of `glibc` on your system, use the command `yum info glibc`.

AIX Command-Line Tools Not Working with DNs using Special Characters

The UnboundID Data Store command-line tools may not successfully run with base DNs that contain special characters (characters that require escaping) on AIX using some IBM Java versions.

Providing Information for Support Cases

If a problem arises that you are unable to fully diagnose and correct on your own, then contact your authorized support provider for assistance. To ensure that the problem can be addressed as quickly as possible, be sure to provide all of the information that the support personnel may need to fully understand the underlying cause by running the `collect-support-data` tool, and then sending the generated zip file to your authorized support provider. It is good practice to run this tool and send the ZIP file to your authorized support provider before any corrective action has taken place.

Chapter 27 Command-Line Tools

The UnboundID Data Store provides a full suite of command-line tools necessary to administer the server. The command-line tools are available in the `bin` directory for UNIX or Linux systems and `bat` directory for Microsoft Windows systems.

This chapter presents the following topics:

Topics:

Using the Help Option

Each command-line utility provides a description of the subcommands, arguments, and usage examples needed to run the tool. You can view detailed argument options and examples by typing `--help` with the command.

```
bin/dsconfig --help
```

For those utilities that support additional subcommands (for example, `dsconfig`), you can get a list of the subcommands by typing `--help-subcommands`.

```
bin/dsconfig --help-subcommands
```

You can also get more detailed subcommand information by typing `--help` with the specific subcommand.

```
bin/dsconfig list-log-publishers --help
```

Note: For detailed information and examples of the command-line tools, see the *UnboundID Data Store Command-Line Tool Reference*.

Available Command-Line Utilities

The Data Store provides the following command-line utilities, which can be run directly in interactive, non-interactive, or script mode.

Table 73: Command-Line Utilities

Command-Line Tools	Description
audit-data-security	Performs an internal task that examines all or a subset of entries in the server, writing a series of reports on potential risks with the data. Reports are written to the output directory organized by backend name and audit items.
authrate	Perform repeated authentications against the Data Store, where each authentication consists of a search to find a user followed by a bind to verify the credentials for that user.
backup	Run full or incremental backups on one or more data store backends. This utility also supports the use of a properties file to pass predefined command-line arguments. See *Managing the tools.properties File* for more information.
base64	Encode raw data using the base64 algorithm or decode base64-encoded data back to its raw representation.
collect-support-data	Collect and package system information useful in troubleshooting problems. The information is packaged as a ZIP archive that can be sent to a technical support representative.
config-diff	Generate a summary of the configuration changes in a local or remote server instance. The tool can be used to compare configuration settings when troubleshooting issues, or when verifying configuration settings on new servers.

