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OpenLDAP Software 2.6 Administrator's Guide

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Preface

Copyright

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Scope of this Document

This document provides a guide for installing OpenLDAP Software 2.6 (http://www.openldap.org/software/) on UNIX (and UNIX-like) systems. The document is aimed at experienced system administrators with basic understanding of LDAP-based directory services.

This document is meant to be used in conjunction with other OpenLDAP information resources provided with the software package and on the project's site (http://www.OpenLDAP.org/) on the World Wide Web. The site makes available a number of resources.

OpenLDAP Resources

Resource	**URL**
Document Catalog	http://www.OpenLDAP.org/doc/
Frequently Asked Questions	http://www.OpenLDAP.org/faq/
Issue Tracking System	http://www.OpenLDAP.org/its/
Mailing Lists	http://www.OpenLDAP.org/lists/
Manual Pages	http://www.OpenLDAP.org/software/man.cgi
Software Pages	http://www.OpenLDAP.org/software/
Support Pages	http://www.OpenLDAP.org/support/

This document is not a complete reference for OpenLDAP software; the manual pages are the definitive documentation. For best results, you should use the manual pages that were installed on your system with your version of OpenLDAP software so that you're looking at documentation that matches the code. While the OpenLDAP web site also provides the manual pages for convenience, you can not assume that they correspond to the particular version you're running.

Acknowledgments

The OpenLDAP Project is comprised of a team of volunteers. This document would not be possible without their contribution of time and energy.

The OpenLDAP Project would also like to thank the University of Michigan LDAP Team for building the foundation of LDAP software and information to which OpenLDAP Software is built upon. This document is based upon University of Michigan document: The SLAPD and SLURPD Administrators Guide.

Amendments

Suggested enhancements and corrections to this document should be submitted using the OpenLDAP Issue Tracking System (http://www.openldap.org/its/).

About this document

This document was produced using the Simple Document Format (SDF) documentation system (http://search.cpan.org/src/IANC/sdf-2.001/doc/catalog.html) developed by *Ian Clatworthy*. Tools for SDF are available from CPAN (http://search.cpan.org/search?query=SDF&mode=dist).

1. Introduction to OpenLDAP Directory Services

This document describes how to build, configure, and operate OpenLDAP Software to provide directory services. This includes details on how to configure and run the Standalone LDAP Daemon, *slapd*(8). It is intended for new and experienced administrators alike. This section provides a basic introduction to directory services and, in particular, the directory services provided by *slapd*(8). This introduction is only intended to provide enough information so one might get started learning about LDAP, X.500, and directory services.

1.1. What is a directory service?

A directory is a specialized database specifically designed for searching and browsing, in additional to supporting basic lookup and update functions.

Note: A directory is defined by some as merely a database optimized for read access. This definition, at best, is overly simplistic.

Directories tend to contain descriptive, attribute-based information and support sophisticated filtering capabilities. Directories generally do not support complicated transaction or roll-back schemes found in database management systems designed for handling high-volume complex updates. Directory updates are typically simple all-or-nothing changes, if they are allowed at all. Directories are generally tuned to give quick response to high-volume lookup or search operations. They may have the ability to replicate information widely in order to increase availability and reliability, while reducing response time. When directory information is replicated, temporary inconsistencies between the consumers may be okay, as long as inconsistencies are resolved in a timely manner.

There are many different ways to provide a directory service. Different methods allow different kinds of information to be stored in the directory, place different requirements on how that information can be referenced, queried and updated, how it is protected from unauthorized access, etc. Some directory services are *local*, providing service to a restricted context (e.g., the finger service on a single machine). Other services are global, providing service to a much broader context (e.g., the entire Internet). Global services are usually *distributed*, meaning that the data they contain is spread across many machines, all of which cooperate to provide the directory service. Typically a global service defines a uniform *namespace* which gives the same view of the data no matter where you are in relation to the data itself.

A web directory, such as provided by the *Curlie Project* <https://curlie.org>, is a good example of a directory service. These services catalog web pages and are specifically designed to support browsing and searching.

While some consider the Internet Domain Name System (DNS) is an example of a globally distributed directory service, DNS is not browsable nor searchable. It is more properly described as a globally distributed *lookup* service.

1.2. What is LDAP?

LDAP stands for Lightweight Directory Access Protocol. As the name suggests, it is a lightweight protocol for accessing directory services, specifically X.500-based directory services. LDAP runs over TCP/IP or other connection oriented transfer services. LDAP is an IETF Standard Track protocol and is specified in "Lightweight Directory Access Protocol (LDAP) Technical Specification Road Map" RFC4510.

This section gives an overview of LDAP from a user's perspective.

What kind of information can be stored in the directory? The LDAP information model is based on *entries*. An entry is a collection of attributes that has a globally-unique Distinguished Name (DN). The DN is used to refer to the entry unambiguously. Each of the entry's attributes has a *type* and one or more *values*. The types are typically mnemonic strings, like "`cn`" for common name, or "`mail`" for email address. The syntax of values depend on the attribute type. For example, a `cn` attribute might contain the value `Babs Jensen`. A `mail` attribute might contain the value "`babs@example.com`". A `jpegPhoto` attribute would contain a photograph in the JPEG (binary) format.

How is the information arranged? In LDAP, directory entries are arranged in a hierarchical tree-like structure. Traditionally, this structure reflected the geographic and/or organizational boundaries. Entries representing countries appear at the top of the tree. Below them are entries representing states and national organizations. Below them might be entries representing organizational units, people, printers, documents, or just about anything else you can think of. Figure 1.1 shows an example LDAP directory tree using traditional naming.

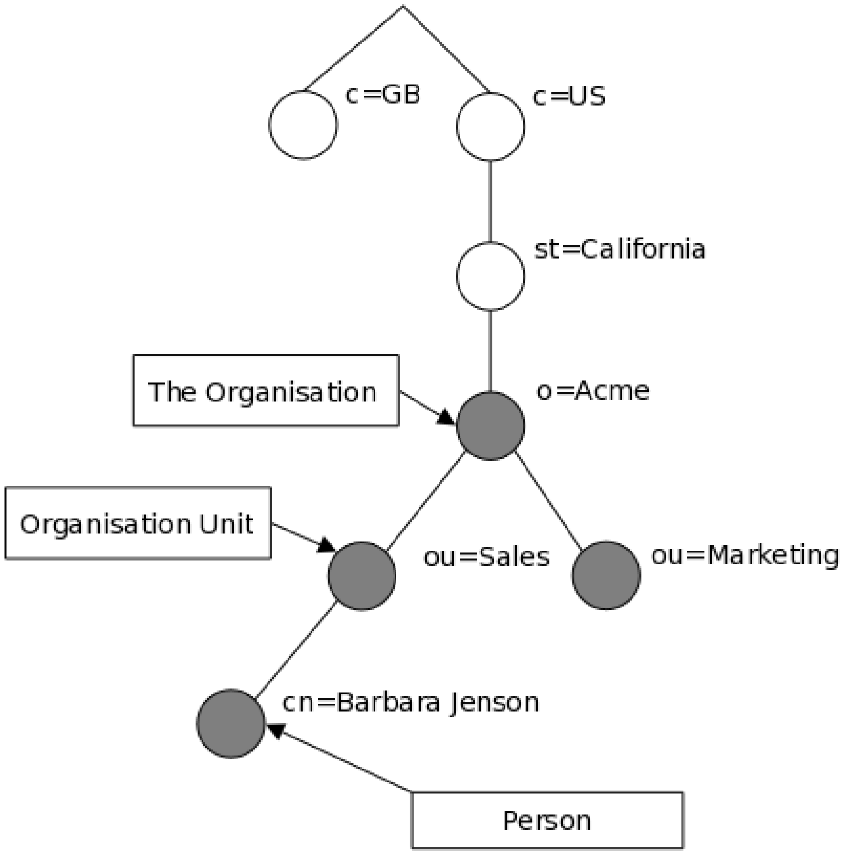


Figure 1.1: LDAP directory tree (traditional naming)

The tree may also be arranged based upon Internet domain names. This naming approach is becoming increasing popular as it allows for directory services to be located using the *DNS*. Figure 1.2 shows an example LDAP directory tree using domain-based naming.

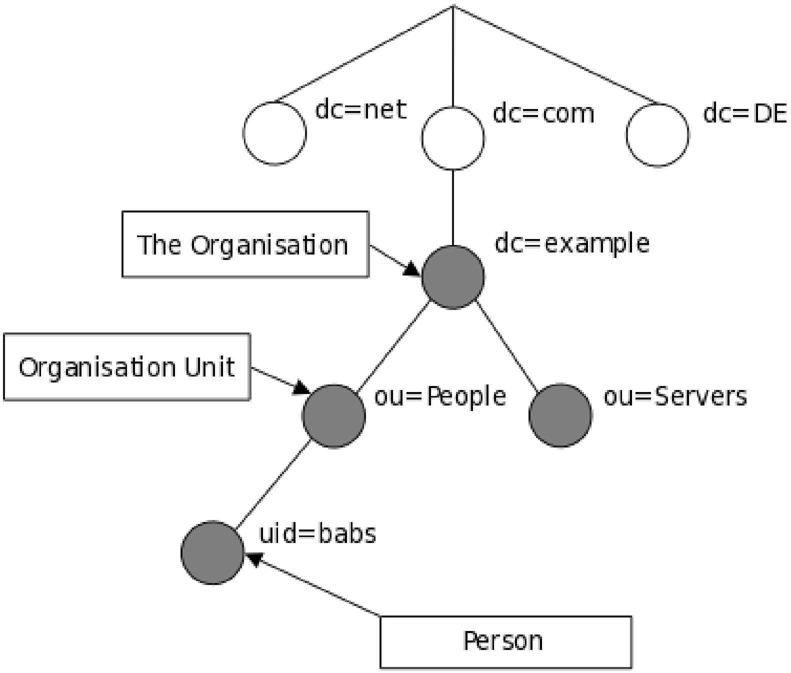


Figure 1.2: LDAP directory tree (Internet naming)

In addition, LDAP allows you to control which attributes are required and allowed in an entry through the use of a special attribute called `objectClass`. The values of the `objectClass` attribute determine the *schema* rules the entry must obey.

How is the information referenced? An entry is referenced by its distinguished name, which is constructed by taking the name of the entry itself (called the Relative Distinguished Name or RDN) and concatenating the names of its ancestor entries. For example, the entry for Barbara Jensen in the Internet naming example above has an RDN of `uid=babs` and a DN of `uid=babs,ou=People,dc=example,dc=com`. The full DN format is described in RFC4514, "LDAP: String Representation of Distinguished Names."

How is the information accessed? LDAP defines operations for interrogating and updating the directory. Operations are provided for adding and deleting an entry from the directory, changing an existing entry, and changing the name of an entry. Most of the time, though, LDAP is used to search for information in the directory. The LDAP search operation allows some portion of the directory to be searched for entries that match some criteria specified by a search filter. Information can be requested from each entry that matches the criteria.

For example, you might want to search the entire directory subtree at and below `dc=example,dc=com` for people with the name `Barbara Jensen`, retrieving the email address of each entry found. LDAP lets you do this easily. Or you might want to search the entries directly below the `st=California,c=US` entry for organizations with the string `Acme` in their name, and that have a fax number. LDAP lets you do this too. The next section describes in more detail what you can do with LDAP and how it might be useful to you.

How is the information protected from unauthorized access? Some directory services provide no protection, allowing anyone to see the information. LDAP provides a mechanism for a client to authenticate, or prove its identity to a directory server, paving the way for rich access control to protect the information the server contains. LDAP also supports data security (integrity and confidentiality) services.

1.3. When should I use LDAP?

This is a very good question. In general, you should use a Directory server when you require data to be centrally managed, stored and accessible via standards based methods.

Some common examples found throughout the industry are, but not limited to:

- Machine Authentication
- User Authentication
- User/System Groups
- Address book
- Organization Representation
- Asset Tracking
- Telephony Information Store
- User resource management
- E-mail address lookups
- Application Configuration store
- PBX Configuration store
- etc.....

There are various Distributed Schema Files that are standards based, but you can always create your own Schema Specification.

There are always new ways to use a Directory and apply LDAP principles to address certain problems, therefore there is no simple answer to this question.

If in doubt, join the general LDAP forum for non-commercial discussions and information relating to LDAP at: http://www.umich.edu/~dirsvcs/ldap/mailinglist.html and ask

1.4. When should I not use LDAP?

When you start finding yourself bending the directory to do what you require, maybe a redesign is needed. Or if you only require one application to use and manipulate your data (for discussion of LDAP vs RDBMS, please read the LDAP vs RDBMS section).

It will become obvious when LDAP is the right tool for the job.

1.5. How does LDAP work?

LDAP utilizes a *client-server model*. One or more LDAP servers contain the data making up the directory information tree (DIT). The client connects to servers and asks it a question. The server responds with an answer and/or with a pointer to where the client can get additional information (typically, another LDAP server). No matter which LDAP server a client connects to, it sees the same view of the directory; a name presented to one LDAP server references the same entry it would at another LDAP server. This is an important feature of a global directory service.

1.6. What about X.500?

Technically, LDAP is a directory access protocol to an X.500 directory service, the OSI directory service. Initially, LDAP clients accessed gateways to the X.500 directory service. This gateway ran LDAP between the client and gateway and X.500's Directory Access Protocol (DAP) between the gateway and the X.500 server. DAP is a heavyweight protocol that operates over a full OSI protocol stack and requires a significant amount of computing resources. LDAP is designed to operate over TCP/IP and provides most of the functionality of DAP at a much lower cost.

While LDAP is still used to access X.500 directory service via gateways, LDAP is now more commonly directly implemented in X.500 servers.

The Standalone LDAP Daemon, or *slapd*(8), can be viewed as a *lightweight* X.500 directory server. That is, it does not implement the X.500's DAP nor does it support the complete X.500 models.

If you are already running a X.500 DAP service and you want to continue to do so, you can probably stop reading this guide. This guide is all about running LDAP via *slapd*(8), without running X.500 DAP. If you are not running X.500 DAP, want to stop running X.500 DAP, or have no immediate plans to run X.500 DAP, read on.

It is possible to replicate data from an LDAP directory server to a X.500 DAP DSA. This requires an LDAP/DAP gateway. OpenLDAP Software does not include such a gateway.

1.7. What is the difference between LDAPv2 and LDAPv3?

LDAPv3 was developed in the late 1990's to replace LDAPv2. LDAPv3 adds the following features to LDAP:

- Strong authentication and data security services via SASL
- Certificate authentication and data security services via TLS (SSL)
- Internationalization through the use of Unicode
- Referrals and Continuations
- Schema Discovery
- Extensibility (controls, extended operations, and more)

LDAPv2 is historic (RFC3494). As most *so-called* LDAPv2 implementations (including *slapd*(8)) do not conform to the LDAPv2 technical specification, interoperability amongst implementations claiming LDAPv2 support is limited. As LDAPv2 differs significantly from LDAPv3, deploying both LDAPv2 and LDAPv3 simultaneously is quite problematic. LDAPv2 should be avoided. LDAPv2 is disabled by default.

1.8. LDAP vs RDBMS

This question is raised many times, in different forms. The most common, however, is: *Why doesn't OpenLDAP use a relational database management system (RDBMS) instead of an embedded key/value store like LMDB?* In general, expecting that the sophisticated algorithms implemented by commercial-grade RDBMS would make *OpenLDAP* be faster or somehow better and, at the same time, permitting sharing of data with other applications.

The short answer is that use of an embedded database and custom indexing system allows OpenLDAP to provide greater performance and scalability without loss of reliability. OpenLDAP uses LMDB concurrent /

transactional database software.

Now for the long answer. We are all confronted all the time with the choice RDBMSes vs. directories. It is a hard choice and no simple answer exists.

It is tempting to think that having a RDBMS backend to the directory solves all problems. However, it is a pig. This is because the data models are very different. Representing directory data with a relational database is going to require splitting data into multiple tables.

Think for a moment about the person objectclass. Its definition requires attribute types objectclass, sn and cn and allows attribute types userPassword, telephoneNumber, seeAlso and description. All of these attributes are multivalued, so a normalization requires putting each attribute type in a separate table.

Now you have to decide on appropriate keys for those tables. The primary key might be a combination of the DN, but this becomes rather inefficient on most database implementations.

The big problem now is that accessing data from one entry requires seeking on different disk areas. On some applications this may be OK but in many applications performance suffers.

The only attribute types that can be put in the main table entry are those that are mandatory and single-value. You may add also the optional single-valued attributes and set them to NULL or something if not present.

But wait, the entry can have multiple objectclasses and they are organized in an inheritance hierarchy. An entry of objectclass organizationalPerson now has the attributes from person plus a few others and some formerly optional attribute types are now mandatory.

What to do? Should we have different tables for the different objectclasses? This way the person would have an entry on the person table, another on organizationalPerson, etc. Or should we get rid of person and put everything on the second table?

But what do we do with a filter like (cn=*) where cn is an attribute type that appears in many, many objectclasses. Should we search all possible tables for matching entries? Not very attractive.

Once this point is reached, three approaches come to mind. One is to do full normalization so that each attribute type, no matter what, has its own separate table. The simplistic approach where the DN is part of the primary key is extremely wasteful, and calls for an approach where the entry has a unique numeric id that is used instead for the keys and a main table that maps DNs to ids. The approach, anyway, is very inefficient when several attribute types from one or more entries are requested. Such a database, though cumbersomely, can be managed from SQL applications.

The second approach is to put the whole entry as a blob in a table shared by all entries regardless of the objectclass and have additional tables that act as indices for the first table. Index tables are not database indices, but are fully managed by the LDAP server-side implementation. However, the database becomes unusable from SQL. And, thus, a fully fledged database system provides little or no advantage. The full generality of the database is unneeded. Much better to use something light and fast, like LMDB.

A completely different way to see this is to give up any hopes of implementing the directory data model. In this case, LDAP is used as an access protocol to data that provides only superficially the directory data model. For instance, it may be read only or, where updates are allowed, restrictions are applied, such as making single-value attribute types that would allow for multiple values. Or the impossibility to add new objectclasses to an existing entry or remove one of those present. The restrictions span the range from allowed restrictions (that might be elsewhere the result of access control) to outright violations of the data model. It can be, however, a method to provide LDAP access to preexisting data that is used by other applications. But in the understanding that we don't really have a "directory".

Existing commercial LDAP server implementations that use a relational database are either from the first kind or the third. I don't know of any implementation that uses a relational database to do inefficiently what LMDB does efficiently. For those who are interested in "third way" (exposing EXISTING data from RDBMS as LDAP tree, having some limitations compared to classic LDAP model, but making it possible to interoperate between LDAP and SQL applications):

OpenLDAP includes back-sql - the backend that makes it possible. It uses ODBC + additional metainformation about translating LDAP queries to SQL queries in your RDBMS schema, providing different levels of access - from read-only to full access depending on RDBMS you use, and your schema.

For more information on concept and limitations, see *slapd-sql*(5) man page, or the Backends section. There are also several examples for several RDBMSes in `back-sql/rdbms_depend/*` subdirectories.

1.9. What is slapd and what can it do?

slapd(8) is an LDAP directory server that runs on many different platforms. You can use it to provide a directory service of your very own. Your directory can contain pretty much anything you want to put in it. You can connect it to the global LDAP directory service, or run a service all by yourself. Some of slapd's more interesting features and capabilities include:

LDAPv3: *slapd* implements version 3 of Lightweight Directory Access Protocol. *slapd* supports LDAP over both IPv4 and IPv6 and Unix IPC.

Simple Authentication and Security Layer: *slapd* supports strong authentication and data security (integrity and confidentiality) services through the use of SASL. *slapd*'s SASL implementation utilizes Cyrus SASL software which supports a number of mechanisms including DIGEST-MD5, EXTERNAL, and GSSAPI.

Transport Layer Security: *slapd* supports certificate-based authentication and data security (integrity and confidentiality) services through the use of TLS (or SSL). *slapd*'s TLS implementation can utilize OpenSSL or GnuTLS, software.

Topology control: *slapd* can be configured to restrict access at the socket layer based upon network topology information. This feature utilizes *TCP wrappers*.

Access control: *slapd* provides a rich and powerful access control facility, allowing you to control access to the information in your database(s). You can control access to entries based on LDAP authorization information, IP address, domain name and other criteria. *slapd* supports both *static* and *dynamic* access control information.

Internationalization: *slapd* supports Unicode and language tags.

Choice of database backends: *slapd* comes with a variety of different database backends you can choose from. They include MDB, a hierarchical high-performance transactional database backend; and PASSWD, a simple backend interface to the *passwd*(5) file. The MDB backend utilizes LMDB.