Command-Line Tools	Description
create-rc-script	Create a Run Control (RC) script that may be used to start, stop, and restart the Data Store on UNIX-based systems.
dbtest	Inspect the contents of Data Store backends that store their information in Oracle® Berkeley DB Java Edition databases.
deliver-one-time-password	Submit a "deliver one-time password" extended request, OID 1.3.6.1.4.1.30221.2.6.24, to the server which results in a the generation of a one-time password which is delivered out-of-band to the specified user. This tool can be used to test the UNBOUNDID-DELIVERED-OTP SASL mechanism.
dsconfig	View and edit the Data Store configuration.
dsframework	Manage administrative server groups or the global administrative user accounts that are used to configure servers within server groups.
dsjavaproperties	Configure the JVM arguments used to run the Data Store and associated tools. Before launching the command, edit the properties file located in `config/java.properties` to specify the desired JVM options and *JAVA_HOME* environment variable.
dsreplication	Manage data replication between two or more Data Store instances.
dump-dns	Obtain a listing of all of the DNs for all entries below a specified base DN in the Data Store.
encode-password	Encode user passwords with a specified storage scheme or determine whether a given clear-text value matches a provided encoded password.
encryption-settings	Manage the server encryption settings database.
enter-lockdown-mode	Request that the Data Store enter lockdown mode, during which it only processes operations requested by users holding the `lockdown-mode` privilege.
export-ldif	Export data from the Data Store backend in LDIF form.
identify-references-to-missing-entries	Identify entries containing one or more attributes that reference entries that do not exist. This may require the ability to perform unindexed searches and/or the ability to use the simple paged results control.
identify-unique-attribute-conflicts	Identify unique attribute conflicts. The tool may identify values of one or more attributes that are supposed to exist only in a single entry but are found in multiple entries.
import-ldif	Import LDIF data into the Data Store backend.
ldap-diff	Compare the contents of two LDAP servers.
ldap-result-code	Display and query LDAP result codes.
ldapcompare	Perform LDAP compare operations in the Data Store.
ldapdelete	Perform LDAP delete operations in the Data Store.
ldapmodify	Perform LDAP modify, add, delete, and modify DN operations in the Data Store.
ldappasswordmodify	Perform LDAP password modify operations in the Data Store.
ldapsearch	Perform LDAP search operations in the Data Store.
ldif-diff	Compare the contents of two LDIF files, the output being an LDIF file needed to bring the source file in sync with the target.
ldifmodify	Apply a set of modify, add, and delete operations against data in an LDIF file.
ldifsearch	Perform search operations against data in an LDIF file.
leave-lockdown-mode	Request that the Data Store leave lockdown mode and resume normal operation.
list-backends	List the backends and base DNs configured in the Data Store.
make-ldif	Generate LDIF data based on a definition in a template file.

Command-Line Tools	Description
manage-account	Access and alter password policy state properties for user entries.
manage-extension	Install or update extension bundles. An extension bundle is a package of extension(s) that utilize the Server SDK to extend the functionality of the UnboundID Data Store. Extension bundles are installed from a zip archive or file system directory. UnboundID Data Store will be restarted if running to activate the extension(s).
manage-tasks	Access information about pending, running, and completed tasks scheduled in the Data Store.
migrate-ldap-schema	Migrate schema information from an existing LDAP server into an UnboundID Data Store instance.
migrate-sun-ds-config	Update an instance of the UnboundID Data Store to match the configuration of an existing Sun Java System 5.x, 6.x, or 7.x directory instance.
modrate	Perform repeated modifications against a Data Store.
move-subtree	Move a subtree entries or a single entry from one server to another.
parallel-update	Perform add, delete, modify, and modify DN operations concurrently using multiple threads.
profile-viewer	View information in data files captured by the Data Store profiler.
re-encode-entries	Initiate a task that causes a local DB backend to re-encode all or a specified subset of the entries that it contains. The tool does not alter the entries themselves but provides a useful mechanism for applying significant changes to the way that entries are stored in the backend (e.g., to apply encoding changes if a feature like data encryption or uncached attributes or entries is enabled).
rebuild-index	Rebuild index data within a backend based on the Berkeley DB Java Edition. Note that this tool uses different approaches to rebuilding indexes based on whether it is running in online mode (as a task) rather than in offline mode. Running in offline mode will often provide significantly better performance. Also note that running in online mode will prevent the server from using that index while the rebuild is in progress, so some searches may behave differently while a rebuild is active than when it is not.
remove-backup	Safely remove a backup and optionally all of its dependent backups from the specified Data Store backend.
restore	Restore a backup of the Data Store backend.
revert-update	Returns a server to the version before the last update was performed.
review-license	Review and/or indicate your acceptance of the product license.
scramble-ldif	Obscure the contents of a specified set of attributes in an LDIF file.
search-and-mod-rate	Perform repeated searches against an LDAP data store and modify each entry returned.
searchrate	Perform repeated searches against an LDAP data store.
server-state	View information about the current state of the Data Store process.
setup	Perform the initial setup for the Data Store instance.
start-ds	Start the Data Store.
status	Display basic server information.
stop-ds	Stop or restart the Data Store.
subtree-accessibility	List or update the a set of subtree accessibility restrictions defined in the Data Store.
sum-file-sizes	Calculate the sum of the sizes for a set of files.

Command-Line Tools	Description
summarize-access-log	Generate a summary of one or more access logs to display a number of metrics about operations processed within the server.
uninstall	Uninstall the Data Store.
update	Update the Data Store to a newer version by downloading and unzipping the new server install package on the same host as the server you wish to update. Then, use the `update` tool from the new server package to update the older version of the server. Before upgrading a server, you should ensure that it is capable of starting without severe or fatal errors. During the update process, the server is stopped if running, then the update is performed, and a check is made to determine if the newly updated server starts without major errors. If it cannot start cleanly, the update will be backed out and the server returned to its prior state. See the `revert-update` tool for information on reverting an update.
validate-acis	Validates a set of access control definitions contained in an LDAP server (including Sun/Oracle DSEE instances) or an LDIF file to determine whether they are acceptable for use in the Data Store. Note that the output generated by this tool will be in LDIF format, but each entry in the output will have exactly one ACI, so entries that have more than one ACI will appear multiple times in the output with different ACI values.
validate-file-signature	Validate the signature information in a signed text file, such as a signed log file or a signed LDIF export.
validate-ldif	Validate the contents of an LDIF file against the server schema.
verify-index	Verify that indexes in a backend using the Oracle Berkeley DB Java Edition are consistent with the entry data contained in the database.

Managing the tools.properties File

The UnboundID Data Store supports the use of a tools properties file that simplifies command-line invocations by reading in a set of arguments for each tool from a text file. Each property is in the form of name/value pairs that define predetermined values for a tool's arguments. Properties files are convenient when quickly testing the Data Store in multiple environments.

The Data Store supports two types of properties file: default properties files that can be applied to all command-line utilities or tool-specific properties file that can be specified using the `--propertiesFilePath` option. You can override all of the Data Store's command-line utilities with a properties file using the `config/tools.properties` file.

Creating a Tools Properties File

You can create a properties file with a text editor by specifying each argument, or option, using standard Java properties file format (name=value). For example, you can create a simple properties file that define a set of LDAP connection parameters as follows:

```
hostname=server1.example.com
port=1389
bindDN=cn=Directory\ Manager
bindPassword=secret
baseDN=dc=example,dc=com
```

Next, you can specify the location of the file using the `--propertiesFilePath /path/to/File` option with the command-line tool. For example, if you save the previous properties file as `bin/mytool.properties`, you can specify the path to the properties file with `ldapsearch` as follows:

```
$ bin/ldapsearch --propertiesFilePath bin/mytools.properties "(objectclass=*)"
```

Properties files do not allow quotation marks of any kind around values. Any spaces or special characters should be escaped. For example,

```
bindDN=cn=QA\ Managers,ou=groups,dc=example,dc=com
```

The following is not allowed as it contains quotation marks:

```
bindDN=cn="QA Managers,ou=groups,dc=example,dc=com"
```

Tool-Specific Properties

The Data Store also supports properties for specific tool options using the format: `tool.option=value`. Tool-specific options have precedence over general options. For example, the following properties file uses `ldapsearch.port=2389` for `ldapsearch` requests by the client. All other tools that use the properties file uses `port=1389`.

```
hostname=server1.example.com
port=1389
ldapsearch.port=2389
bindDN=cn=Directory\ Manager
```

Another example using the `dsconfig` configuration tool is as follows:

```
hostname=server1.example.com
port=1389
bindDN=cn=Directory\ Manager
dsconfig.bindPasswordFile=/ds/config/password
```

Note: The `.bindPasswordFile` property requires an absolute path. If you were to specify `~/ds/config/password`, where ~ refers to the home directory, the server does not expand the ~ value when read from the properties file.

Specifying Default Properties Files

The Data Store provides a default properties files that apply to all command-line utilities used in client requests. A default properties file, `tools.properties`, is located in the `<server-root>/config` directory.

If you place a custom properties file that has a different filename as `tools.properties` in this default location, you need to specify the path using the `--propertiesFilePath` option. If you make changes to the `tools.properties` file, you do not need the `--propertiesFilePath` option. See the examples in the next section.