Multiple database instances: *slapd* can be configured to serve multiple databases at the same time. This means that a single *slapd* server can respond to requests for many logically different portions of the LDAP tree, using the same or different database backends.

Generic modules API: If you require even more customization, *slapd* lets you write your own modules easily. *slapd* consists of two distinct parts: a front end that handles protocol communication with LDAP clients; and modules which handle specific tasks such as database operations. Because these two pieces communicate via a well-defined C API, you can write your own customized modules which extend *slapd* in numerous ways. Also, a number of *programmable database* modules are provided. These allow you to expose external data sources to *slapd* using popular programming languages (Perl, and SQL).

Threads: *slapd* is threaded for high performance. A single multi-threaded *slapd* process handles all incoming requests using a pool of threads. This reduces the amount of system overhead required while providing high performance.

Replication: *slapd* can be configured to maintain shadow copies of directory information. This *single-provider/multiple-consumer* replication scheme is vital in high-volume environments where a single *slapd* installation just doesn't provide the necessary availability or reliability. For extremely demanding environments where a single point of failure is not acceptable, *multi-provider* replication is also available. With *multi-provider* replication two or more nodes can accept write operations allowing for redundancy at the provider level.

slapd includes support for *LDAP Sync*-based replication.

Proxy Cache: *slapd* can be configured as a caching LDAP proxy service.

Configuration: *slapd* is highly configurable through a single configuration file which allows you to change just about everything you'd ever want to change. Configuration options have reasonable defaults, making your job much easier. Configuration can also be performed dynamically using LDAP itself, which greatly improves manageability.

1.10. What is lloadd and what can it do?

lloadd(8) is a daemon that provides an LDAPv3 load balancer service. It is responsible for distributing requests across a set of *slapd* instances.

See the Load Balancing with lloadd chapter for information about how to configure and run *lloadd*(8).

Alternatively, the load balancer can run as a module embedded inside of *slapd*. This is also described in the Load Balancing with lloadd chapter.

2. A Quick-Start Guide

The following is a quick start guide to OpenLDAP Software 2.6, including the Standalone LDAP Daemon, *slapd*(8).

It is meant to walk you through the basic steps needed to install and configure OpenLDAP Software. It should be used in conjunction with the other chapters of this document, manual pages, and other materials provided with the distribution (e.g. the `INSTALL` document) or on the OpenLDAP web site (http://www.OpenLDAP.org), in particular the OpenLDAP Software FAQ (http://www.OpenLDAP.org/faq/?file=2).

If you intend to run OpenLDAP Software seriously, you should review all of this document before attempting to install the software.

Note: This quick start guide does not use strong authentication nor any integrity or confidential protection services. These services are described in other chapters of the OpenLDAP Administrator's Guide.

1. **Get the software**
   You can obtain a copy of the software by following the instructions on the OpenLDAP Software download page (http://www.openldap.org/software/download/). It is recommended that new users start with the latest *release*.

2. **Unpack the distribution**
   Pick a directory for the source to live under, change directory to there, and unpack the distribution using the following commands:
   ```
   gunzip -c openldap-VERSION.tgz | tar xvfB -
   ```
   then relocate yourself into the distribution directory:
   ```
   cd openldap-VERSION
   ```
   You'll have to replace `VERSION` with the version name of the release.

3. **Review documentation**
   You should now review the `COPYRIGHT`, `LICENSE`, `README` and `INSTALL` documents provided with the distribution. The `COPYRIGHT` and `LICENSE` provide information on acceptable use, copying, and limitation of warranty of OpenLDAP Software.

   You should also review other chapters of this document. In particular, the Building and Installing OpenLDAP Software chapter of this document provides detailed information on prerequisite software and installation procedures.

4. **Run `configure`**
   You will need to run the provided `configure` script to *configure* the distribution for building on your system. The `configure` script accepts many command line options that enable or disable optional software features. Usually the defaults are okay, but you may want to change them. To get a complete list of options that `configure` accepts, use the `--help` option:
   ```
   ./configure --help
   ```
   However, given that you are using this guide, we'll assume you are brave enough to just let `configure` determine what's best:

```
./configure
```

Assuming `configure` doesn't dislike your system, you can proceed with building the software. If `configure` did complain, well, you'll likely need to go to the Software FAQ *Installation* section (http://www.openldap.org/faq/?file=8) and/or actually read the Building and Installing OpenLDAP Software chapter of this document.

5. **Build the software**.
   The next step is to build the software. This step has two parts, first we construct dependencies and then we compile the software:
   ```
   make depend
   make
   ```
   Both makes should complete without error.

6. **Test the build**.
   To ensure a correct build, you should run the test suite (it only takes a few minutes):
   ```
   make test
   ```
   Tests which apply to your configuration will run and they should pass. Some tests, such as the replication test, may be skipped.

7. **Install the software**.
   You are now ready to install the software; this usually requires *super-user* privileges:
   ```
   su root -c 'make install'
   ```
   Everything should now be installed under `/usr/local` (or whatever installation prefix was used by `configure`).

8. **Edit the configuration file**.
   Use your favorite editor to edit the provided *slapd.ldif* example (usually installed as `/usr/local/etc/openldap/slapd.ldif`) to contain a MDB database definition of the form:
   ```
   dn: olcDatabase=mdb,cn=config
   objectClass: olcDatabaseConfig
   objectClass: olcMdbConfig
   olcDatabase: mdb
   OlcDbMaxSize: 1073741824
   olcSuffix: dc=<MY-DOMAIN>,dc=<COM>
   olcRootDN: cn=Manager,dc=<MY-DOMAIN>,dc=<COM>
   olcRootPW: secret
   olcDbDirectory: /usr/local/var/openldap-data
   olcDbIndex: objectClass eq
   ```
   Be sure to replace `<MY-DOMAIN>` and `<COM>` with the appropriate domain components of your domain name. For example, for `example.com`, use:
   ```
   dn: olcDatabase=mdb,cn=config
   objectClass: olcDatabaseConfig
   objectClass: olcMdbConfig
   olcDatabase: mdb
   OlcDbMaxSize: 1073741824
   olcSuffix: dc=example,dc=com
   olcRootDN: cn=Manager,dc=example,dc=com
   olcRootPW: secret
   olcDbDirectory: /usr/local/var/openldap-data
   olcDbIndex: objectClass eq
   ```

If your domain contains additional components, such as `eng.uni.edu.eu`, use:

```
dn: olcDatabase=mdb,cn=config
objectClass: olcDatabaseConfig
objectClass: olcMdbConfig
olcDatabase: mdb
OlcDbMaxSize: 1073741824
olcSuffix: dc=eng,dc=uni,dc=edu,dc=eu
olcRootDN: cn=Manager,dc=eng,dc=uni,dc=edu,dc=eu
olcRootPW: secret
olcDbDirectory: /usr/local/var/openldap-data
olcDbIndex: objectClass eq
```

Details regarding configuring *slapd*(8) can be found in the *slapd-config*(5) manual page and the Configuring slapd chapter of this document. Note that the specified olcDbDirectory must exist prior to starting *slapd*(8).

9. **Import the configuration database**
   You are now ready to import your configuration database for use by *slapd*(8), by running the command:

   ```
   su root -c /usr/local/sbin/slapadd -n 0 -F /usr/local/etc/slapd.d -l
   /usr/local/etc/openldap/slapd.ldif
   ```

10. **Start SLAPD**.
    You are now ready to start the Standalone LDAP Daemon, *slapd*(8), by running the command:

    ```
    su root -c /usr/local/libexec/slapd -F /usr/local/etc/slapd.d
    ```

    To check to see if the server is running and configured correctly, you can run a search against it with *ldapsearch*(1). By default, *ldapsearch* is installed as `/usr/local/bin/ldapsearch`:

    ```
    ldapsearch -x -b '' -s base '(objectclass=*)' namingContexts
    ```

    Note the use of single quotes around command parameters to prevent special characters from being interpreted by the shell. This should return:

    ```
    dn:
    namingContexts: dc=example,dc=com
    ```

    Details regarding running *slapd*(8) can be found in the *slapd*(8) manual page and the Running slapd chapter of this document.

11. **Add initial entries to your directory**.
    You can use *ldapadd*(1) to add entries to your LDAP directory. *ldapadd* expects input in LDIF form. We'll do it in two steps:
    1. create an LDIF file
    2. run ldapadd

    Use your favorite editor and create an LDIF file that contains:

    ```
    dn: dc=<MY-DOMAIN>,dc=<COM>
    objectclass: dcObject
    objectclass: organization
    o: <MY ORGANIZATION>
    dc: <MY-DOMAIN>

    dn: cn=Manager,dc=<MY-DOMAIN>,dc=<COM>
    objectclass: organizationalRole
    cn: Manager
    ```

    Be sure to replace `<MY-DOMAIN>` and `<COM>` with the appropriate domain components of your domain name. `<MY ORGANIZATION>` should be replaced with the name of your organization. When you cut and paste, be sure to trim any leading and trailing whitespace from the example.

```
dn: dc=example,dc=com
objectclass: dcObject
objectclass: organization
o: Example Company
dc: example

dn: cn=Manager,dc=example,dc=com
objectclass: organizationalRole
cn: Manager
```

Now, you may run *ldapadd*(1) to insert these entries into your directory.

```
ldapadd -x -D "cn=Manager,dc=<MY-DOMAIN>,dc=<COM>" -W -f
example.ldif
```

Be sure to replace `<MY-DOMAIN>` and `<COM>` with the appropriate domain components of your domain name. You will be prompted for the `"secret"` specified in `slapd.conf`. For example, for `example.com`, use:

```
ldapadd -x -D "cn=Manager,dc=example,dc=com" -W -f example.ldif
```

where `example.ldif` is the file you created above.

Additional information regarding directory creation can be found in the Database Creation and Maintenance Tools chapter of this document.

12. **See if it works**.
Now we're ready to verify the added entries are in your directory. You can use any LDAP client to do this, but our example uses the *ldapsearch*(1) tool. Remember to replace `dc=example,dc=com` with the correct values for your site:

```
ldapsearch -x -b 'dc=example,dc=com' '(objectclass=*)'
```

This command will search for and retrieve every entry in the database.

You are now ready to add more entries using *ldapadd*(1) or another LDAP client, experiment with various configuration options, backend arrangements, etc..

Note that by default, the *slapd*(8) database grants *read access to everybody* excepting the *super-user* (as specified by the `rootdn` configuration directive). It is highly recommended that you establish controls to restrict access to authorized users. Access controls are discussed in the Access Control chapter. You are also encouraged to read the Security Considerations, Using SASL and Using TLS sections.

The following chapters provide more detailed information on making, installing, and running *slapd*(8).

3. The Big Picture - Configuration Choices

This section gives a brief overview of various LDAP directory configurations, and how your Standalone LDAP Daemon *slapd*(8) fits in with the rest of the world.

3.1. Local Directory Service

In this configuration, you run a *slapd*(8) instance which provides directory service for your local domain only. It does not interact with other directory servers in any way. This configuration is shown in Figure 3.1.

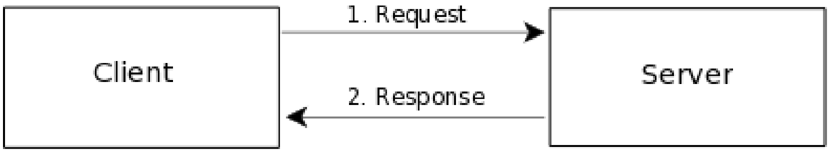


Figure 3.1: Local service configuration.

Use this configuration if you are just starting out (it's the one the quick-start guide makes for you) or if you want to provide a local service and are not interested in connecting to the rest of the world. It's easy to upgrade to another configuration later if you want.

3.2. Local Directory Service with Referrals

In this configuration, you run a *slapd*(8) instance which provides directory service for your local domain and configure it to return referrals to other servers capable of handling requests. You may run this service (or services) yourself or use one provided to you. This configuration is shown in Figure 3.2.

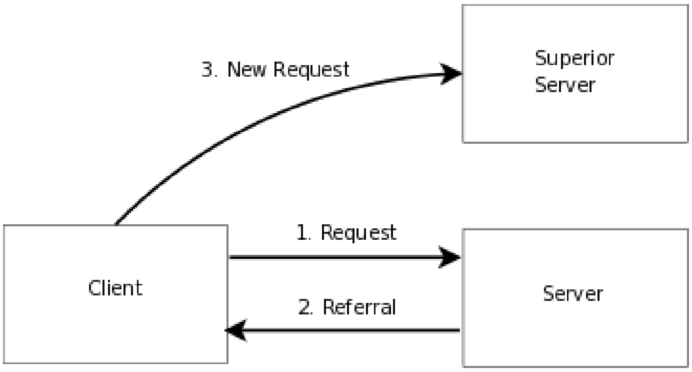


Figure 3.2: Local service with referrals

Use this configuration if you want to provide local service and participate in the Global Directory, or you want to delegate responsibility for *subordinate* entries to another server.

3.3. Replicated Directory Service

slapd(8) includes support for *LDAP Sync*-based replication, called *syncrepl*, which may be used to maintain shadow copies of directory information on multiple directory servers. In its most basic configuration, the *provider* is a syncrepl provider and one or more *consumer* (or *shadow*) are syncrepl consumers. An example provider-consumer configuration is shown in figure 3.3. Multi-Provider configurations are also supported.

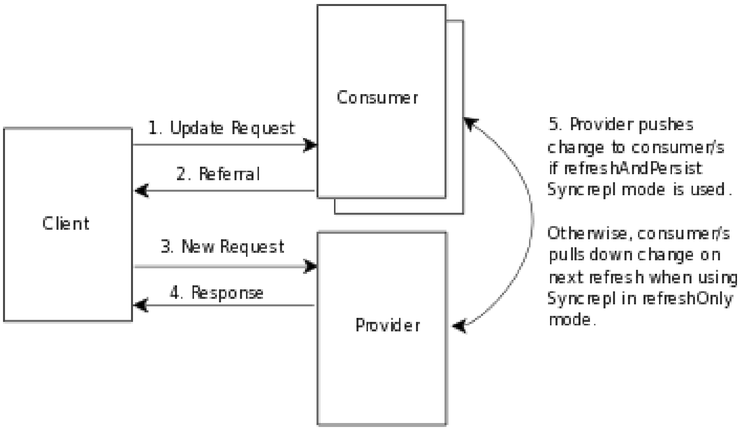

Consumer
1. Update Request
2. Referral
Client
3. New Request
4. Response
Provider
5. Provider pushes change to consumer/s if refreshAndPersist Syncrepl mode is used.
Otherwise, consumer/s pulls down change on next refresh when using Syncrepl in refreshOnly mode.

Figure 3.3: Replicated Directory Services

This configuration can be used in conjunction with either of the first two configurations in situations where a single *slapd*(8) instance does not provide the required reliability or availability.

3.4. Distributed Local Directory Service

In this configuration, the local service is partitioned into smaller services, each of which may be replicated, and *glued* together with *superior* and *subordinate* referrals.

4. Building and Installing OpenLDAP Software

This chapter details how to build and install the OpenLDAP Software package including *slapd*(8), the Standalone LDAP Daemon. Building and installing OpenLDAP Software requires several steps: installing prerequisite software, configuring OpenLDAP Software itself, making, and finally installing. The following sections describe this process in detail.

4.1. Obtaining and Extracting the Software

You can obtain OpenLDAP Software from the project's download page at http://www.openldap.org/software/download/ or directly from the project's FTP service at ftp://ftp.openldap.org/pub/OpenLDAP/.

The project makes available two series of packages for *general use*. The project makes *releases* as new features and bug fixes come available. Though the project takes steps to improve stability of these releases, it is common for problems to arise only after *release*. The *stable* release is the latest *release* which has demonstrated stability through general use.

Users of OpenLDAP Software can choose, depending on their desire for the *latest features* versus *demonstrated stability*, the most appropriate series to install.

After downloading OpenLDAP Software, you need to extract the distribution from the compressed archive file and change your working directory to the top directory of the distribution:

```
gunzip -c openldap-VERSION.tgz | tar xf -
cd openldap-VERSION
```

You'll have to replace `VERSION` with the version name of the release.

You should now review the `COPYRIGHT`, `LICENSE`, `README` and `INSTALL` documents provided with the distribution. The `COPYRIGHT` and `LICENSE` provide information on acceptable use, copying, and limitation of warranty of OpenLDAP Software. The `README` and `INSTALL` documents provide detailed information on prerequisite software and installation procedures.

4.2. Prerequisite software

OpenLDAP Software relies upon a number of software packages distributed by third parties. Depending on the features you intend to use, you may have to download and install a number of additional software packages. This section details commonly needed third party software packages you might have to install. However, for an up-to-date prerequisite information, the `README` document should be consulted. Note that some of these third party packages may depend on additional software packages. Install each package per the installation instructions provided with it.

4.2.1.

OpenLDAP clients and servers require installation of OpenSSL or GnuTLS TLS libraries to provide Transport Layer Security services. Though some operating systems may provide these libraries as part of the base system or as an optional software component, OpenSSL and GnuTLS often require separate installation.

OpenSSL is available from http://www.openssl.org/. GnuTLS is available from http://www.gnu.org/software/gnutls/.

OpenLDAP Software will not be fully LDAPv3 compliant unless OpenLDAP's `configure` detects a usable TLS library.

4.2.2.

OpenLDAP clients and servers require installation of Cyrus SASL libraries to provide Simple Authentication and Security Layer services. Though some operating systems may provide this library as part of the base system or as an optional software component, Cyrus SASL often requires separate installation.

Cyrus SASL is available from http://asg.web.cmu.edu/sasl/sasl-library.html. Cyrus SASL will make use of OpenSSL and Kerberos/GSSAPI libraries if preinstalled.

OpenLDAP Software will not be fully LDAPv3 compliant unless OpenLDAP's configure detects a usable Cyrus SASL installation.

4.2.3.

OpenLDAP clients and servers support Kerberos authentication services. In particular, OpenLDAP supports the Kerberos V GSS-API SASL authentication mechanism known as the GSSAPI mechanism. This feature requires, in addition to Cyrus SASL libraries, either Heimdal or MIT Kerberos V libraries.

Heimdal Kerberos is available from https://github.com/heimdal/heimdal/. MIT Kerberos is available from http://web.mit.edu/kerberos/www/.

Use of strong authentication services, such as those provided by Kerberos, is highly recommended.

4.2.4. Database Software

OpenLDAP's *slapd*(8) MDB primary database backend uses the LMDB software included with the OpenLDAP source. There is no need to download any additional software to have *MDB* support.

4.2.5. Threads

OpenLDAP is designed to take advantage of threads. OpenLDAP supports POSIX *pthreads*, NT threads and a number of other varieties. `configure` will complain if it cannot find a suitable thread subsystem. If this occurs, please consult the `Software|Installation|Platform Hints` section of the OpenLDAP FAQ http://www.openldap.org/faq/.

4.2.6. TCP Wrappers

slapd(8) supports TCP Wrappers (IP level access control filters) if preinstalled. Use of TCP Wrappers or other IP-level access filters (such as those provided by an IP-level firewall) is recommended for servers containing non-public information.

4.3. Running configure

Now you should probably run the `configure` script with the `--help` option. This will give you a list of options that you can change when building OpenLDAP. Many of the features of OpenLDAP can be enabled or disabled using this method.

```
./configure --help
```

The `configure` script also looks for certain variables on the command line and in the environment. These include:

Table 4.1: Variables

Variable	Description
`CC`	Specify alternative C Compiler
`CFLAGS`	Specify additional compiler flags
`CPPFLAGS`	Specify C Preprocessor flags
`LDFLAGS`	Specify linker flags
`LIBS`	Specify additional libraries

Now run the configure script with any desired configuration options or variables.

```
./configure [options] [variable=value ...]
```

As an example, let's assume that we want to install OpenLDAP with MDB backend and TCP Wrappers support. By default, MDB is enabled and TCP Wrappers is not. So, we just need to specify `--enable-wrappers` to include TCP Wrappers support:

```
./configure --enable-wrappers
```

However, this will fail to locate dependent software not installed in system directories. For example, if TCP Wrappers headers and libraries are installed in `/usr/local/include` and `/usr/local/lib` respectively, the `configure` script should typically be called as follows:

```
./configure --enable-wrappers \
        CPPFLAGS="-I/usr/local/include" \
        LDFLAGS="-L/usr/local/lib -Wl,-rpath,/usr/local/lib"
```

The `configure` script will normally auto-detect appropriate settings. If you have problems at this stage, consult any platform specific hints and check your `configure` options, if any.

4.4. Building the Software

Once you have run the `configure` script the last line of output should be:

```
Please "make depend" to build dependencies
```

If the last line of output does not match, `configure` has failed, and you will need to review its output to determine what went wrong. You should not proceed until `configure` completes successfully.

To build dependencies, run:

```
make depend
```

Now build the software, this step will actually compile OpenLDAP.

```
make
```

You should examine the output of this command carefully to make sure everything is built correctly. Note that this command builds the LDAP libraries and associated clients as well as *slapd*(8).

4.5. Testing the Software

Once the software has been properly configured and successfully made, you should run the test suite to verify the build.

```
make test
```

Tests which apply to your configuration will run and they should pass. Some tests, such as the replication test, may be skipped if not supported by your configuration.

4.6. Installing the Software

Once you have successfully tested the software, you are ready to install it. You will need to have write permission to the installation directories you specified when you ran configure. By default OpenLDAP Software is installed in `/usr/local`. If you changed this setting with the `--prefix` configure option, it will be installed in the location you provided.

Typically, the installation requires *super-user* privileges. From the top level OpenLDAP source directory, type:

```
su root -c 'make install'
```

and enter the appropriate password when requested.

You should examine the output of this command carefully to make sure everything is installed correctly. You will find the configuration files for *slapd*(8) in `/usr/local/etc/openldap` by default. See the chapter Configuring slapd for additional information.

5. Configuring slapd

Once the software has been built and installed, you are ready to configure *slapd*(8) for use at your site.

OpenLDAP 2.3 and later have transitioned to using a dynamic runtime configuration engine, *slapd-config*(5). *slapd-config*(5)

- is fully LDAP-enabled
- is managed using the standard LDAP operations
- stores its configuration data in an LDIF database, generally in the `/usr/local/etc/openldap/slapd.d` directory.
- allows all of slapd's configuration options to be changed on the fly, generally without requiring a server restart for the changes to take effect.

This chapter describes the general format of the *slapd-config*(5) configuration system, followed by a detailed description of commonly used settings.

The older style *slapd.conf*(5) file is still supported, but its use is deprecated and support for it will be withdrawn in a future OpenLDAP release. Configuring *slapd*(8) via *slapd.conf*(5) is described in the next chapter.

Refer to *slapd*(8) for information on how to have slapd automatically convert from *slapd.conf*(5) to *slapd-config*(5).

Note: Although the *slapd-config*(5) system stores its configuration as (text-based) LDIF files, you should *never* edit any of the LDIF files directly. Configuration changes should be performed via LDAP operations, e.g. *ldapadd*(1), *ldapdelete*(1), or *ldapmodify*(1). For offline modifications (when the server is not running), use *slapadd*(8) and *slapmodify*(8).

Note: You will need to continue to use the older *slapd.conf*(5) configuration system if your OpenLDAP installation requires the use of one or more backends or overlays that have not been updated to use the *slapd-config*(5) system. As of OpenLDAP 2.4.33, all of the official backends have been updated. There may be additional contributed or experimental overlays that also have not been updated.

5.1. Configuration Layout

The slapd configuration is stored as a special LDAP directory with a predefined schema and DIT. There are specific objectClasses used to carry global configuration options, schema definitions, backend and database definitions, and assorted other items. A sample config tree is shown in Figure 5.1.

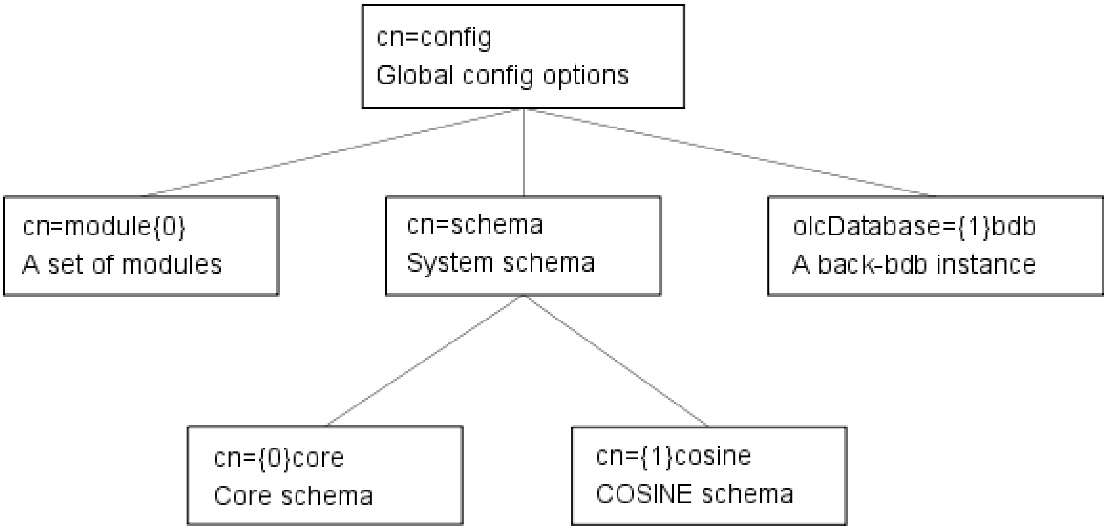


Figure 5.1: Sample configuration tree.

Other objects may be part of the configuration but were omitted from the illustration for clarity.

The *slapd-config* configuration tree has a very specific structure. The root of the tree is named `cn=config` and contains global configuration settings. Additional settings are contained in separate child entries:

- Dynamically loaded modules
  These may only be used if the `--enable-modules` option was used to configure the software.
- Schema definitions
  The `cn=schema,cn=config` entry contains the system schema (all the schema that is hard-coded in slapd).
  Child entries of `cn=schema,cn=config` contain user schema as loaded from config files or added at runtime.
- Backend-specific configuration
- Database-specific configuration
  Overlays are defined in children of the Database entry.
  Databases and Overlays may also have other miscellaneous children.

The usual rules for LDIF files apply to the configuration information: Comment lines beginning with a '#' character are ignored. If a line begins with a single space, it is considered a continuation of the previous line (even if the previous line is a comment) and the single leading space is removed. Entries are separated by blank lines.

The general layout of the config LDIF is as follows:

```
# global configuration settings
dn: cn=config
objectClass: olcGlobal
cn: config
<global config settings>

# schema definitions
dn: cn=schema,cn=config
objectClass: olcSchemaConfig
cn: schema
```

```
<system schema>

dn: cn={X}core,cn=schema,cn=config
objectClass: olcSchemaConfig
cn: {X}core
<core schema>

# additional user-specified schema
...

# backend definitions
dn: olcBackend=<typeA>,cn=config
objectClass: olcBackendConfig
olcBackend: <typeA>
<backend-specific settings>

# database definitions
dn: olcDatabase={X}<typeA>,cn=config
objectClass: olcDatabaseConfig
olcDatabase: {X}<typeA>
<database-specific settings>

# subsequent definitions and settings
...
```

Some of the entries listed above have a numeric index `"{X}"` in their names. While most configuration settings have an inherent ordering dependency (i.e., one setting must take effect before a subsequent one may be set), LDAP databases are inherently unordered. The numeric index is used to enforce a consistent ordering in the configuration database, so that all ordering dependencies are preserved. In most cases the index does not have to be provided; it will be automatically generated based on the order in which entries are created.

Configuration directives are specified as values of individual attributes. Most of the attributes and objectClasses used in the slapd configuration have a prefix of `"olc"` (OpenLDAP Configuration) in their names. Generally there is a one-to-one correspondence between the attributes and the old-style `slapd.conf` configuration keywords, using the keyword as the attribute name, with the "olc" prefix attached.

A configuration directive may take arguments. If so, the arguments are separated by whitespace. If an argument contains whitespace, the argument should be enclosed in double quotes `"like this"`. In the descriptions that follow, arguments that should be replaced by actual text are shown in brackets <>.

The distribution contains an example configuration file that will be installed in the `/usr/local/etc/openldap` directory. A number of files containing schema definitions (attribute types and object classes) are also provided in the `/usr/local/etc/openldap/schema` directory.

5.2. Configuration Directives

This section details commonly used configuration directives. For a complete list, see the *slapd-config*(5) manual page. This section will treat the configuration directives in a top-down order, starting with the global directives in the `cn=config` entry. Each directive will be described along with its default value (if any) and an example of its use.

5.2.1. cn=config

Directives contained in this entry generally apply to the server as a whole. Most of them are system or connection oriented, not database related. This entry must have the `olcGlobal` objectClass.

5.2.1.1. olcIdleTimeout: <integer>

Specify the number of seconds to wait before forcibly closing an idle client connection. A value of 0, the default, disables this feature.

5.2.1.2. olcLogLevel: <level>

This directive specifies the level at which log statements and operation statistics should be sent to syslog (currently logged to the *syslogd*(8) `LOG_LOCAL4` facility). You must have configured OpenLDAP `--enable-debug` (the default) for this to work, except for the two statistics levels, which are always enabled. Log levels may be specified as integers or by keyword. Multiple log levels may be used and the levels are additive. The possible values for <level> are:

Table 5.1: Logging Levels

Level	Keyword	Description
-1	any	enable all debugging
0		no debugging
1	(0x1 trace)	trace function calls
2	(0x2 packets)	debug packet handling
4	(0x4 args)	heavy trace debugging
8	(0x8 conns)	connection management
16	(0x10 BER)	print out packets sent and received
32	(0x20 filter)	search filter processing
64	(0x40 config)	configuration processing
128	(0x80 ACL)	access control list processing
256	(0x100 stats)	stats log connections/operations/results
512	(0x200 stats2)	stats log entries sent
1024	(0x400 shell)	print communication with shell backends
2048	(0x800 parse)	print entry parsing debugging
16384	(0x4000 sync)	syncrepl consumer processing
32768	(0x8000 none)	only messages that get logged regardless of configured log level

The desired log level can be input as a single integer that combines the (ORed) desired levels, both in decimal or in hexadecimal notation, as a list of integers (that are ORed internally), or as a list of the names that are shown between brackets, such that

```
olcLogLevel 129
olcLogLevel 0x81
olcLogLevel 128 1
olcLogLevel 0x80 0x1
olcLogLevel acl trace
```

are equivalent.

Examples:

```
        olcLogLevel -1
```

This will enable all log levels.

```
        olcLogLevel conns filter
```

Just log the connection and search filter processing.

```
        olcLogLevel none
```

Log those messages that are logged regardless of the configured loglevel. This differs from setting the log level to 0, when no logging occurs. At least the `None` level is required to have high priority messages logged.

Default:

```
        olcLogLevel stats
```

Basic stats logging is configured by default.

5.2.1.3. olcReferral <URI>

This directive specifies the referral to pass back when slapd cannot find a local database to handle a request.

Example:

```
                olcReferral: ldap://root.openldap.org
```

This will refer non-local queries to the global root LDAP server at the OpenLDAP Project. Smart LDAP clients can re-ask their query at that server, but note that most of these clients are only going to know how to handle simple LDAP URLs that contain a host part and optionally a distinguished name part.

5.2.1.4. Sample Entry

```
        dn: cn=config
        objectClass: olcGlobal
        cn: config
        olcIdleTimeout: 30
        olcLogLevel: Stats
        olcReferral: ldap://root.openldap.org
```

5.2.2. cn=module

If support for dynamically loaded modules was enabled when configuring slapd, `cn=module` entries may be used to specify sets of modules to load. Module entries must have the `olcModuleList` objectClass.

5.2.2.1. olcModuleLoad: <filename>

Specify the name of a dynamically loadable module to load. The filename may be an absolute path name or a simple filename. Non-absolute names are searched for in the directories specified by the `olcModulePath` directive.

5.2.2.2. olcModulePath: <pathspec>

Specify a list of directories to search for loadable modules. Typically the path is colon-separated but this depends on the operating system.

5.2.2.3. Sample Entries

```
dn: cn=module{0},cn=config
objectClass: olcModuleList
cn: module{0}
olcModuleLoad: /usr/local/lib/smbk5pwd.la

dn: cn=module{1},cn=config
objectClass: olcModuleList
cn: module{1}
olcModulePath: /usr/local/lib:/usr/local/lib/slapd
olcModuleLoad: accesslog.la
olcModuleLoad: pcache.la
```

5.2.3. cn=schema

The cn=schema entry holds all of the schema definitions that are hard-coded in slapd. As such, the values in this entry are generated by slapd so no schema values need to be provided in the config file. The entry must still be defined though, to serve as a base for the user-defined schema to add in underneath. Schema entries must have the `olcSchemaConfig` objectClass.

5.2.3.1. olcAttributeTypes: <RFC4512 Attribute Type Description>

This directive defines an attribute type. Please see the Schema Specification chapter for information regarding how to use this directive.

5.2.3.2. olcObjectClasses: <RFC4512 Object Class Description>

This directive defines an object class. Please see the Schema Specification chapter for information regarding how to use this directive.

5.2.3.3. Sample Entries

```
dn: cn=schema,cn=config
objectClass: olcSchemaConfig
cn: schema

dn: cn=test,cn=schema,cn=config
objectClass: olcSchemaConfig
cn: test
olcAttributeTypes: ( 1.1.1
  NAME 'testAttr'
  EQUALITY integerMatch
  SYNTAX 1.3.6.1.4.1.1466.115.121.1.27 )
olcAttributeTypes: ( 1.1.2 NAME 'testTwo' EQUALITY caseIgnoreMatch
  SUBSTR caseIgnoreSubstringsMatch SYNTAX 1.3.6.1.4.1.1466.115.121.1.44 )
olcObjectClasses: ( 1.1.3 NAME 'testObject'
  MAY ( testAttr $ testTwo ) AUXILIARY )
```

5.2.4. Backend-specific Directives

Backend directives apply to all database instances of the same type and, depending on the directive, may be overridden by database directives. Backend entries must have the `olcBackendConfig` objectClass.

5.2.4.1. olcBackend: <type>

This directive names a backend-specific configuration entry. `<type>` should be one of the supported backend types listed in Table 5.2.

Table 5.2: Database Backends

Types	**Description**
`asyncmeta`	a Asynchronous Metadirectory backend
`config`	Slapd configuration backend
`dnssrv`	DNS SRV backend
`ldap`	Lightweight Directory Access Protocol (Proxy) backend
`ldif`	Lightweight Data Interchange Format backend
`mdb`	Memory-Mapped DB backend
`meta`	Metadirectory backend
`monitor`	Monitor backend
`null`	Null backend
`passwd`	Provides read-only access to *passwd*(5)
`perl`	Perl Programmable backend
`relay`	Relay backend
`sock`	Socket backend
`sql`	SQL Programmable backend
`wt`	WiredTiger backend

Example:

```
olcBackend: mdb
```

This marks the beginning of a new MDB backend definition. At present, only back-mdb implements any options of this type, so this setting is not needed for any other backends.

5.2.4.2. Sample Entry

```
dn: olcBackend=mdb,cn=config
objectClass: olcBackendConfig
olcBackend: mdb
olcBkMdbIdlExp: 16
```

5.2.5. Database-specific Directives

Directives in this section are supported by every type of database. Database entries must have the `olcDatabaseConfig` objectClass.

5.2.5.1. olcDatabase: [{<index>}]<type>

This directive names a specific database instance. The numeric {<index>} may be provided to distinguish multiple databases of the same type. Usually the index can be omitted, and slapd will generate it automatically. `<type>` should be one of the supported backend types listed in Table 5.2 or the `frontend` type.

The `frontend` is a special database that is used to hold database-level options that should be applied to all the other databases. Subsequent database definitions may also override some frontend settings.

The `config` database is also special; both the `config` and the `frontend` databases are always created implicitly even if they are not explicitly configured, and they are created before any other databases.

Example:

```
        olcDatabase: mdb
```

This marks the beginning of a new MDB database instance.

5.2.5.2. olcAccess: to <what> [by <who> [<accesslevel>] [<control>]]+

This directive grants access (specified by <accesslevel>) to a set of entries and/or attributes (specified by <what>) by one or more requestors (specified by <who>). See the Access Control section of this guide for basic usage.

Note: If no `olcAccess` directives are specified, the default access control policy, `to * by * read`, allows all users (both authenticated and anonymous) read access.

Note: Access controls defined in the frontend are appended to all other databases' controls.

5.2.5.3. olcReadonly { TRUE | FALSE }

This directive puts the database into "read-only" mode. Any attempts to modify the database will return an "unwilling to perform" error. If set on a consumer, modifications sent by syncrepl will still occur.

Default:

```
        olcReadonly: FALSE
```

5.2.5.4. olcRootDN: <DN>

This directive specifies the DN that is not subject to access control or administrative limit restrictions for operations on this database. The DN need not refer to an entry in this database or even in the directory. The DN may refer to a SASL identity.

Entry-based Example:

```
        olcRootDN: cn=Manager,dc=example,dc=com
```

SASL-based Example:

```
        olcRootDN: uid=root,cn=example.com,cn=digest-md5,cn=auth
```

See the SASL Authentication section for information on SASL authentication identities.

5.2.5.5. olcRootPW: <password>

This directive can be used to specify a password for the DN for the rootdn (when the rootdn is set to a DN within the database).

Example:

```
        olcRootPW: secret
```

It is also permissible to provide a hash of the password in RFC2307 form. *slappasswd*(8) may be used to generate the password hash.

Example:

```
        olcRootPW: {SSHA}ZKKuqbEKJfKSXhUbHG3fG8MDn9j1v4QN
```

The hash was generated using the command `slappasswd -s secret`.

5.2.5.6. olcSizeLimit: <integer>

This directive specifies the maximum number of entries to return from a search operation.

Default:

```
        olcSizeLimit: 500
```

See the Limits section of this guide and slapd-config(5) for more details.

5.2.5.7. olcSuffix: <dn suffix>

This directive specifies the DN suffix of queries that will be passed to this backend database. Multiple suffix lines can be given, and usually at least one is required for each database definition. (Some backend types, such as `frontend` and `monitor` use a hard-coded suffix which may not be overridden in the configuration.)

Example:

```
        olcSuffix: dc=example,dc=com
```

Queries with a DN ending in "dc=example,dc=com" will be passed to this backend.

Note: When the backend to pass a query to is selected, slapd looks at the suffix value(s) in each database definition in the order in which they were configured. Thus, if one database suffix is a prefix of another, it must appear after it in the configuration.

5.2.5.8. olcSyncrepl

```
olcSyncrepl: rid=<replica ID>
        provider=ldap[s]://<hostname>[:port]
        [type=refreshOnly|refreshAndPersist]
        [interval=dd:hh:mm:ss]
        [retry=[<retry interval> <# of retries>]+]
        searchbase=<base DN>
        [filter=<filter str>]
        [scope=sub|one|base]
        [attrs=<attr list>]
        [exattrs=<attr list>]
        [attrsonly]
        [sizelimit=<limit>]
        [timelimit=<limit>]
        [schemachecking=on|off]
        [bindmethod=simple|sasl]
        [binddn=<DN>]
        [saslmech=<mech>]
        [authcid=<identity>]
        [authzid=<identity>]
        [credentials=<passwd>]
        [realm=<realm>]
        [secprops=<properties>]
        [starttls=yes|critical]
        [tls_cert=<file>]
        [tls_key=<file>]
        [tls_cacert=<file>]
        [tls_cacertdir=<path>]
        [tls_reqcert=never|allow|try|demand]
        [tls_cipher_suite=<ciphers>]
        [tls_crlcheck=none|peer|all]
        [logbase=<base DN>]
        [logfilter=<filter str>]
        [syncdata=default|accesslog|changelog]
```

This directive specifies the current database as a consumer of the provider content by establishing the current *slapd*(8) as a replication consumer site running a syncrepl replication engine. The provider database is located at the provider site specified by the `provider` parameter. The consumer database is kept up-to-date with the provider content using the LDAP Content Synchronization protocol. See RFC4533 for more information on the protocol.

The `rid` parameter is used for identification of the current `syncrepl` directive within the replication consumer server, where `<replica ID>` uniquely identifies the syncrepl specification described by the current `syncrepl` directive. `<replica ID>` is non-negative and is no more than three decimal digits in length.

The `provider` parameter specifies the replication provider site containing the provider content as an LDAP URI. The `provider` parameter specifies a scheme, a host and optionally a port where the provider slapd instance can be found. Either a domain name or IP address may be used for <hostname>. Examples are `ldap://provider.example.com:389` or `ldaps://192.168.1.1:636`. If <port> is not given, the standard LDAP port number (389 or 636) is used. Note that the syncrepl uses a consumer-initiated protocol, and hence its specification is located on the consumer.

The content of the syncrepl consumer is defined using a search specification as its result set. The consumer slapd will send search requests to the provider slapd according to the search specification. The search specification includes `searchbase`, `scope`, `filter`, `attrs`, `exattrs`, `attrsonly`, `sizelimit`, and `timelimit` parameters as in the normal search specification. The `searchbase` parameter has no default value and must always be specified. The `scope` defaults to `sub`, the `filter` defaults to `(objectclass=*)`, `attrs` defaults to `"*,+"` to replicate all user and operational attributes, and `attrsonly` is unset by default. Both `sizelimit` and `timelimit` default to "unlimited", and only positive integers or "unlimited" may be specified. The `exattrs` option may also be used to specify attributes that should be omitted from incoming entries.