Evaluation Order Summary

The Data Store uses the following evaluation ordering to determine options for a given command-line utility:

- All options used with a utility on the command line takes precedence over any options in any properties file.
- If the `--propertiesFilePath` option is used with no other options, the Data Store takes its options from the specified properties file.
- If no options are used on the command line including the `--propertiesFilePath` option (and `--noPropertiesFile`), the Data Store searches for the `tools.properties` file at `<server-root>`
- If no default properties file is found and a required option is missing, the tool generates an error.
- Tool-specific properties (for example, `ldapsearch.port=3389`) have precedence over general properties (for example, `port=1389`).

Evaluation Order Example

Given the following properties file that is saved as `<server-root>/bin/tools.properties`:

```
hostname=server1.example.com
port=1389
bindDN=cn=Directory\ Manager
bindPassword=secret
```

The Data Store locates a command-line option in a specific priority order.

1. All options presented with the tool on the command line take precedence over any options in any properties file. In the following example, the client request is run with the options specified on the command line (port and baseDN). The command uses the `bindDN` and `bindPassword` arguments specified in the properties file.

   ```
   $ bin/ldapsearch --port 2389 --baseDN ou=People,dc=example,dc=com \
     --propertiesFilePath bin/tools.properties “(objectclass=*)”
   ```

2. Next, if you specify the properties file using the `--propertiesFilePath` option and no other command-line options, the Data Store uses the specified properties file as follows:

   ```
   $ bin/ldapsearch --propertiesFilePath bin/tools.properties \
     “(objectclass=*)”
   ```

3. If no options are presented with the tool on the command line and the `--noPropertiesFile` option is not present, the Data Store attempts to locate any default `tools.properties` file in the following location:

   ```
   <server-root>/config/tools.properties
   ```

   Assume that you move your tools.properties file from `<server-root>/bin` to the `<server-root>/config` directory. You can then run your tools as follows:

```
$ bin/ldapsearch "(objectclass=*)"
```

The Data Store can be configured so that it does not search for a properties file by using the `--noPropertiesFile` option. This options tells the Data Store to use only those options specified on the command line. The `--propertiesFilePath` and `--noPropertiesFile` options are mutually exclusive and cannot be used together.

4. If no default `tools.properties` file is found and no options are specified with the command-line tool, then the tool generates an error for any missing arguments.

Running Task-based Utilities

The Data Store has a Tasks subsystem that allows you to schedule basic operations, such as backup, restore, bin/start-ds, bin/start-ds and others. All task-based utilities require the `--task` option that explicitly indicates the utility is intended to run as a task rather than in offline mode. The following table shows the arguments that can be used for task-based operations:

Table 74: Task-based Utilities

Option	Description
--task	Indicates that the tool is invoked as a task. The `--task` argument is required. If a tool is invoked as a task without this `--task` argument, then a warning message will be displayed stating that it must be used. If the `--task` argument is provided but the tool was not given the appropriate set of authentication arguments to the server, then an error message will be displayed and the tool will exit with an error.
--start	Indicates the date and time, expressed in the format 'YYYYMMDDhhmmss', when the operation starts when scheduled as a server task. A value of '0' causes the task to be scheduled for immediate execution. When this option is used, the operation is scheduled to start at the specified time, after which this utility will exit immediately.
--dependency	Specifies the ID of a task upon which this task depends. A task will not start execution until all its dependencies have completed execution. This option can be used multiple times in a single command.
--failedDependencyAction	Specifies the action this task will take should one of its dependent tasks fail. The value must be one of the following: `PROCESS`, `CANCEL`, `DISABLE`. If not specified, the default value is `CANCEL`. This option can be used multiple times in a single command.
--completionNotify	Specifies the email address of a recipient to be notified when the task completes. This option can be used multiple times in a single command.
--errorNotify	Specifies the email address of a recipient to be notified if an error occurs when this task executes. This option can be used multiple times in a single command.