The LDAP Content Synchronization protocol has two operation types: `refreshOnly` and `refreshAndPersist`. The operation type is specified by the `type` parameter. In the `refreshOnly` operation, the next synchronization search operation is periodically rescheduled at an interval time after each synchronization operation finishes. The interval is specified by the `interval` parameter. It is set to one day by default. In the `refreshAndPersist` operation, a synchronization search remains persistent in the provider *slapd* instance. Further updates to the provider will generate `searchResultEntry` to the consumer slapd as the search responses to the persistent synchronization search.

If an error occurs during replication, the consumer will attempt to reconnect according to the retry parameter which is a list of the <retry interval> and <# of retries> pairs. For example, retry="60 10 300 3" lets the consumer retry every 60 seconds for the first 10 times and then retry every 300 seconds for the next three times before stop retrying. + in <# of retries> means indefinite number of retries until success.

The schema checking can be enforced at the LDAP Sync consumer site by turning on the `schemachecking` parameter. If it is turned on, every replicated entry will be checked for its schema as the entry is stored on the consumer. Every entry in the consumer should contain those attributes required by the schema definition. If it is turned off, entries will be stored without checking schema conformance. The default is off.

The `binddn` parameter gives the DN to bind as for the syncrepl searches to the provider slapd. It should be a DN which has read access to the replication content in the provider database.

The `bindmethod` is `simple` or `sasl`, depending on whether simple password-based authentication or SASL authentication is to be used when connecting to the provider *slapd* instance.

Simple authentication should not be used unless adequate data integrity and confidentiality protections are in place (e.g. TLS or IPsec). Simple authentication requires specification of `binddn` and `credentials` parameters.

SASL authentication is generally recommended. SASL authentication requires specification of a mechanism using the `saslmech` parameter. Depending on the mechanism, an authentication identity and/or credentials can be specified using `authcid` and `credentials`, respectively. The `authzid` parameter may be used to specify an authorization identity.

The `realm` parameter specifies a realm which a certain mechanisms authenticate the identity within. The `secprops` parameter specifies Cyrus SASL security properties.

The `starttls` parameter specifies use of the StartTLS extended operation to establish a TLS session before authenticating to the provider. If the `critical` argument is supplied, the session will be aborted if the StartTLS request fails. Otherwise the syncrepl session continues without TLS. The tls_reqcert setting defaults to `"demand"` and the other TLS settings default to the same as the main slapd TLS settings.

Rather than replicating whole entries, the consumer can query logs of data modifications. This mode of operation is referred to as *delta syncrepl*. In addition to the above parameters, the `logbase` and `logfilter` parameters must be set appropriately for the log that will be used. The `syncdata` parameter must be set to either `"accesslog"` if the log conforms to the *slapo-accesslog*(5) log format, or `"changelog"` if the log conforms to the obsolete *changelog* format. If the `syncdata` parameter is omitted or set to `"default"` then the log parameters are ignored.

The *syncrepl* replication mechanism is supported by the *mdb* backend.

See the LDAP Sync Replication chapter of this guide for more information on how to use this directive.

5.2.5.9. olcTimeLimit: <integer>

This directive specifies the maximum number of seconds (in real time) slapd will spend answering a search request. If a request is not finished in this time, a result indicating an exceeded timelimit will be returned.

Default:

```
                olcTimeLimit: 3600
```

See the Limits section of this guide and slapd-config(5) for more details.

5.2.5.10. olcUpdateref: <URL>

This directive is only applicable in a *replica* (or *shadow*) *slapd*(8) instance. It specifies the URL to return to clients which submit update requests upon the replica. If specified multiple times, each URL is provided.

Example:

```
                olcUpdateref:   ldap://provider.example.net
```

5.2.5.11. Sample Entries

```
        dn: olcDatabase=frontend,cn=config
        objectClass: olcDatabaseConfig
        objectClass: olcFrontendConfig
        olcDatabase: frontend
        olcReadOnly: FALSE

        dn: olcDatabase=config,cn=config
        objectClass: olcDatabaseConfig
        olcDatabase: config
        olcRootDN: cn=Manager,dc=example,dc=com
```

5.2.6. MDB Backend Directives

Directives in this category only apply to the MDB database backend. They will apply to all "database mdb" instances in the configuration. For a complete reference of MDB backend configuration directives, see *slapd-mdb*(5).

5.2.6.1. olcBkMdbIdlExp <exponent>

Specify a power of 2 for the maximum size of an index slot. The default is 16, yielding a maximum slot size of 2^16 or 65536. The specified value must be in the range of 16-30.

This setting helps with the case where certain search filters are slow to return results due to an index slot having collapsed to a range value. This occurs when the number of candidate entries that match the filter for the index slot exceed the configured slot size.

If this setting is decreased on a server with existing MDB databases, each db will immediately need its indices to be rebuilt while slapd is offline with the "slapindex -q -t" command.

If this setting is increased on a server with existing MDB databases, each db will need its indices rebuilt to take advantage of the change for indices that have already been converted to ranges.

5.2.7. MDB Database Directives

Directives in this category apply to the MDB database backend. They are used in an olcDatabase entry in addition to the generic database directives defined above. For a complete reference of MDB configuration directives, see *slapd-mdb*(5). In addition to the `olcDatabaseConfig` objectClass, MDB database entries must have the `olcMdbConfig` objectClass.

5.2.7.1. olcDbDirectory: <directory>

This directive specifies the directory where the MDB files containing the database and associated indices live.

Default:

```
        olcDbDirectory: /usr/local/var/openldap-data
```

5.2.7.2. olcDbCheckpoint: <kbyte> <min>

This directive specifies the frequency for flushing the database disk buffers. This directive is only needed if the *olcDbNoSync* option is `TRUE`. The checkpoint will occur if either <kbyte> data has been written or <min> minutes have passed since the last checkpoint. Both arguments default to zero, in which case they are ignored. When the <min> argument is non-zero, an internal task will run every <min> minutes to perform the checkpoint. Note: currently the _kbyte_ setting is unimplemented.

Example:

```
        olcDbCheckpoint: 1024 10
```

5.2.7.3. olcDbEnvFlags: {nosync,nometasync,writemap,mapasync,nordahead}

This option specifies flags for finer-grained control of the LMDB library's operation.

- `nosync`: This is exactly the same as the dbnosync directive.
- `nometasync`: Flush the data on a commit, but skip the sync of the meta page. This mode is slightly faster than doing a full sync, but can potentially lose the last committed transaction if the operating system crashes. If both nometasync and nosync are set, the nosync flag takes precedence.

- `writemap`: Use a writable memory map instead of just read-only. This speeds up write operations but makes the database vulnerable to corruption in case any bugs in slapd cause stray writes into the mmap region.
- `mapasync`: When using a writable memory map and performing flushes on each commit, use an asynchronous flush instead of a synchronous flush (the default). This option has no effect if writemap has not been set. It also has no effect if nosync is set.
- `nordahead`: Turn off file readahead. Usually the OS performs readahead on every read request. This usually boosts read performance but can be harmful to random access read performance if the system's memory is full and the DB is larger than RAM. This option is not implemented on Windows.

5.2.7.4. olcDbIndex: {<attrlist> | default} [pres,eq,approx,sub,none]

This directive specifies the indices to maintain for the given attribute. If only an `<attrlist>` is given, the default indices are maintained. The index keywords correspond to the common types of matches that may be used in an LDAP search filter.

Example:

```
olcDbIndex: default pres,eq
olcDbIndex: uid
olcDbIndex: cn,sn pres,eq,sub
olcDbIndex: objectClass eq
```

The first line sets the default set of indices to maintain to present and equality. The second line causes the default (pres,eq) set of indices to be maintained for the `uid` attribute type. The third line causes present, equality, and substring indices to be maintained for `cn` and `sn` attribute types. The fourth line causes an equality index for the `objectClass` attribute type.

There is no index keyword for inequality matches. Generally these matches do not use an index. However, some attributes do support indexing for inequality matches, based on the equality index.

A substring index can be more explicitly specified as `subinitial`, `subany`, or `subfinal`, corresponding to the three possible components of a substring match filter. A subinitial index only indexes substrings that appear at the beginning of an attribute value. A subfinal index only indexes substrings that appear at the end of an attribute value, while subany indexes substrings that occur anywhere in a value.

Note that by default, setting an index for an attribute also affects every subtype of that attribute. E.g., setting an equality index on the `name` attribute causes `cn`, `sn`, and every other attribute that inherits from `name` to be indexed.

By default, no indices are maintained. It is generally advised that minimally an equality index upon objectClass be maintained.

```
olcDbIndex: objectClass eq
```

Additional indices should be configured corresponding to the most common searches that are used on the database. Presence indexing should not be configured for an attribute unless the attribute occurs very rarely in the database, and presence searches on the attribute occur very frequently during normal use of the directory. Most applications don't use presence searches, so usually presence indexing is not very useful.

If this setting is changed while slapd is running, an internal task will be run to generate the changed index data. All server operations can continue as normal while the indexer does its work. If slapd is stopped before the index task completes, indexing will have to be manually completed using the slapindex tool.

5.2.7.5. olcDbMaxEntrySize: <bytes>

Specify the maximum size of an entry in bytes. Attempts to store an entry larger than this size will be rejected with the error LDAP_ADMINLIMIT_EXCEEDED. The default is 0, which is unlimited.

5.2.7.6. olcDbMaxReaders: <integer>

This directive specifies the maximum number of threads that may have concurrent read access to the database. Tools such as slapcat count as a single thread, in addition to threads in any active slapd processes. The default is 126.

5.2.7.7. olcDbMaxSize: <bytes>

This directive specifies the maximum size of the database in bytes. A memory map of this size is allocated at startup time and the database will not be allowed to grow beyond this size. The default is 10485760 bytes (10MB). This setting may be changed upward if the configured limit needs to be increased.

Note: It is important to set this to as large a value as possible, (relative to anticipated growth of the actual data over time) since growing the size later may not be practical when the system is under heavy load.

5.2.7.8. olcDbMode: { <octal> | <symbolic> }

This directive specifies the file protection mode that newly created database index files should have. This can be in the form `0600` or `-rw-------`

Default:

```
        olcDbMode: 0600
```

5.2.7.9. olcDbMultival: { <attrlist> | default } <integer> hi,<integer> lo

Specify the number of values for which a multivalued attribute is stored in a separate table. Normally entries are stored as a single blob inside the database. When an entry gets very large or contains attributes with a very large number of values, modifications on that entry may get very slow. Splitting the large attributes out to a separate table can improve the performance of modification operations. The threshold is specified as a pair of integers. If the number of values exceeds the hi threshold the values will be split out. If a modification deletes enough values to bring an attribute below the lo threshold the values will be removed from the separate table and merged back into the main entry blob. The threshold can be set for a specific list of attributes, or the default can be configured for all other attributes. The default value for both hi and lo thresholds is UINT_MAX, which keeps all attributes in the main blob.

In addition to increasing write performance of operations the use of multival can also decrease fragmentation of the primary MDB database.

5.2.7.10. olcDbRtxnsize: <entries>

This directive specifies the maximum number of entries to process in a single read transaction when executing a large search. Long-lived read transactions prevent old database pages from being reused in write transactions, and so can cause significant growth of the database file when there is heavy write traffic. This setting causes the read transaction in large searches to be released and reacquired after the given number of entries has been read, to give writers the opportunity to reclaim old database pages. The default is 10000.

5.2.7.11. olcDbSearchStack: <integer>

Specify the depth of the stack used for search filter evaluation. Search filters are evaluated on a stack to accommodate nested `AND` / `OR` clauses. An individual stack is allocated for each server thread. The depth of the stack determines how complex a filter can be evaluated without requiring any additional memory allocation. Filters that are nested deeper than the search stack depth will cause a separate stack to be allocated for that particular search operation. These separate allocations can have a major negative impact on server performance, but specifying too much stack will also consume a great deal of memory. Each search uses 512K bytes per level on a 32-bit machine, or 1024K bytes per level on a 64-bit machine. The default stack depth is 16, thus 8MB or 16MB per thread is used on 32 and 64 bit machines, respectively. Also the 512KB size of a single stack slot is set by a compile-time constant which may be changed if needed; the code must be recompiled for the change to take effect.

Default:

```
olcDbSearchStack: 16
```

5.2.7.12. olcDbNosync: { TRUE | FALSE }

This directive causes on-disk database contents to not be immediately synchronized with in memory changes upon change. Setting this option to `TRUE` may improve performance at the expense of data integrity.

5.2.7.13. Sample Entry

```
dn: olcDatabase=mdb,cn=config
objectClass: olcDatabaseConfig
objectClass: olcMdbConfig
olcDatabase: mdb
olcSuffix: dc=example,dc=com
olcDbDirectory: /usr/local/var/openldap-data
olcDbIndex: objectClass eq
```

5.3. Configuration Example

The following is an example configuration, interspersed with explanatory text. It defines two databases to handle different parts of the X.500 tree; both are MDB database instances. The line numbers shown are provided for reference only and are not included in the actual file. First, the global configuration section:

```
1.    # example config file - global configuration entry
2.    dn: cn=config
3.    objectClass: olcGlobal
4.    cn: config
5.    olcReferral: ldap://root.openldap.org
6.
```

Line 1 is a comment. Lines 2-4 identify this as the global configuration entry. The `olcReferral:` directive on line 5 means that queries not local to one of the databases defined below will be referred to the LDAP server running on the standard port (389) at the host `root.openldap.org`. Line 6 is a blank line, indicating the end of this entry.

```
 7.    # internal schema
 8.    dn: cn=schema,cn=config
 9.    objectClass: olcSchemaConfig
10.    cn: schema
11.
```

Line 7 is a comment. Lines 8-10 identify this as the root of the schema subtree. The actual schema definitions in this entry are hardcoded into slapd so no additional attributes are specified here. Line 11 is a blank line, indicating the end of this entry.

```
12.    # include the core schema
13.    include: file:///usr/local/etc/openldap/schema/core.ldif
14.
```

Line 12 is a comment. Line 13 is an LDIF include directive which accesses the *core* schema definitions in LDIF format. Line 14 is a blank line.

Next comes the database definitions. The first database is the special `frontend` database whose settings are applied globally to all the other databases.

```
15.    # global database parameters
16.    dn: olcDatabase=frontend,cn=config
17.    objectClass: olcDatabaseConfig
18.    olcDatabase: frontend
19.    olcAccess: to * by * read
20.
```

Line 15 is a comment. Lines 16-18 identify this entry as the global database entry. Line 19 is a global access control. It applies to all entries (after any applicable database-specific access controls). Line 20 is a blank line.

The next entry defines the config backend.

```
21.    # set a rootpw for the config database so we can bind.
22.    # deny access to everyone else.
23.    dn: olcDatabase=config,cn=config
24.    objectClass: olcDatabaseConfig
25.    olcDatabase: config
26.    olcRootPW: {SSHA}XKYnrjvGT3wZFQrDD5040US592LxsdLy
27.    olcAccess: to * by * none
28.
```

Lines 21-22 are comments. Lines 23-25 identify this entry as the config database entry. Line 26 defines the *super-user* password for this database. (The DN defaults to *"cn=config"*.) Line 27 denies all access to this database, so only the super-user will be able to access it. (This is already the default access on the config database. It is just listed here for illustration, and to reiterate that unless a means to authenticate as the super-user is explicitly configured, the config database will be inaccessible.)

Line 28 is a blank line.

The next entry defines an MDB backend that will handle queries for things in the "dc=example,dc=com" portion of the tree. Indices are to be maintained for several attributes, and the `userPassword` attribute is to be protected from unauthorized access.

```
29.    # MDB definition for example.com
30.    dn: olcDatabase=mdb,cn=config
```

```
31.    objectClass: olcDatabaseConfig
32.    objectClass: olcMdbConfig
33.    olcDatabase: mdb
34.    olcSuffix: dc=example,dc=com
35.    olcDbDirectory: /usr/local/var/openldap-data
36.    olcRootDN: cn=Manager,dc=example,dc=com
37.    olcRootPW: secret
38.    olcDbIndex: uid pres,eq
39.    olcDbIndex: cn,sn pres,eq,approx,sub
40.    olcDbIndex: objectClass eq
41.    olcAccess: to attrs=userPassword
42.      by self write
43.      by anonymous auth
44.      by dn.base="cn=Admin,dc=example,dc=com" write
45.      by * none
46.    olcAccess: to *
47.      by self write
48.      by dn.base="cn=Admin,dc=example,dc=com" write
49.      by * read
50.
```

Line 29 is a comment. Lines 30-33 identify this entry as a MDB database configuration entry. Line 34 specifies the DN suffix for queries to pass to this database. Line 35 specifies the directory in which the database files will live.

Lines 36 and 37 identify the database *super-user* entry and associated password. This entry is not subject to access control or size or time limit restrictions.

Lines 38 through 40 indicate the indices to maintain for various attributes.

Lines 41 through 49 specify access control for entries in this database. For all applicable entries, the `userPassword` attribute is writable by the entry itself and by the "admin" entry. It may be used for authentication/authorization purposes, but is otherwise not readable. All other attributes are writable by the entry and the "admin" entry, but may be read by all users (authenticated or not).

Line 50 is a blank line, indicating the end of this entry.

The next entry defines another MDB database. This one handles queries involving the `dc=example,dc=net` subtree but is managed by the same entity as the first database. Note that without line 60, the read access would be allowed due to the global access rule at line 19.

```
51.    # MDB definition for example.net
52.    dn: olcDatabase=mdb,cn=config
53.    objectClass: olcDatabaseConfig
54.    objectClass: olcMdbConfig
55.    olcDatabase: mdb
56.    olcSuffix: dc=example,dc=net
57.    olcDbDirectory: /usr/local/var/openldap-data-net
58.    olcRootDN: cn=Manager,dc=example,dc=com
59.    olcDbIndex: objectClass eq
60.    olcAccess: to * by users read
```

5.4. Converting old style *slapd.conf*(5) file to *cn=config* format

Before converting to the *cn=config* format you should make sure that the config backend is properly configured in your existing config file. While the config backend is always present inside slapd, by default it is only accessible by its rootDN, and there are no default credentials assigned so unless you explicitly configure a means to authenticate to it, it will be unusable.

If you do not already have a `database config` section, add something like this to the end of `slapd.conf`

```
        database config
        rootpw VerySecret
```

Note: Since the config backend can be used to load arbitrary code into the slapd process, it is extremely important to carefully guard whatever credentials are used to access it. Since simple passwords are vulnerable to password guessing attacks, it is usually better to omit the rootpw and only use SASL authentication for the config rootDN.

An existing *slapd.conf*(5) file can be converted to the new format using *slaptest*(8) or any of the slap tools:

```
                slaptest -f /usr/local/etc/openldap/slapd.conf -F /usr/local/etc/openldap/slapd.
```

Test that you can access entries under `cn=config` using the default *rootdn* and the *rootpw* configured above:

```
                ldapsearch -x -D cn=config -w VerySecret -b cn=config
```

You can then discard the old *slapd.conf*(5) file. Make sure to launch *slapd*(8) with the *-F* option to specify the configuration directory if you are not using the default directory path.

Note: When converting from the slapd.conf format to slapd.d format, any included files will also be integrated into the resulting configuration database.

5.5. Recovering from a broken configuration

If the server using *cn=config* does not start, either because the configuration does not represent the current version or because it has been corrupted, these actions are available, in the order of decreasing preference.

Make sure you have made a backup of the "broken" version before you attempt any of these:

5.5.1. Generate an ldif version of the configuration database and reload from that

Most of the time, the configuration can be parsed and a text version generated with *slapcat*(8):

```
        slapcat -F /usr/local/etc/openldap/slapd.d -n0 -l extracted_config.ldif
```

After you have backed up and removed the old configuration database contents, this output ldif can be hand-edited to adjust or remove the offending entries and imported again:

```
        slapadd -F /usr/local/etc/openldap/slapd.d -l updated_config.ldif
        slaptest -F /usr/local/etc/openldap/slapd.d
```

5.5.2. Modify config in-place

If the configuration can be parsed and you know exactly what you need to do, you can use *slapmodify*(8) to effect the required changes directly:

```
slapmodify -F /usr/local/etc/openldap/slapd.d
dn: ..., cn=config
changetype: ...
...
```

5.5.3. Recover with plain back-ldif

If the configuration contains items that *slapd*(8) cannot process as a *cn=config* database at all, the last resort is to disable schema checking and operate on it as a regular back-ldif database. This might cease to work with future versions of OpenLDAP without notice, attempt this only when all of the above fail.

First, create a directory to serve as the hosting DB and create the structure:

```
mkdir ./recovery ./recovery/cn=recovery
cp /usr/local/etc/openldap/slapd.d/cn=config.ldif ./recovery/cn=recovery
cp -r /usr/local/etc/openldap/slapd.d/cn=config ./recovery/cn=recovery
```

Or, if you have already backed up your old configuration, you can symlink it into place:

```
mkdir ./recovery
ln -s /usr/local/etc/openldap/slapd.d ./recovery/cn=recovery
```

Next, create a trivial *slapd.conf*(5) to access the new database:

```
database ldif
suffix cn=recovery
directory ./recovery/
```

Note the change of suffix, `cn=config` is hardcoded to correspond to an active config database, so we have to home it one level deeper - at `cn=config,cn=recovery`.

Now you can use *slapmodify*(8) to modify the database, it is most likely you will need to run with schema checking disabled:

```
slapmodify -f ./recovery.conf -s
```

You can test the validity of your config with *slaptest*(8):

```
slaptest -F ./recovery/cn=recovery
```

And generate a full ldif with *slapcat*(8):

```
slapcat -F ./recovery/cn=recovery -n0
```

6. The slapd Configuration File

This chapter describes configuring *slapd*(8) via the *slapd.conf*(5) configuration file. *slapd.conf*(5) has been deprecated and should only be used if your site requires one of the backends that hasn't yet been updated to work with the newer *slapd-config*(5) system. Configuring *slapd*(8) via *slapd-config*(5) is described in the previous chapter.

The *slapd.conf*(5) file is normally installed in the `/usr/local/etc/openldap` directory. An alternate configuration file location can be specified via a command-line option to *slapd*(8).

6.1. Configuration File Format

The *slapd.conf*(5) file consists of three types of configuration information: global, backend specific, and database specific. Global information is specified first, followed by information associated with a particular backend type, which is then followed by information associated with a particular database instance. Global directives can be overridden in backend and/or database directives, and backend directives can be overridden by database directives.

Blank lines and comment lines beginning with a '#' character are ignored. If a line begins with whitespace, it is considered a continuation of the previous line (even if the previous line is a comment).

The general format of slapd.conf is as follows:

```
# global configuration directives
<global config directives>

# backend definition
backend <typeA>
<backend-specific directives>

# first database definition & config directives
database <typeA>
<database-specific directives>

# second database definition & config directives
database <typeB>
<database-specific directives>

# second database definition & config directives
database <typeA>
<database-specific directives>

# subsequent backend & database definitions & config directives
...
```

A configuration directive may take arguments. If so, they are separated by whitespace. If an argument contains whitespace, the argument should be enclosed in double quotes `"like this"`. If an argument contains a double quote or a backslash character `\', the character should be preceded by a backslash character `\'.

The distribution contains an example configuration file that will be installed in the `/usr/local/etc/openldap` directory. A number of files containing schema definitions (attribute types and object classes) are also provided in the `/usr/local/etc/openldap/schema` directory.

6.2. Configuration File Directives

This section details commonly used configuration directives. For a complete list, see the *slapd.conf*(5) manual page. This section separates the configuration file directives into global, backend-specific and data-specific categories, describing each directive and its default value (if any), and giving an example of its use.

6.2.1. Global Directives

Directives described in this section apply to all backends and databases unless specifically overridden in a backend or database definition. Arguments that should be replaced by actual text are shown in brackets <>.

6.2.1.1. access to <what> [by <who> [<accesslevel>] [<control>]]+

This directive grants access (specified by <accesslevel>) to a set of entries and/or attributes (specified by <what>) by one or more requestors (specified by <who>). See the Access Control section of this guide for basic usage.

Note: If no `access` directives are specified, the default access control policy, `access to * by * read`, allows all both authenticated and anonymous users read access.

6.2.1.2. attributetype <RFC4512 Attribute Type Description>

This directive defines an attribute type. Please see the Schema Specification chapter for information regarding how to use this directive.

6.2.1.3. idletimeout <integer>

Specify the number of seconds to wait before forcibly closing an idle client connection. An idletimeout of 0, the default, disables this feature.

6.2.1.4. include <filename>

This directive specifies that slapd should read additional configuration information from the given file before continuing with the next line of the current file. The included file should follow the normal slapd config file format. The file is commonly used to include files containing schema specifications.

Note: You should be careful when using this directive - there is no small limit on the number of nested include directives, and no loop detection is done.

6.2.1.5. loglevel <level>

This directive specifies the level at which log statements and operation statistics should be sent to syslog (currently logged to the *syslogd*(8) `LOG_LOCAL4` facility). You must have configured OpenLDAP `--enable-debug` (the default) for this to work, except for the two statistics levels, which are always enabled. Log levels may be specified as integers or by keyword. Multiple log levels may be used and the levels are additive. The possible values for <integer> are:

Table 6.1: Logging Levels

Level	Keyword	Description
-1	any	enable all debugging
0		no debugging
1	(0x1 trace)	trace function calls
2	(0x2 packets)	debug packet handling
4	(0x4 args)	heavy trace debugging
8	(0x8 conns)	connection management
16	(0x10 BER)	print out packets sent and received
32	(0x20 filter)	search filter processing
64	(0x40 config)	configuration processing
128	(0x80 ACL)	access control list processing
256	(0x100 stats)	stats log connections/operations/results
512	(0x200 stats2)	stats log entries sent
1024	(0x400 shell)	print communication with shell backends
2048	(0x800 parse)	print entry parsing debugging
16384	(0x4000 sync)	syncrepl consumer processing
32768	(0x8000 none)	only messages that get logged regardless of configured log level

The desired log level can be input as a single integer that combines the (ORed) desired levels, both in decimal or in hexadecimal notation, as a list of integers (that are ORed internally), or as a list of the names that are shown between brackets, such that

```
loglevel 129
loglevel 0x81
loglevel 128 1
loglevel 0x80 0x1
loglevel acl trace
```

are equivalent.

Examples:

```
loglevel -1
```

This will enable all log levels.

```
loglevel conns filter
```

Just log the connection and search filter processing.

```
loglevel none
```

Log those messages that are logged regardless of the configured loglevel. This differs from setting the log level to 0, when no logging occurs. At least the `None` level is required to have high priority messages logged.

Default:

```
loglevel stats
```

Basic stats logging is configured by default.

6.2.1.6. objectclass <RFC4512 Object Class Description>

This directive defines an object class. Please see the Schema Specification chapter for information regarding how to use this directive.

6.2.1.7. referral <URI>

This directive specifies the referral to pass back when slapd cannot find a local database to handle a request.

Example:

```
        referral ldap://root.openldap.org
```

This will refer non-local queries to the global root LDAP server at the OpenLDAP Project. Smart LDAP clients can re-ask their query at that server, but note that most of these clients are only going to know how to handle simple LDAP URLs that contain a host part and optionally a distinguished name part.

6.2.1.8. sizelimit <integer>

This directive specifies the maximum number of entries to return from a search operation.

Default:

```
        sizelimit 500
```

See the Limits section of this guide and *slapd.conf*(5) for more details.

6.2.1.9. timelimit <integer>

This directive specifies the maximum number of seconds (in real time) slapd will spend answering a search request. If a request is not finished in this time, a result indicating an exceeded timelimit will be returned.

Default:

```
        timelimit 3600
```

See the Limits section of this guide and *slapd.conf*(5) for more details.

6.2.2. General Backend Directives

Directives in this section apply only to the backend in which they are defined. They are supported by every type of backend. Backend directives apply to all databases instances of the same type and, depending on the directive, may be overridden by database directives.

6.2.2.1. backend <type>

This directive marks the beginning of a backend declaration. `<type>` should be one of the supported backend types listed in Table 6.2.

Table 6.2: Database Backends

Types	Description
asyncmet	a Asynchronous Metadirectory backend
config	Slapd configuration backend
dnssrv	DNS SRV backend
ldap	Lightweight Directory Access Protocol (Proxy) backend
ldif	Lightweight Data Interchange Format backend
mdb	Memory-Mapped DB backend
meta	Metadirectory backend
monitor	Monitor backend
null	Null backend
passwd	Provides read-only access to *passwd*(5)
perl	Perl Programmable backend
relay	Relay backend
sock	Socket backend
sql	SQL Programmable backend
wt	WiredTiger backend

Example:

```
backend mdb
idlexp 16
```

This marks the beginning of a new MDB backend definition. At present, only back-mdb implements any options of this type, so this setting is not needed for any other backends.

6.2.3. General Database Directives

Directives in this section apply only to the database in which they are defined. They are supported by every type of database.

6.2.3.1. database <type>

This directive marks the beginning of a database instance declaration. `<type>` should be one of the supported backend types listed in Table 6.2.

Example:

```
database mdb
```

This marks the beginning of a new MDB database instance declaration.

6.2.3.2. limits <selector> <limit> [<limit> [...]]

Specify time and size limits based on the operation's initiator or base DN.

See the Limits section of this guide and *slapd.conf*(5) for more details.

6.2.3.3. readonly { on | off }

This directive puts the database into "read-only" mode. Any attempts to modify the database will return an "unwilling to perform" error. If set on a consumer, modifications sent by syncrepl will still occur.

Default:

```
        readonly off
```

6.2.3.4. rootdn <DN>

This directive specifies the DN that is not subject to access control or administrative limit restrictions for operations on this database. The DN need not refer to an entry in this database or even in the directory. The DN may refer to a SASL identity.

Entry-based Example:

```
        rootdn "cn=Manager,dc=example,dc=com"
```

SASL-based Example:

```
        rootdn "uid=root,cn=example.com,cn=digest-md5,cn=auth"
```

See the SASL Authentication section for information on SASL authentication identities.

6.2.3.5. rootpw <password>

This directive can be used to specifies a password for the DN for the rootdn (when the rootdn is set to a DN within the database).

Example:

```
        rootpw secret
```

It is also permissible to provide hash of the password in RFC2307 form. *slappasswd*(8) may be used to generate the password hash.

Example:

```
        rootpw {SSHA}ZKKuqbEKJfKSXhUbHG3fG8MDn9j1v4QN
```

The hash was generated using the command `slappasswd -s secret`.

6.2.3.6. suffix <dn suffix>

This directive specifies the DN suffix of queries that will be passed to this backend database. Multiple suffix lines can be given, and at least one is required for each database definition.

Example:

```
        suffix "dc=example,dc=com"
```

Queries with a DN ending in "dc=example,dc=com" will be passed to this backend.

Note: When the backend to pass a query to is selected, slapd looks at the suffix line(s) in each database definition in the order they appear in the file. Thus, if one database suffix is a prefix of another, it must appear after it in the config file.

6.2.3.7. syncrepl

```
syncrepl rid=<replica ID>
        provider=ldap[s]://<hostname>[:port]
        searchbase=<base DN>
        [type=refreshOnly|refreshAndPersist]
        [interval=dd:hh:mm:ss]
        [retry=[<retry interval> <# of retries>]+]
        [filter=<filter str>]
        [scope=sub|one|base]
        [attrs=<attr list>]
        [exattrs=<attr list>]
        [attrsonly]
        [sizelimit=<limit>]
        [timelimit=<limit>]
        [schemachecking=on|off]
        [network-timeout=<seconds>]
        [timeout=<seconds>]
        [bindmethod=simple|sasl]
        [binddn=<DN>]
        [saslmech=<mech>]
        [authcid=<identity>]
        [authzid=<identity>]
        [credentials=<passwd>]
        [realm=<realm>]
        [secprops=<properties>]
        [keepalive=<idle>:<probes>:<interval>]
        [starttls=yes|critical]
        [tls_cert=<file>]
        [tls_key=<file>]
        [tls_cacert=<file>]
        [tls_cacertdir=<path>]
        [tls_reqcert=never|allow|try|demand]
        [tls_cipher_suite=<ciphers>]
        [tls_crlcheck=none|peer|all]
        [tls_protocol_min=<major>[.<minor>]]
        [suffixmassage=<real DN>]
        [logbase=<base DN>]
        [logfilter=<filter str>]
        [syncdata=default|accesslog|changelog]
```

This directive specifies the current database as a consumer of the provider content by establishing the current *slapd*(8) as a replication consumer site running a syncrepl replication engine. The provider database is located at the replication provider site specified by the `provider` parameter. The consumer database is kept up-to-date with the provider content using the LDAP Content Synchronization protocol. See RFC4533 for more information on the protocol.

The `rid` parameter is used for identification of the current `syncrepl` directive within the replication consumer server, where `<replica ID>` uniquely identifies the syncrepl specification described by the current `syncrepl` directive. `<replica ID>` is non-negative and is no more than three decimal digits in length.

The `provider` parameter specifies the replication provider site containing the provider content as an LDAP URI. The `provider` parameter specifies a scheme, a host and optionally a port where the provider slapd instance can be found. Either a domain name or IP address may be used for <hostname>. Examples are `ldap://provider.example.com:389` or `ldaps://192.168.1.1:636`. If <port> is not given, the standard LDAP port number (389 or 636) is used. Note that the syncrepl uses a consumer-initiated protocol, and hence its specification is located on the consumer.

The content of the syncrepl consumer is defined using a search specification as its result set. The consumer slapd will send search requests to the provider slapd according to the search specification. The search specification includes `searchbase`, `scope`, `filter`, `attrs`, `exattrs`, `attrsonly`, `sizelimit`, and `timelimit` parameters as in the normal search specification. The `searchbase` parameter has no default value and must always be specified. The `scope` defaults to `sub`, the `filter` defaults to `(objectclass=*)`, `attrs` defaults to `"*,+"` to replicate all user and operational attributes, and `attrsonly` is unset by default. Both `sizelimit` and `timelimit` default to "unlimited", and only positive integers or "unlimited" may be specified. The `exattrs` option may also be used to specify attributes that should be omitted from incoming entries.

The LDAP Content Synchronization protocol has two operation types: `refreshOnly` and `refreshAndPersist`. The operation type is specified by the `type` parameter. In the `refreshOnly` operation, the next synchronization search operation is periodically rescheduled at an interval time after each synchronization operation finishes. The interval is specified by the `interval` parameter. It is set to one day by default. In the `refreshAndPersist` operation, a synchronization search remains persistent in the provider *slapd* instance. Further updates to the provider will generate `searchResultEntry` to the consumer slapd as the search responses to the persistent synchronization search.

If an error occurs during replication, the consumer will attempt to reconnect according to the retry parameter which is a list of the <retry interval> and <# of retries> pairs. For example, retry="60 10 300 3" lets the consumer retry every 60 seconds for the first 10 times and then retry every 300 seconds for the next three times before stop retrying. + in <# of retries> means indefinite number of retries until success.

The schema checking can be enforced at the LDAP Sync consumer site by turning on the `schemachecking` parameter. If it is turned on, every replicated entry will be checked for its schema as the entry is stored on the consumer. Every entry in the consumer should contain those attributes required by the schema definition. If it is turned off, entries will be stored without checking schema conformance. The default is off.

The `network-timeout` parameter sets how long the consumer will wait to establish a network connection to the provider. Once a connection is established, the `timeout` parameter determines how long the consumer will wait for the initial Bind request to complete. The defaults for these parameters come from *ldap.conf*(5).

The `binddn` parameter gives the DN to bind as for the syncrepl searches to the provider slapd. It should be a DN which has read access to the replication content in the provider database.

The `bindmethod` is `simple` or `sasl`, depending on whether simple password-based authentication or SASL authentication is to be used when connecting to the provider *slapd* instance.

Simple authentication should not be used unless adequate data integrity and confidentiality protections are in place (e.g. TLS or IPsec). Simple authentication requires specification of `binddn` and `credentials` parameters.

SASL authentication is generally recommended. SASL authentication requires specification of a mechanism using the `saslmech` parameter. Depending on the mechanism, an authentication identity and/or credentials can be specified using `authcid` and `credentials`, respectively. The `authzid` parameter may be used to specify an authorization identity.

The `realm` parameter specifies a realm which a certain mechanisms authenticate the identity within. The `secprops` parameter specifies Cyrus SASL security properties.

The `keepalive` parameter sets the values of idle, probes, and interval used to check whether a socket is alive; idle is the number of seconds a connection needs to remain idle before TCP starts sending keepalive probes; probes is the maximum number of keepalive probes TCP should send before dropping the connection; interval is interval in seconds between individual keepalive probes. Only some systems support the customization of these values; the keepalive parameter is ignored otherwise, and system-wide settings are used. For example, keepalive="240:10:30" will send a keepalive probe 10 times, every 30 seconds, after 240 seconds of idle activity. If no response to the probes is received, the connection will be dropped.

The `starttls` parameter specifies use of the StartTLS extended operation to establish a TLS session before authenticating to the provider. If the `critical` argument is supplied, the session will be aborted if the StartTLS request fails. Otherwise the syncrepl session continues without TLS. The tls_reqcert setting defaults to `"demand"` and the other TLS settings default to the same as the main slapd TLS settings.

The `suffixmassage` parameter allows the consumer to pull entries from a remote directory whose DN suffix differs from the local directory. The portion of the remote entries' DNs that matches the searchbase will be replaced with the suffixmassage DN.

Rather than replicating whole entries, the consumer can query logs of data modifications. This mode of operation is referred to as *delta syncrepl*. In addition to the above parameters, the `logbase` and `logfilter` parameters must be set appropriately for the log that will be used. The `syncdata` parameter must be set to either `"accesslog"` if the log conforms to the *slapo-accesslog*(5) log format, or `"changelog"` if the log conforms to the obsolete *changelog* format. If the `syncdata` parameter is omitted or set to `"default"` then the log parameters are ignored.

The *syncrepl* replication mechanism is supported by the *mdb* backend.

See the LDAP Sync Replication chapter of this guide for more information on how to use this directive.

6.2.3.8. updateref <URL>

This directive is only applicable in a *replica* (or *shadow*) *slapd*(8) instance. It specifies the URL to return to clients which submit update requests upon the replica. If specified multiple times, each URL is provided.

Example:

```
        updateref       ldap://provider.example.net
```

6.2.4. MDB Backend Directives

Directives in this category only apply to the MDB database backend. They will apply to all "database mdb" instances in the configuration. For a complete reference of MDB backend configuration directives, see *slapd-mdb*(5).

6.2.4.1. idlexp <exponent>

Specify a power of 2 for the maximum size of an index slot. The default is 16, yielding a maximum slot size of 2^16 or 65536. The specified value must be in the range of 16-30.

This setting helps with the case where certain search filters are slow to return results due to an index slot having collapsed to a range value. This occurs when the number of candidate entries that match the filter for the index slot exceed the configured slot size.

If this setting is decreased on a server with existing MDB databases, each db will immediately need its indices to be rebuilt while slapd is offline with the "slapindex -q -t" command.

If this setting is increased on a server with existing MDB databases, each db will need its indices rebuilt to take advantage of the change for indices that have already been converted to ranges.

6.2.5. MDB Database Directives

Directives in this category only apply to the MDB database backend. That is, they must follow a "database mdb" line and come before any subsequent "backend" or "database" lines. For a complete reference of MDB configuration directives, see *slapd-mdb*(5).

6.2.5.1. directory <directory>

This directive specifies the directory where the MDB files containing the database and associated indices live.

Default:

```
        directory /usr/local/var/openldap-data
```

6.2.5.2. checkpoint <kbyte> <min>

This directive specifies the frequency for flushing the database disk buffers. This directive is only needed if the *dbnosync* option is `TRUE`. The checkpoint will occur if either <kbyte> data has been written or <min> minutes have passed since the last checkpoint. Both arguments default to zero, in which case they are ignored. When the <min> argument is non-zero, an internal task will run every <min> minutes to perform the checkpoint. Note: currently the _kbyte_ setting is unimplemented.

Example:

```
    checkpoint: 1024 10
```

6.2.5.3. dbnosync: { TRUE | FALSE }

This directive causes on-disk database contents to not be immediately synchronized with in memory changes upon change. Setting this option to `TRUE` may improve performance at the expense of data integrity.

6.2.5.4. envflags: {nosync,nometasync,writemap,mapasync,nordahead}

This option specifies flags for finer-grained control of the LMDB library's operation.

- `nosync`: This is exactly the same as the dbnosync directive.

- nometasync: Flush the data on a commit, but skip the sync of the meta page. This mode is slightly faster than doing a full sync, but can potentially lose the last committed transaction if the operating system crashes. If both nometasync and nosync are set, the nosync flag takes precedence.
- writemap: Use a writable memory map instead of just read-only. This speeds up write operations but makes the database vulnerable to corruption in case any bugs in slapd cause stray writes into the mmap region.
- mapasync: When using a writable memory map and performing flushes on each commit, use an asynchronous flush instead of a synchronous flush (the default). This option has no effect if writemap has not been set. It also has no effect if nosync is set.
- nordahead: Turn off file readahead. Usually the OS performs readahead on every read request. This usually boosts read performance but can be harmful to random access read performance if the system's memory is full and the DB is larger than RAM. This option is not implemented on Windows.

6.2.5.5. index: {<attrlist> | default} [pres,eq,approx,sub,none]

This directive specifies the indices to maintain for the given attribute. If only an <attrlist> is given, the default indices are maintained. The index keywords correspond to the common types of matches that may be used in an LDAP search filter.

Example:

```
index: default pres,eq
index: uid
index: cn,sn pres,eq,sub
index: objectClass eq
```

The first line sets the default set of indices to maintain to present and equality. The second line causes the default (pres,eq) set of indices to be maintained for the uid attribute type. The third line causes present, equality, and substring indices to be maintained for cn and sn attribute types. The fourth line causes an equality index for the objectClass attribute type.

There is no index keyword for inequality matches. Generally these matches do not use an index. However, some attributes do support indexing for inequality matches, based on the equality index.

A substring index can be more explicitly specified as subinitial, subany, or subfinal, corresponding to the three possible components of a substring match filter. A subinitial index only indexes substrings that appear at the beginning of an attribute value. A subfinal index only indexes substrings that appear at the end of an attribute value, while subany indexes substrings that occur anywhere in a value.

Note that by default, setting an index for an attribute also affects every subtype of that attribute. E.g., setting an equality index on the name attribute causes cn, sn, and every other attribute that inherits from name to be indexed.

By default, no indices are maintained. It is generally advised that minimally an equality index upon objectClass be maintained.

```
index: objectClass eq
```

Additional indices should be configured corresponding to the most common searches that are used on the database. Presence indexing should not be configured for an attribute unless the attribute occurs very rarely in the database, and presence searches on the attribute occur very frequently during normal use of the directory. Most applications don't use presence searches, so usually presence indexing is not very useful.

6.2.5.6. maxentrysize: <bytes>

Specify the maximum size of an entry in bytes. Attempts to store an entry larger than this size will be rejected with the error LDAP_ADMINLIMIT_EXCEEDED. The default is 0, which is unlimited.

6.2.5.7. maxreaders: <integer>

This directive specifies the maximum number of threads that may have concurrent read access to the database. Tools such as slapcat count as a single thread, in addition to threads in any active slapd processes. The default is 126.

6.2.5.8. maxsize: <bytes>

This directive specifies the maximum size of the database in bytes. A memory map of this size is allocated at startup time and the database will not be allowed to grow beyond this size. The default is 10485760 bytes (10MB). This setting may be changed upward if the configured limit needs to be increased.

Note: It is important to set this to as large a value as possible, (relative to anticipated growth of the actual data over time) since growing the size later may not be practical when the system is under heavy load.

6.2.5.9. mode: { <octal> | <symbolic> }

This directive specifies the file protection mode that newly created database index files should have. This can be in the form `0600` or `-rw-------`

Default:

```
        mode: 0600
```

6.2.5.10. multival: { <attrlist> | default } <integer> hi,<integer> lo

Specify the number of values for which a multivalued attribute is stored in a separate table. Normally entries are stored as a single blob inside the database. When an entry gets very large or contains attributes with a very large number of values, modifications on that entry may get very slow. Splitting the large attributes out to a separate table can improve the performance of modification operations. The threshold is specified as a pair of integers. If the number of values exceeds the hi threshold the values will be split out. If a modification deletes enough values to bring an attribute below the lo threshold the values will be removed from the separate table and merged back into the main entry blob. The threshold can be set for a specific list of attributes, or the default can be configured for all other attributes. The default value for both hi and lo thresholds is UINT_MAX, which keeps all attributes in the main blob.

In addition to increasing write performance of operations the use of multival can also decrease fragmentation of the primary MDB database.

6.2.5.11. rtxnsize: <entries>

This directive specifies the maximum number of entries to process in a single read transaction when executing a large search. Long-lived read transactions prevent old database pages from being reused in write transactions, and so can cause significant growth of the database file when there is heavy write traffic. This setting causes the read transaction in large searches to be released and reacquired after the given number of entries has been read, to give writers the opportunity to reclaim old database pages. The default is 10000.

6.2.5.12. searchstack: <integer>

Specify the depth of the stack used for search filter evaluation. Search filters are evaluated on a stack to accommodate nested `AND` / `OR` clauses. An individual stack is allocated for each server thread. The depth of the stack determines how complex a filter can be evaluated without requiring any additional memory allocation. Filters that are nested deeper than the search stack depth will cause a separate stack to be allocated for that particular search operation. These separate allocations can have a major negative impact on server performance, but specifying too much stack will also consume a great deal of memory. Each search uses 512K bytes per level on a 32-bit machine, or 1024K bytes per level on a 64-bit machine. The default stack depth is 16, thus 8MB or 16MB per thread is used on 32 and 64 bit machines, respectively. Also the 512KB size of a single stack slot is set by a compile-time constant which may be changed if needed; the code must be recompiled for the change to take effect.

Default:

```
        searchstack: 16
```

6.2.5.13. Sample Entry

```
database mdb
suffix: "dc=example,dc=com"
directory: /usr/local/var/openldap-data
index: objectClass eq
```

6.3. Configuration File Example

The following is an example configuration file, interspersed with explanatory text. It defines two databases to handle different parts of the X.500 tree; both are MDB database instances. The line numbers shown are provided for reference only and are not included in the actual file. First, the global configuration section:

```
 1.    # example config file - global configuration section
 2.    include /usr/local/etc/schema/core.schema
 3.    referral ldap://root.openldap.org
 4.    access to * by * read
```

Line 1 is a comment. Line 2 includes another config file which contains *core* schema definitions. The `referral` directive on line 3 means that queries not local to one of the databases defined below will be referred to the LDAP server running on the standard port (389) at the host `root.openldap.org`.

Line 4 is a global access control. It applies to all entries (after any applicable database-specific access controls).

The next section of the configuration file defines a MDB backend that will handle queries for things in the "dc=example,dc=com" portion of the tree. The database is to be replicated to two replica slapds, one on truelies, the other on judgmentday. Indices are to be maintained for several attributes, and the `userPassword` attribute is to be protected from unauthorized access.

```
 5.    # MDB definition for the example.com
 6.    database mdb
 7.    suffix "dc=example,dc=com"
 8.    directory /usr/local/var/openldap-data
 9.    rootdn "cn=Manager,dc=example,dc=com"
10.    rootpw secret
```

```
11.    # indexed attribute definitions
12.    index uid pres,eq
13.    index cn,sn pres,eq,approx,sub
14.    index objectClass eq
15.    # database access control definitions
16.    access to attrs=userPassword
17.        by self write
18.        by anonymous auth
19.        by dn.base="cn=Admin,dc=example,dc=com" write
20.        by * none
21.    access to *
22.        by self write
23.        by dn.base="cn=Admin,dc=example,dc=com" write
24.        by * read
```

Line 5 is a comment. The start of the database definition is marked by the database keyword on line 6. Line 7 specifies the DN suffix for queries to pass to this database. Line 8 specifies the directory in which the database files will live.

Lines 9 and 10 identify the database *super-user* entry and associated password. This entry is not subject to access control or size or time limit restrictions.

Lines 12 through 14 indicate the indices to maintain for various attributes.

Lines 16 through 24 specify access control for entries in this database. For all applicable entries, the `userPassword` attribute is writable by the entry itself and by the "admin" entry. It may be used for authentication/authorization purposes, but is otherwise not readable. All other attributes are writable by the entry and the "admin" entry, but may be read by all users (authenticated or not).

The next section of the example configuration file defines another MDB database. This one handles queries involving the `dc=example,dc=net` subtree but is managed by the same entity as the first database. Note that without line 39, the read access would be allowed due to the global access rule at line 4.

```
33.    # MDB definition for example.net
34.    database mdb
35.    suffix "dc=example,dc=net"
36.    directory /usr/local/var/openldap-data-net
37.    rootdn "cn=Manager,dc=example,dc=com"
38.    index objectClass eq
39.    access to * by users read
```

7. Running slapd

slapd(8) is designed to be run as a standalone service. This allows the server to take advantage of caching, manage concurrency issues with underlying databases, and conserve system resources. Running from *inetd*(8) is *NOT* an option.

7.1. Command-Line Options

slapd(8) supports a number of command-line options as detailed in the manual page. This section details a few commonly used options.

```
-f <filename>
```

This option specifies an alternate configuration file for slapd. The default is normally `/usr/local/etc/openldap/slapd.conf`.

```
-F <slapd-config-directory>
```

Specifies the slapd configuration directory. The default is `/usr/local/etc/openldap/slapd.d`.

If both `-f` and `-F` are specified, the config file will be read and converted to config directory format and written to the specified directory. If neither option is specified, slapd will attempt to read the default config directory before trying to use the default config file. If a valid config directory exists then the default config file is ignored. All of the slap tools that use the config options observe this same behavior.

```
-h <URLs>
```

This option specifies alternative listener configurations. The default is `ldap:///` which implies LDAP over TCP on all interfaces on the default LDAP port 389. You can specify specific host-port pairs or other protocol schemes (such as `ldaps://` or `ldapi://`). slapd supports the HAProxy proxy protocol version 2, which allows a load balancer or proxy server to provide the remote client IP address to slapd to be used for access control or logging. Listeners configured using either `pldap:///` or `pldaps:///` URLS will only accept connections that include the necessary proxy protocol header. Connections to the ports used by these listeners should be restricted at the network level to only trusted load balancers or proxies to avoid spoofing of client IP addresses by third parties.

URL	Protocol	Transport
ldap:///	LDAP	TCP port 389
pldap:///	proxied LDAP	TCP port 389
ldaps:///	LDAP over SSL	TCP port 636
pldaps:///	proxied LDAP over SSL	TCP port 636
ldapi:///	LDAP	IPC (Unix-domain socket)

For example, `-h "ldaps:// ldap://127.0.0.1:666"` will create two listeners: one for the (non-standard) `ldaps://` scheme on all interfaces on the default `ldaps://` port 636, and one for the standard `ldap://` scheme on the `localhost` (*loopback*) interface on port 666. Hosts may be specified using using hostnames or IPv4 or IPv6 addresses. Port values must be numeric.

For LDAP over IPC, the pathname of the Unix-domain socket can be encoded in the URL. Note that directory separators must be URL-encoded, like any other characters that are special to URLs. Thus the socket

`/usr/local/var/ldapi` must be encoded as

```
ldapi://%2Fusr%2Flocal%2Fvar%2Fldapi
```

ldapi: is described in detail in *Using LDAP Over IPC Mechanisms* [Chu-LDAPI]

Note that the ldapi:/// transport is not widely implemented: non-OpenLDAP clients may not be able to use it.

```
-n <service-name>
```

This option specifies the service name used for logging and other purposes. The default service name is `slapd`.

```
-l <syslog-local-user>
```

This option specifies the local user for the *syslog*(8) facility. Values can be `LOCAL0`, `LOCAL1`, `LOCAL2`, ..., and `LOCAL7`. The default is `LOCAL4`. This option may not be supported on all systems.

```
-u user -g group
```

These options specify the user and group, respectively, to run as. `user` can be either a user name or uid. `group` can be either a group name or gid.

```
-r directory
```

This option specifies a run-time directory. slapd will *chroot*(2) to this directory after opening listeners but before reading any configuration files or initializing any backends.

```
-d <level> | ?
```

This option sets the slapd debug level to <level>. When level is a `?' character, the various debugging levels are printed and slapd exits, regardless of any other options you give it. Current debugging levels are

Table 7.1: Debugging Levels

Level	Keyword	Description
-1	any	enable all debugging
0		no debugging
1	(0x1 trace)	trace function calls
2	(0x2 packets)	debug packet handling
4	(0x4 args)	heavy trace debugging
8	(0x8 conns)	connection management
16	(0x10 BER)	print out packets sent and received
32	(0x20 filter)	search filter processing
64	(0x40 config)	configuration processing
128	(0x80 ACL)	access control list processing
256	(0x100 stats)	stats log connections/operations/results
512	(0x200 stats2)	stats log entries sent
1024	(0x400 shell)	print communication with shell backends

2048	(0x800 parse)	print entry parsing debugging
16384	(0x4000 sync)	syncrepl consumer processing
32768	(0x8000 none)	only messages that get logged whatever log level is set

You may enable multiple levels by specifying the debug option once for each desired level. Or, since debugging levels are additive, you can do the math yourself. That is, if you want to trace function calls and watch the config file being processed, you could set level to the sum of those two levels (in this case, `-d 65`). Or, you can let slapd do the math, (e.g. `-d 1 -d 64`). Consult `<ldap_log.h>` for more details.

Note: slapd must have been compiled with `--enable-debug`, which is the default, for any debugging information other than the stats and stats2 levels to be available as options.

7.2. Starting slapd

In general, slapd is run like this:

```
        /usr/local/libexec/slapd [<option>]*
```

where `/usr/local/libexec` is determined by `configure` and <option> is one of the options described above (or in *slapd*(8)). Unless you have specified a debugging level (including level `0`), slapd will automatically fork and detach itself from its controlling terminal and run in the background.

7.3. Stopping slapd

To kill off *slapd*(8) safely, you should give a command like this

```
        kill -INT `cat /usr/local/var/slapd.pid`
```

where `/usr/local/var` is determined by `configure`.

Killing slapd by a more drastic method may cause information loss or database corruption.

8. Access Control

8.1. Introduction

As the directory gets populated with more and more data of varying sensitivity, controlling the kinds of access granted to the directory becomes more and more critical. For instance, the directory may contain data of a confidential nature that you may need to protect by contract or by law. Or, if using the directory to control access to other services, inappropriate access to the directory may create avenues of attack to your sites security that result in devastating damage to your assets.

Access to your directory can be configured via two methods, the first using The slapd Configuration File and the second using the *slapd-config*(5) format (Configuring slapd).

The default access control policy is allow read by all clients. Regardless of what access control policy is defined, the *rootdn* is always allowed full rights (i.e. auth, search, compare, read and write) on everything and anything.

As a consequence, it's useless (and results in a performance penalty) to explicitly list the *rootdn* among the <*by*> clauses.

The following sections will describe Access Control Lists in greater depth and follow with some examples and recommendations. See *slapd.access*(5) for complete details.

8.2. Access Control via Static Configuration

Access to entries and attributes is controlled by the access configuration file directive. The general form of an access line is:

```
<access directive> ::= access to <what>
    [by <who> [<access>] [<control>] ]+
<what> ::= * |
    [dn[.<basic-style>]=<regex> | dn.<scope-style>=<DN>]
    [filter=<ldapfilter>] [attrs=<attrlist>]
<basic-style> ::= regex | exact
<scope-style> ::= base | one | subtree | children
<attrlist> ::= <attr> [val[.<basic-style>]=<regex>] | <attr> , <attrlist>
<attr> ::= <attrname> | entry | children
<who> ::= * | [anonymous | users | self
        | dn[.<basic-style>]=<regex> | dn.<scope-style>=<DN>]
    [dnattr=<attrname>]
    [group[/<objectclass>[/<attrname>][.<basic-style>]]=<regex>]
    [peername[.<basic-style>]=<regex>]
    [sockname[.<basic-style>]=<regex>]
    [domain[.<basic-style>]=<regex>]
    [sockurl[.<basic-style>]=<regex>]
    [set=<setspec>]
    [aci=<attrname>]
<access> ::= [self]{<level>|<priv>}
<level> ::= none | disclose | auth | compare | search | read | write | manage
<priv> ::= {=|+|-}{m|w|r|s|c|x|d|0}+
<control> ::= [stop | continue | break]
```

where the <what> part selects the entries and/or attributes to which the access applies, the `<who>` part specifies which entities are granted access, and the `<access>` part specifies the access granted. Multiple `<who> <access> <control>` triplets are supported, allowing many entities to be granted different access to the same set of entries and attributes. Not all of these access control options are described here; for more details see the *slapd.access*(5) man page.

8.2.1. What to control access to

The <what> part of an access specification determines the entries and attributes to which the access control applies. Entries are commonly selected in two ways: by DN and by filter. The following qualifiers select entries by DN:

```
        to *
        to dn[.<basic-style>]=<regex>
        to dn.<scope-style>=<DN>
```

The first form is used to select all entries. The second form may be used to select entries by matching a regular expression against the target entry's *normalized DN*. (The second form is not discussed further in this document.) The third form is used to select entries which are within the requested scope of DN. The <DN> is a string representation of the Distinguished Name, as described in RFC4514.

The scope can be either `base`, `one`, `subtree`, or `children`. Where `base` matches only the entry with provided DN, `one` matches the entries whose parent is the provided DN, `subtree` matches all entries in the subtree whose root is the provided DN, and `children` matches all entries under the DN (but not the entry named by the DN).

For example, if the directory contained entries named:

```
        0: o=suffix
        1: cn=Manager,o=suffix
        2: ou=people,o=suffix
        3: uid=kdz,ou=people,o=suffix
        4: cn=addresses,uid=kdz,ou=people,o=suffix
        5: uid=hyc,ou=people,o=suffix
```

Then:

`dn.base="ou=people,o=suffix"` match 2;
`dn.one="ou=people,o=suffix"` match 3, and 5;
`dn.subtree="ou=people,o=suffix"` match 2, 3, 4, and 5; and
`dn.children="ou=people,o=suffix"` match 3, 4, and 5.

Entries may also be selected using a filter:

```
        to filter=<ldap filter>
```

where <ldap filter> is a string representation of an LDAP search filter, as described in RFC4515. For example:

```
        to filter=(objectClass=person)
```

Note that entries may be selected by both DN and filter by including both qualifiers in the <what> clause.

```
        to dn.one="ou=people,o=suffix" filter=(objectClass=person)
```

Attributes within an entry are selected by including a comma-separated list of attribute names in the <what> selector:

```
        attrs=<attribute list>
```

A specific value of an attribute is selected by using a single attribute name and also using a value selector:

```
        attrs=<attribute> val[.<style>]=<regex>
```

There are two special *pseudo* attributes `entry` and `children`. To read (and hence return) a target entry, the subject must have `read` access to the target's *entry* attribute. To perform a search, the subject must have `search` access to the search base's *entry* attribute. To add or delete an entry, the subject must have `write` access to the entry's `entry` attribute AND must have `write` access to the entry's parent's `children` attribute. To rename an entry, the subject must have `write` access to entry's `entry` attribute AND have `write` access to both the old parent's and new parent's `children` attributes. The complete examples at the end of this section should help clear things up.

Lastly, there is a special entry selector `"*"` that is used to select any entry. It is used when no other `<what>` selector has been provided. It's equivalent to "`dn=.*`"

8.2.2. Who to grant access to

The <who> part identifies the entity or entities being granted access. Note that access is granted to "entities" not "entries." The following table summarizes entity specifiers:

Table 6.3: Access Entity Specifiers

Specifier	**Entities**
`*`	All, including anonymous and authenticated users
`anonymous`	Anonymous (non-authenticated) users
`users`	Authenticated users
`self`	User associated with target entry
`dn[.<basic-style>]=<regex>`	Users matching a regular expression
`dn.<scope-style>=<DN>`	Users within scope of a DN

The DN specifier behaves much like <what> clause DN specifiers.

Other control factors are also supported. For example, a `<who>` can be restricted by an entry listed in a DN-valued attribute in the entry to which the access applies:

```
        dnattr=<dn-valued attribute name>
```

The dnattr specification is used to give access to an entry whose DN is listed in an attribute of the entry (e.g., give access to a group entry to whoever is listed as the owner of the group entry).

Some factors may not be appropriate in all environments (or any). For example, the domain factor relies on IP to domain name lookups. As these can easily be spoofed, the domain factor should be avoided.

8.2.3. The access to grant

The kind of <access> granted can be one of the following:

Table 6.4: Access Levels

Level	Privileges	Description
`none =`	`0`	no access
`disclose =`	`d`	needed for information disclosure on error
`auth =`	`dx`	needed to authenticate (bind)
`compare =`	`cdx`	needed to compare
`search =`	`scdx`	needed to apply search filters
`read =`	`rscdx`	needed to read search results
`write =`	`wrscdx`	needed to modify/rename
`manage =`	`mwrscdx`	needed to manage

Each level implies all lower levels of access. So, for example, granting someone `write` access to an entry also grants them `read`, `search`, `compare`, `auth` and `disclose` access. However, one may use the privileges specifier to grant specific permissions.

8.2.4. Access Control Evaluation

When evaluating whether some requester should be given access to an entry and/or attribute, slapd compares the entry and/or attribute to the `<what>` selectors given in the configuration file. For each entry, access controls provided in the database which holds the entry (or the global access directives if not held in any database) apply first, followed by the global access directives. However, when dealing with an access list, because the global access list is effectively appended to each per-database list, if the resulting list is non-empty then the access list will end with an implicit `access to * by * none` directive. If there are no access directives applicable to a backend, then a default read is used.

Within this priority, access directives are examined in the order in which they appear in the config file. Slapd stops with the first `<what>` selector that matches the entry and/or attribute. The corresponding access directive is the one slapd will use to evaluate access.

Next, slapd compares the entity requesting access to the `<who>` selectors within the access directive selected above in the order in which they appear. It stops with the first `<who>` selector that matches the requester. This determines the access the entity requesting access has to the entry and/or attribute.

Finally, slapd compares the access granted in the selected `<access>` clause to the access requested by the client. If it allows greater or equal access, access is granted. Otherwise, access is denied.

The order of evaluation of access directives makes their placement in the configuration file important. If one access directive is more specific than another in terms of the entries it selects, it should appear first in the config file. Similarly, if one `<who>` selector is more specific than another it should come first in the access directive. The access control examples given below should help make this clear.

8.2.5. Access Control Examples

The access control facility described above is quite powerful. This section shows some examples of its use for descriptive purposes.

A simple example:

```
access to * by * read
```

This access directive grants read access to everyone.

```
access to *
    by self write
    by anonymous auth
    by * read
```

This directive allows the user to modify their entry, allows anonymous to authenticate against these entries, and allows all others to read these entries. Note that only the first `by <who>` clause which matches applies. Hence, the anonymous users are granted `auth`, not `read`. The last clause could just as well have been "`by users read`".

It is often desirable to restrict operations based upon the level of protection in place. The following shows how security strength factors (SSF) can be used.

```
access to *
    by ssf=128 self write
    by ssf=64 anonymous auth
    by ssf=64 users read
```

This directive allows users to modify their own entries if security protections of strength 128 or better have been established, allows authentication access to anonymous users, and read access when 64 or better security protections have been established. If a client has not established sufficient security protections, the implicit `by * none` clause would be applied.

The following example shows the use of a style specifiers to select the entries by DN in two access directives where ordering is significant.

```
access to dn.children="dc=example,dc=com"
     by * search
access to dn.children="dc=com"
     by * read
```

Read access is granted to entries under the `dc=com` subtree, except for those entries under the `dc=example,dc=com` subtree, to which search access is granted. No access is granted to `dc=com` as neither access directive matches this DN. If the order of these access directives was reversed, the trailing directive would never be reached, since all entries under `dc=example,dc=com` are also under `dc=com` entries.

Also note that if no `access to` directive matches or no `by <who>` clause, **access is denied**. That is, every `access to` directive ends with an implicit `by * none` clause. When dealing with an access list, because the global access list is effectively appended to each per-database list, if the resulting list is non-empty then the access list will end with an implicit `access to * by * none` directive. If there are no access directives applicable to a backend, then a default read is used.

The next example again shows the importance of ordering, both of the access directives and the `by <who>` clauses. It also shows the use of an attribute selector to grant access to a specific attribute and various `<who>` selectors.

```
access to dn.subtree="dc=example,dc=com" attrs=homePhone
    by self write
    by dn.children="dc=example,dc=com" search
    by peername.regex=IP=10\..+ read
access to dn.subtree="dc=example,dc=com"
    by self write
    by dn.children="dc=example,dc=com" search
    by anonymous auth
```

This example applies to entries in the "`dc=example,dc=com`" subtree. To all attributes except `homePhone`, an entry can write to itself, entries under `example.com` entries can search by them, anybody else has no access (implicit `by * none`) excepting for authentication/authorization (which is always done anonymously). The `homePhone` attribute is writable by the entry, searchable by entries under `example.com`, readable by clients connecting from network 10, and otherwise not readable (implicit `by * none`). All other access is denied by the implicit `access to * by * none`.

Sometimes it is useful to permit a particular DN to add or remove itself from an attribute. For example, if you would like to create a group and allow people to add and remove only their own DN from the member attribute, you could accomplish it with an access directive like this:

```
access to attrs=member,entry
     by dnattr=member selfwrite
```

The dnattr `<who>` selector says that the access applies to entries listed in the `member` attribute. The `selfwrite` access selector says that such members can only add or delete their own DN from the attribute, not other values. The addition of the entry attribute is required because access to the entry is required to access any of the entry's attributes.

8.3. Access Control via Dynamic Configuration

Access to slapd entries and attributes is controlled by the olcAccess attribute, whose values are a sequence of access directives. The general form of the olcAccess configuration is:

```
olcAccess: <access directive>
<access directive> ::= to <what>
    [by <who> [<access>] [<control>] ]+
<what> ::= * |
    [dn[.<basic-style>]=<regex> | dn.<scope-style>=<DN>]
    [filter=<ldapfilter>] [attrs=<attrlist>]
<basic-style> ::= regex | exact
<scope-style> ::= base | one | subtree | children
<attrlist> ::= <attr> [val[.<basic-style>]=<regex>] | <attr> , <attrlist>
<attr> ::= <attrname> | entry | children
<who> ::= * | [anonymous | users | self
        | dn[.<basic-style>]=<regex> | dn.<scope-style>=<DN>]
    [dnattr=<attrname>]
    [group[/<objectclass>[/<attrname>][.<basic-style>]]=<regex>]
    [peername[.<basic-style>]=<regex>]
    [sockname[.<basic-style>]=<regex>]
    [domain[.<basic-style>]=<regex>]
    [sockurl[.<basic-style>]=<regex>]
```

```
            [set=<setspec>]
            [aci=<attrname>]
        <access> ::= [self]{<level>|<priv>}
        <level> ::= none | disclose | auth | compare | search | read | write | manage
        <priv> ::= {=|+|-}{m|w|r|s|c|x|d|0}+
        <control> ::= [stop | continue | break]
```

where the <what> part selects the entries and/or attributes to which the access applies, the `<who>` part specifies which entities are granted access, and the `<access>` part specifies the access granted. Multiple `<who> <access> <control>` triplets are supported, allowing many entities to be granted different access to the same set of entries and attributes. Not all of these access control options are described here; for more details see the *slapd.access*(5) man page.

8.3.1. What to control access to

The <what> part of an access specification determines the entries and attributes to which the access control applies. Entries are commonly selected in two ways: by DN and by filter. The following qualifiers select entries by DN:

```
        to *
        to dn[.<basic-style>]=<regex>
        to dn.<scope-style>=<DN>
```

The first form is used to select all entries. The second form may be used to select entries by matching a regular expression against the target entry's *normalized DN*. (The second form is not discussed further in this document.) The third form is used to select entries which are within the requested scope of DN. The <DN> is a string representation of the Distinguished Name, as described in RFC4514.

The scope can be either `base`, `one`, `subtree`, or `children`. Where `base` matches only the entry with provided DN, `one` matches the entries whose parent is the provided DN, `subtree` matches all entries in the subtree whose root is the provided DN, and `children` matches all entries under the DN (but not the entry named by the DN).

For example, if the directory contained entries named:

```
        0: o=suffix
        1: cn=Manager,o=suffix
        2: ou=people,o=suffix
        3: uid=kdz,ou=people,o=suffix
        4: cn=addresses,uid=kdz,ou=people,o=suffix
        5: uid=hyc,ou=people,o=suffix
```

Then:

`dn.base="ou=people,o=suffix"` match 2;
`dn.one="ou=people,o=suffix"` match 3, and 5;
`dn.subtree="ou=people,o=suffix"` match 2, 3, 4, and 5; and
`dn.children="ou=people,o=suffix"` match 3, 4, and 5.

Entries may also be selected using a filter:

```
        to filter=<ldap filter>
```

where <ldap filter> is a string representation of an LDAP search filter, as described in RFC4515. For example:

```
to filter=(objectClass=person)
```

Note that entries may be selected by both DN and filter by including both qualifiers in the <what> clause.

```
to dn.one="ou=people,o=suffix" filter=(objectClass=person)
```

Attributes within an entry are selected by including a comma-separated list of attribute names in the <what> selector:

```
attrs=<attribute list>
```

A specific value of an attribute is selected by using a single attribute name and also using a value selector:

```
attrs=<attribute> val[.<style>]=<regex>
```

There are two special *pseudo* attributes `entry` and `children`. To read (and hence return) a target entry, the subject must have `read` access to the target's *entry* attribute. To perform a search, the subject must have `search` access to the search base's *entry* attribute. To add or delete an entry, the subject must have `write` access to the entry's `entry` attribute AND must have `write` access to the entry's parent's `children` attribute. To rename an entry, the subject must have `write` access to entry's `entry` attribute AND have `write` access to both the old parent's and new parent's `children` attributes. The complete examples at the end of this section should help clear things up.

Lastly, there is a special entry selector `"*"` that is used to select any entry. It is used when no other `<what>` selector has been provided. It's equivalent to "`dn=.*`"

8.3.2. Who to grant access to

The <who> part identifies the entity or entities being granted access. Note that access is granted to "entities" not "entries." The following table summarizes entity specifiers:

Table 5.3: Access Entity Specifiers

Specifier	**Entities**
`*`	All, including anonymous and authenticated users
`anonymous`	Anonymous (non-authenticated) users
`users`	Authenticated users
`self`	User associated with target entry
`dn[.<basic-style>]=<regex>`	Users matching a regular expression
`dn.<scope-style>=<DN>`	Users within scope of a DN

The DN specifier behaves much like <what> clause DN specifiers.

Other control factors are also supported. For example, a `<who>` can be restricted by an entry listed in a DN-valued attribute in the entry to which the access applies:

```
dnattr=<dn-valued attribute name>
```

The dnattr specification is used to give access to an entry whose DN is listed in an attribute of the entry (e.g., give access to a group entry to whoever is listed as the owner of the group entry).

Some factors may not be appropriate in all environments (or any). For example, the domain factor relies on IP to domain name lookups. As these can easily be spoofed, the domain factor should be avoided.

8.3.3. The access to grant

The kind of <access> granted can be one of the following:

Table 5.4: Access Levels

Level	Privileges	Description
`none`	`=0`	no access
`disclose`	`=d`	needed for information disclosure on error
`auth`	`=dx`	needed to authenticate (bind)
`compare`	`=cdx`	needed to compare
`search`	`=scdx`	needed to apply search filters
`read`	`=rscdx`	needed to read search results
`write`	`=wrscdx`	needed to modify/rename
`manage`	`=mwrscdx`	needed to manage

Each level implies all lower levels of access. So, for example, granting someone `write` access to an entry also grants them `read`, `search`, `compare`, `auth` and `disclose` access. However, one may use the privileges specifier to grant specific permissions.

8.3.4. Access Control Evaluation

When evaluating whether some requester should be given access to an entry and/or attribute, slapd compares the entry and/or attribute to the `<what>` selectors given in the configuration. For each entry, access controls provided in the database which holds the entry (or the global access directives if not held in any database) apply first, followed by the global access directives (which are held in the `frontend` database definition). However, when dealing with an access list, because the global access list is effectively appended to each per-database list, if the resulting list is non-empty then the access list will end with an implicit `access to * by * none` directive. If there are no access directives applicable to a backend, then a default read is used.

Within this priority, access directives are examined in the order in which they appear in the configuration attribute. Slapd stops with the first `<what>` selector that matches the entry and/or attribute. The corresponding access directive is the one slapd will use to evaluate access.

Next, slapd compares the entity requesting access to the `<who>` selectors within the access directive selected above in the order in which they appear. It stops with the first `<who>` selector that matches the requester. This determines the access the entity requesting access has to the entry and/or attribute.

Finally, slapd compares the access granted in the selected `<access>` clause to the access requested by the client. If it allows greater or equal access, access is granted. Otherwise, access is denied.

The order of evaluation of access directives makes their placement in the configuration file important. If one access directive is more specific than another in terms of the entries it selects, it should appear first in the configuration. Similarly, if one `<who>` selector is more specific than another it should come first in the access directive. The access control examples given below should help make this clear.

8.3.5. Access Control Examples

The access control facility described above is quite powerful. This section shows some examples of its use for descriptive purposes.

A simple example:

```
olcAccess: to * by * read
```

This access directive grants read access to everyone.

```
olcAccess: to *
    by self write
    by anonymous auth
    by * read
```

This directive allows the user to modify their entry, allows anonymous to authenticate against these entries, and allows all others to read these entries. Note that only the first `by <who>` clause which matches applies. Hence, the anonymous users are granted `auth`, not `read`. The last clause could just as well have been "`by users read`".

It is often desirable to restrict operations based upon the level of protection in place. The following shows how security strength factors (SSF) can be used.

```
olcAccess: to *
    by ssf=128 self write
    by ssf=64 anonymous auth
    by ssf=64 users read
```

This directive allows users to modify their own entries if security protections of strength 128 or better have been established, allows authentication access to anonymous users, and read access when strength 64 or better security protections have been established. If the client has not establish sufficient security protections, the implicit `by * none` clause would be applied.

The following example shows the use of style specifiers to select the entries by DN in two access directives where ordering is significant.

```
olcAccess: to dn.children="dc=example,dc=com"
     by * search
olcAccess: to dn.children="dc=com"
     by * read
```

Read access is granted to entries under the `dc=com` subtree, except for those entries under the `dc=example,dc=com` subtree, to which search access is granted. No access is granted to `dc=com` as neither access directive matches this DN. If the order of these access directives was reversed, the trailing directive would never be reached, since all entries under `dc=example,dc=com` are also under `dc=com` entries.

Also note that if no `olcAccess: to` directive matches or no `by <who>` clause, **access is denied**. When dealing with an access list, because the global access list is effectively appended to each per-database list, if the resulting list is non-empty then the access list will end with an implicit `access to * by * none` directive. If there are no access directives applicable to a backend, then a default read is used.

The next example again shows the importance of ordering, both of the access directives and the `by <who>` clauses. It also shows the use of an attribute selector to grant access to a specific attribute and various `<who>` selectors.

```
olcAccess: to dn.subtree="dc=example,dc=com" attrs=homePhone
    by self write
    by dn.children=dc=example,dc=com" search
    by peername.regex=IP=10\..+ read
olcAccess: to dn.subtree="dc=example,dc=com"
    by self write
    by dn.children="dc=example,dc=com" search
    by anonymous auth
```

This example applies to entries in the "`dc=example,dc=com`" subtree. To all attributes except `homePhone`, an entry can write to itself, entries under `example.com` entries can search by them, anybody else has no access (implicit `by * none`) excepting for authentication/authorization (which is always done anonymously). The `homePhone` attribute is writable by the entry, searchable by entries under `example.com`, readable by clients connecting from network 10, and otherwise not readable (implicit `by * none`). All other access is denied by the implicit `access to * by * none`.

Sometimes it is useful to permit a particular DN to add or remove itself from an attribute. For example, if you would like to create a group and allow people to add and remove only their own DN from the member attribute, you could accomplish it with an access directive like this:

```
olcAccess: to attrs=member,entry
     by dnattr=member selfwrite
```

The dnattr `<who>` selector says that the access applies to entries listed in the `member` attribute. The `selfwrite` access selector says that such members can only add or delete their own DN from the attribute, not other values. The addition of the entry attribute is required because access to the entry is required to access any of the entry's attributes.

8.3.6. Access Control Ordering

Since the ordering of `olcAccess` directives is essential to their proper evaluation, but LDAP attributes normally do not preserve the ordering of their values, OpenLDAP uses a custom schema extension to maintain a fixed ordering of these values. This ordering is maintained by prepending a `"{X}"` numeric index to each value, similarly to the approach used for ordering the configuration entries. These index tags are maintained automatically by slapd and do not need to be specified when originally defining the values. For example, when you create the settings

```
olcAccess: to attrs=member,entry
     by dnattr=member selfwrite
olcAccess: to dn.children="dc=example,dc=com"
     by * search
olcAccess: to dn.children="dc=com"
     by * read
```

when you read them back using slapcat or ldapsearch they will contain

```
olcAccess: {0}to attrs=member,entry
     by dnattr=member selfwrite
olcAccess: {1}to dn.children="dc=example,dc=com"
     by * search
olcAccess: {2}to dn.children="dc=com"
     by * read
```

The numeric index may be used to specify a particular value to change when using ldapmodify to edit the access rules. This index can be used instead of (or in addition to) the actual access value. Using this numeric index is very helpful when multiple access rules are being managed.

For example, if we needed to change the second rule above to grant write access instead of search, we could try this LDIF:

```
changetype: modify
delete: olcAccess
olcAccess: to dn.children="dc=example,dc=com" by * search
-
add: olcAccess
olcAccess: to dn.children="dc=example,dc=com" by * write
-
```

But this example **will not** guarantee that the existing values remain in their original order, so it will most likely yield a broken security configuration. Instead, the numeric index should be used:

```
changetype: modify
delete: olcAccess
olcAccess: {1}
-
add: olcAccess
olcAccess: {1}to dn.children="dc=example,dc=com" by * write
-
```

This example deletes whatever rule is in value #1 of the `olcAccess` attribute (regardless of its value) and adds a new value that is explicitly inserted as value #1. The result will be

```
olcAccess: {0}to attrs=member,entry
     by dnattr=member selfwrite
olcAccess: {1}to dn.children="dc=example,dc=com"
     by * write
olcAccess: {2}to dn.children="dc=com"
     by * read
```

which is exactly what was intended.

8.4. Access Control Common Examples

8.4.1. Basic ACLs

Generally one should start with some basic ACLs such as:

```
access to attrs=userPassword
    by self =xw
    by anonymous auth
    by * none
```

```
access to *
  by self write
  by users read
  by * none
```

The first ACL allows users to update (but not read) their passwords, anonymous users to authenticate against this attribute, and (implicitly) denying all access to others.

The second ACL allows users full access to their entry, authenticated users read access to anything, and (implicitly) denying all access to others (in this case, anonymous users).

8.4.2. Matching Anonymous and Authenticated users

An anonymous user has a empty DN. While the *dn.exact=""* or *dn.regex="^$"* could be used, *slapd*(8)) offers an anonymous shorthand which should be used instead.

```
access to *
  by anonymous none
  by * read
```

denies all access to anonymous users while granting others read.

Authenticated users have a subject DN. While *dn.regex=".+"* will match any authenticated user, OpenLDAP provides the users short hand which should be used instead.

```
access to *
  by users read
  by * none
```

This ACL grants read permissions to authenticated users while denying others (i.e.: anonymous users).

8.4.3. Controlling rootdn access

You could specify the *rootdn* in *slapd.conf*(5) or *slapd.d* without specifying a *rootpw*. Then you have to add an actual directory entry with the same dn, e.g.:

```
dn: cn=Manager,o=MyOrganization
cn: Manager
sn: Manager
objectClass: person
objectClass: top
userPassword: {SSHA}someSSHAdata
```

Then binding as the *rootdn* will require a regular bind to that DN, which in turn requires auth access to that entry's DN and *userPassword*, and this can be restricted via ACLs. E.g.:

```
access to dn.base="cn=Manager,o=MyOrganization"
  by peername.regex=127\.0\.0\.1 auth
  by peername.regex=192\.168\.0\..* auth
  by users none
  by * none
```

The ACLs above will only allow binding using rootdn from localhost and 192.168.0.0/24.

8.4.4. Controlling the LDAP Proxied Authorization Control

The Proxied Authorization Control allows a client to request that an operation be processed under a provided authorization identity instead of under the current authentication identity associated with the connection.

This facility is controlled by the `authz-policy` configuration option and by the `authzTo` and `authzFrom` attributes. It can be further controlled by applying access control to those attributes.

A client application might bind as cn=Client,o=MyOrganization whose entry looks like this:

```
dn: cn=Client,o=MyOrganization
cn: Client
objectClass: organizationalRole
objectClass: simpleSecurityObject
objectClass: top
userPassword: {SSHA}someSSHAdata
authzTo: dn.regex:^cn=[^,]+,ou=People,o=MyOrganization$
```

To make use of the proxy facility, the client needs at least `auth` privilege on the `authzTo` attribute:

```
access to dn.exact=cn=Client,o=MyOrganization attr=authzTo
  by self auth
  by * break
```

This access would be automatically granted if cn=Client,o=MyOrganization has `read` privilege on its own entry.

Now if you want to lock down the use of this powerful account, you might write an ACL like this:

```
access to dn.exact=cn=Client,o=MyOrganization attr=authzTo
  by self peername.regex=192\.168\.0\..*  ssf=256 auth
  by * none
```

Now, cn=Client,o=MyOrganization can only make use of the proxy authorization control if it has connected from an appropriate IP address using a sufficient level of cryptographic protection. No other IDs can even see the authzTo attribute.

8.4.5. Managing access with Groups

There are a few ways to do this. One approach is illustrated here. Consider the following DIT layout:

```
+-dc=example,dc=com
+---cn=administrators,dc=example,dc=com
+---cn=fred blogs,dc=example,dc=com
```

and the following group object (in LDIF format):

```
dn: cn=administrators,dc=example,dc=com
cn: administrators of this region
objectclass: groupOfNames  (important for the group acl feature)
member: cn=fred blogs,dc=example,dc=com
member: cn=somebody else,dc=example,dc=com
```

One can then grant access to the members of this this group by adding appropriate *by group* clause to an access directive in *slapd.conf*(5). For instance,

```
access to dn.children="dc=example,dc=com"
    by self write
    by group.exact="cn=Administrators,dc=example,dc=com" write
    by * auth
```

Like by *dn* clauses, one can also use *expand* to expand the group name based upon the regular expression matching of the target, that is, the to *dn.regex*). For instance,

```
access to dn.regex="(.+,)?ou=People,(dc=[^,]+,dc=[^,]+)$"
         attrs=children,entry,uid
    by group.expand="cn=Managers,$2" write
    by users read
    by * auth
```

The above illustration assumed that the group members are to be found in the *member* attribute type of the *groupOfNames* object class. If you need to use a different group object and/or a different attribute type then use the following *slapd.conf*(5) (abbreviated) syntax:

```
access to <what>
        by group/<objectclass>/<attributename>=<DN> <access>
```

For example:

```
access to *
  by group/organizationalRole/roleOccupant="cn=Administrator,dc=example,dc=com" write
```

In this case, we have an ObjectClass *organizationalRole* which contains the administrator DN's in the *roleOccupant* attribute. For instance:

```
dn: cn=Administrator,dc=example,dc=com
cn: Administrator
objectclass: organizationalRole
roleOccupant: cn=Jane Doe,dc=example,dc=com
```

Note: the specified member attribute type MUST be of DN or *NameAndOptionalUID* syntax, and the specified object class SHOULD allow the attribute type.

Dynamic Groups are also supported in Access Control. Please see *slapo-dynlist*(5) and the Dynamic Lists overlay section.

8.4.6. Granting access to a subset of attributes

You can grant access to a set of attributes by specifying a list of attribute names in the ACL *to* clause. To be useful, you also need to grant access to the *entry* itself. Also note how *children* controls the ability to add, delete, and rename entries.

```
# mail: self may write, authenticated users may read
access to attrs=mail
  by self write
  by users read
  by * none
```

```
# cn, sn: self my write, all may read
access to attrs=cn,sn
  by self write
  by * read

# immediate children: only self can add/delete entries under this entry
access to attrs=children
  by self write

# entry itself: self may write, all may read
access to attrs=entry
  by self write
  by * read

# other attributes: self may write, others have no access
access to *
  by self write
  by * none
```

ObjectClass names may also be specified in this list, which will affect all the attributes that are required and/or allowed by that *objectClass*. Actually, names in *attrlist* that are prefixed by @ are directly treated as objectClass names. A name prefixed by *!* is also treated as an objectClass, but in this case the access rule affects the attributes that are not required nor allowed by that *objectClass*.

8.4.7. Allowing a user write to all entries below theirs

For a setup where a user can write to its own record and to all of its children:

```
access to dn.regex="(.+,)?(uid=[^,]+,o=Company)$"
   by dn.exact,expand="$2" write
   by anonymous auth
```

(Add more examples for above)

8.4.8. Allowing entry creation

Let's say, you have it like this:

```
o=<basedn>
    ou=domains
        associatedDomain=<somedomain>
            ou=users
                uid=<someuserid>
                uid=<someotheruserid>
            ou=addressbooks
                uid=<someuserid>
                    cn=<someone>
                    cn=<someoneelse>
```

and, for another domain <someotherdomain>:

```
o=<basedn>
    ou=domains
        associatedDomain=<someotherdomain>
            ou=users
                uid=<someuserid>
```

```
                    uid=<someotheruserid>
                ou=addressbooks
                    uid=<someotheruserid>
                        cn=<someone>
                        cn=<someoneelse>
```

then, if you wanted user *uid=<someuserid>* to **ONLY** create an entry for its own thing, you could write an ACL like this:

```
# this rule lets users of "associatedDomain=<matcheddomain>"
# write under "ou=addressbook,associatedDomain=<matcheddomain>,ou=domains,o=<basedn>
# i.e. a user can write ANY entry below its domain's address book;
# this permission is necessary, but not sufficient, the next
# will restrict this permission further


access to dn.regex="^ou=addressbook,associatedDomain=([^,]+),ou=domains,o=<basedn>$"
        by dn.regex="^uid=([^,]+),ou=users,associatedDomain=$1,ou=domains,o=<basedn>
        by * none


# Note that above the "by" clause needs a "regex" style to make sure
# it expands to a DN that starts with a "uid=<someuserid>" pattern
# while substituting the associatedDomain submatch from the "what" clause.


# This rule lets a user with "uid=<matcheduid>" of "<associatedDomain=matcheddomain>
# write (i.e. add, modify, delete) the entry whose DN is exactly
# "uid=<matcheduid>,ou=addressbook,associatedDomain=<matcheddomain>,ou=domains,o=<ba
# and ANY entry as subtree of it


access to dn.regex="^(.+,)?uid=([^,]+),ou=addressbook,associatedDomain=([^,]+),ou=do
        by dn.exact,expand="uid=$2,ou=users,associatedDomain=$3,ou=domains,o=<basedn
        by * none


# Note that above the "by" clause uses the "exact" style with the "expand"
# modifier because now the whole pattern can be rebuilt by means of the
# submatches from the "what" clause, so a "regex" compilation and evaluation
# is no longer required.
```

8.4.9. Tips for using regular expressions in Access Control

Always use *dn.regex=<pattern>* when you intend to use regular expression matching. *dn=<pattern>* alone defaults to *dn.exact<pattern>*.

Use *(.+)* instead of *(.*)* when you want at least one char to be matched. *(.*)* matches the empty string as well.

Don't use regular expressions for matches that can be done otherwise in a safer and cheaper manner. Examples:

```
dn.regex=".*dc=example,dc=com"
```

is unsafe and expensive:

- unsafe because any string containing _dc=example,dc=com_ will match, not only those that end with the desired pattern; use _.*dc=example,dc=com$_ instead.
- unsafe also because it would allow any _attributeType_ ending with _dc_ as naming attribute for the first RDN in the string, e.g. a custom attributeType _mydc_ would match as well. If you really need a regular expression that allows just _dc=example,dc=com_ or any of its subtrees, use _^(.+,)?dc=example,dc=com$_, which means: anything to the left of dc=..., if any (the question mark after the pattern within brackets), must end with a comma;
- expensive because if you don't need submatches, you could use scoping styles, e.g.

```
dn.subtree="dc=example,dc=com"
```

to include _dc=example,dc=com_ in the matching patterns,

```
dn.children="dc=example,dc=com"
```

to exclude _dc=example,dc=com_ from the matching patterns, or

```
dn.onelevel="dc=example,dc=com"
```

to allow exactly one sublevel matches only.

Always use ^ and _$_ in regexes, whenever appropriate, because _ou=(.+),ou=(.+),ou=addressbooks,o=basedn_ will match _something=bla,ou=xxx,ou=yyy,ou=addressbooks,o=basedn,ou=addressbooks,o=basedn,dc=some,dc=org_

Always use _([^,]+)_ to indicate exactly one RDN, because _(.+)_ can include any number of RDNs; e.g. _ou=(.+),dc=example,dc=com_ will match _ou=My,o=Org,dc=example,dc=com_, which might not be what you want.

Never add the rootdn to the by clauses. ACLs are not even processed for operations performed with rootdn identity (otherwise there would be no reason to define a rootdn at all).

Use shorthands. The user directive matches authenticated users and the anonymous directive matches anonymous users.

Don't use the _dn.regex_ form for <by> clauses if all you need is scoping and/or substring replacement; use scoping styles (e.g. _exact_, _onelevel_, _children_ or _subtree_) and the style modifier expand to cause substring expansion.

For instance,

```
access to dn.regex=".+,dc=([^,]+),dc=([^,]+)$"
  by dn.regex="^[^,],ou=Admin,dc=$1,dc=$2$$" write
```

although correct, can be safely and efficiently replaced by

```
access to dn.regex=".+,(dc=[^,]+,dc=[^,]+)$"
  by dn.onelevel,expand="ou=Admin,$1" write
```

where the regex in the <_what_> clause is more compact, and the one in the <_by_> clause is replaced by a much more efficient scoping style of onelevel with substring expansion.

8.4.10. Granting and Denying access based on security strength factors (ssf)

You can restrict access based on the security strength factor (SSF)

```
access to dn="cn=example,cn=edu"
      by * ssf=256 read
```

0 (zero) implies no protection, 1 implies integrity protection only, 56 DES or other weak ciphers, 112 triple DES and similar ciphers, 128 RC4, Blowfish and other similar ciphers, 256 modern ciphers.

Other possibilities:

```
transport_ssf=<n>
tls_ssf=<n>
sasl_ssf=<n>
```

256 is recommended.

See *slapd.conf*(5) for information on *ssf*.

8.4.11. When things aren't working as expected

Consider this example:

```
access to *
  by anonymous auth

access to *
  by self write

access to *
  by users read
```

You may think this will allow any user to login, to read everything and change his own data if he is logged in. But in this example only the login works and an ldapsearch returns no data. The Problem is that SLAPD goes through its access config line by line and stops as soon as it finds a match in the part of the access rule.(here: *to* *)

To get what we wanted the file has to read:

```
access to *
  by anonymous auth
  by self write
  by users read
```

The general rule is: "special access rules first, generic access rules last"

See also *slapd.access*(5), loglevel 128 and *slapacl*(8) for debugging information.

8.5. Sets - Granting rights based on relationships

Sets are best illustrated via examples. The following sections will present a few set ACL examples in order to facilitate their understanding.

(Sets in Access Controls FAQ Entry: http://www.openldap.org/faq/data/cache/1133.html)

Note: Sets are considered experimental.

8.5.1. Groups of Groups

The OpenLDAP ACL for groups doesn't expand groups within groups, which are groups that have another group as a member. For example:

```
dn: cn=sudoadm,ou=group,dc=example,dc=com
cn: sudoadm
objectClass: groupOfNames
member: uid=john,ou=people,dc=example,dc=com
member: cn=accountadm,ou=group,dc=example,dc=com

dn: cn=accountadm,ou=group,dc=example,dc=com
cn: accountadm
objectClass: groupOfNames
member: uid=mary,ou=people,dc=example,dc=com
```

If we use standard group ACLs with the above entries and allow members of the `sudoadm` group to write somewhere, `mary` won't be included:

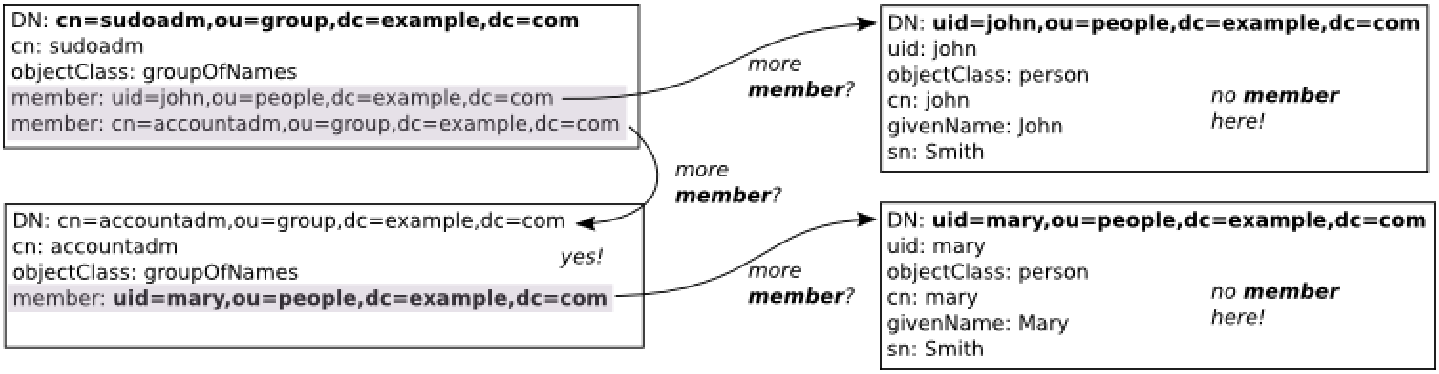
```
access to dn.subtree="ou=sudoers,dc=example,dc=com"
        by group.exact="cn=sudoadm,ou=group,dc=example,dc=com" write
        by * read
```

With sets we can make the ACL be recursive and consider group within groups. So for each member that is a group, it is further expanded:

```
access to dn.subtree="ou=sudoers,dc=example,dc=com"
      by set="[cn=sudoadm,ou=group,dc=example,dc=com]/member* & user" write
      by * read
```

This set ACL means: take the `cn=sudoadm` DN, check its `member` attribute(s) (where the "`*`" means recursively) and intersect the result with the authenticated user's DN. If the result is non-empty, the ACL is considered a match and write access is granted.

The following drawing explains how this set is built:



```
DN: cn=sudoadm,ou=group,dc=example,dc=com
cn: sudoadm
objectClass: groupOfNames
member: uid=john,ou=people,dc=example,dc=com
member: cn=accountadm,ou=group,dc=example,dc=com
```

```
DN: uid=john,ou=people,dc=example,dc=com
uid: john
objectClass: person
cn: john
givenName: John
sn: Smith
```

```
DN: cn=accountadm,ou=group,dc=example,dc=com
cn: accountadm
objectClass: groupOfNames
member: uid=mary,ou=people,dc=example,dc=com
```

```
DN: uid=mary,ou=people,dc=example,dc=com
uid: mary
objectClass: person
cn: mary
givenName: Mary
sn: Smith
```

Figure X.Y: Populating a recursive group set

First we get the `uid=john` DN. This entry doesn't have a `member` attribute, so the expansion stops here. Now we get to `cn=accountadm`. This one does have a `member` attribute, which is `uid=mary`. The `uid=mary` entry, however, doesn't have member, so we stop here again. The end comparison is:

```
{"uid=john,ou=people,dc=example,dc=com","uid=mary,ou=people,dc=example,dc=com"} & user
```

If the authenticated user's DN is any one of those two, write access is granted. So this set will include `mary` in the `sudoadm` group and she will be allowed the write access.

8.5.2. Group ACLs without DN syntax

The traditional group ACLs, and even the previous example about recursive groups, require that the members are specified as DNs instead of just usernames.

With sets, however, it's also possible to use simple names in group ACLs, as this example will show.

Let's say we want to allow members of the `sudoadm` group to write to the `ou=sudoers` branch of our tree. But our group definition now is using `memberUid` for the group members:

```
dn: cn=sudoadm,ou=group,dc=example,dc=com
cn: sudoadm
objectClass: posixGroup
gidNumber: 1000
memberUid: john
```

With this type of group, we can't use group ACLs. But with a set ACL we can grant the desired access:

```
access to dn.subtree="ou=sudoers,dc=example,dc=com"
      by set="[cn=sudoadm,ou=group,dc=example,dc=com]/memberUid & user/uid" write
      by * read
```

We use a simple intersection where we compare the `uid` attribute of the connecting (and authenticated) user with the `memberUid` attributes of the group. If they match, the intersection is non-empty and the ACL will grant write access.

This drawing illustrates this set when the connecting user is authenticated as `uid=john,ou=people,dc=example,dc=com`:

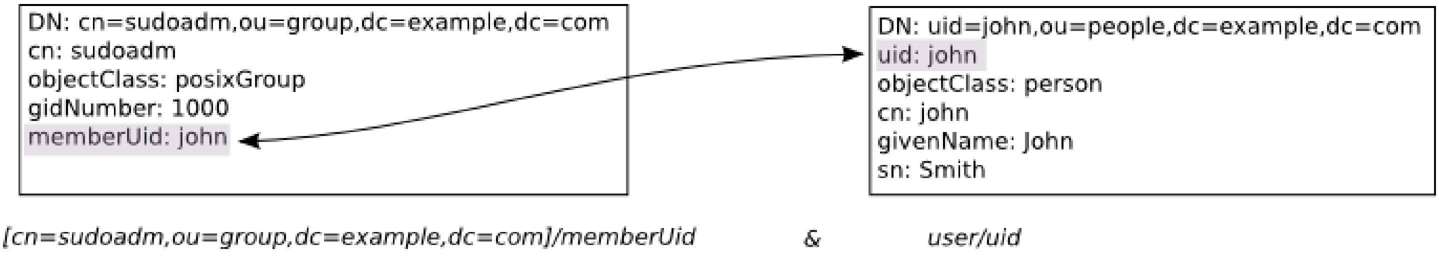


Figure X.Y: Sets with `memberUid`

In this case, it's a match. If it were `mary` authenticating, however, she would be denied write access to `ou=sudoers` because her `uid` attribute is not listed in the group's `memberUid`.

8.5.3. Following references

We will now show a quite powerful example of what can be done with sets. This example tends to make OpenLDAP administrators smile after they have understood it and its implications.

Let's start with an user entry:

```
        dn: uid=john,ou=people,dc=example,dc=com
        uid: john
        objectClass: inetOrgPerson
        givenName: John
        sn: Smith
        cn: john
        manager: uid=mary,ou=people,dc=example,dc=com
```

Writing an ACL to allow the manager to update some attributes is quite simple using sets:

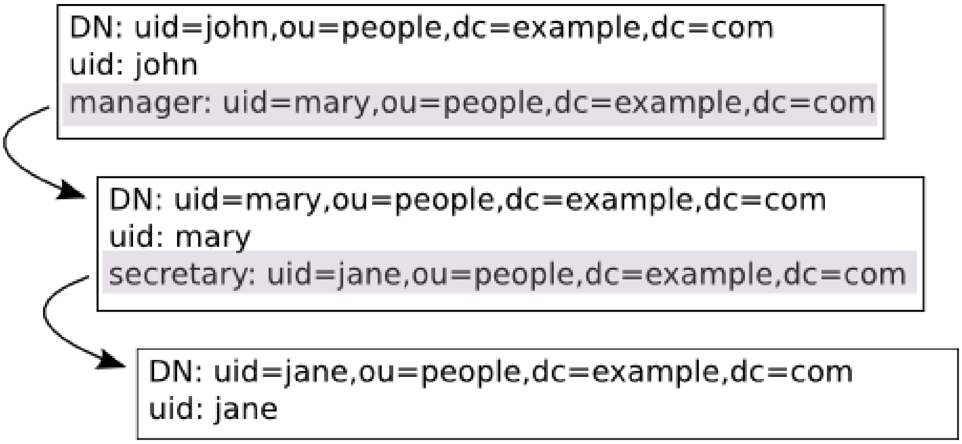
```
        access to dn.exact="uid=john,ou=people,dc=example,dc=com"
           attrs=carLicense,homePhone,mobile,pager,telephoneNumber
           by self write
           by set="this/manager & user" write
           by * read
```

In that set, `this` expands to the entry being accessed, so that `this/manager` expands to `uid=mary,ou=people,dc=example,dc=com` when john's entry is accessed. If the manager herself is accessing John's entry, the ACL will match and write access to those attributes will be granted.

So far, this same behavior can be obtained with the `dnattr` keyword. With sets, however, we can further enhance this ACL. Let's say we want to allow the secretary of the manager to also update these attributes. This is how we do it:

```
        access to dn.exact="uid=john,ou=people,dc=example,dc=com"
           attrs=carLicense,homePhone,mobile,pager,telephoneNumber
           by self write
           by set="this/manager & user" write
           by set="this/manager/secretary & user" write
           by * read
```

Now we need a picture to help explain what is happening here (entries shortened for clarity):



DN: uid=john,ou=people,dc=example,dc=com
uid: john
manager: uid=mary,ou=people,dc=example,dc=com

DN: uid=mary,ou=people,dc=example,dc=com
uid: mary
secretary: uid=jane,ou=people,dc=example,dc=com

DN: uid=jane,ou=people,dc=example,dc=com
uid: jane

Figure X.Y: Sets jumping through entries

In this example, Jane is the secretary of Mary, which is the manager of John. This whole relationship is defined with the `manager` and `secretary` attributes, which are both of the distinguishedName syntax (i.e., full DNs). So, when the `uid=john` entry is being accessed, the `this/manager/secretary` set becomes `{"uid=jane,ou=people,dc=example,dc=com"}` (follow the references in the picture):

```
        this = [uid=john,ou=people,dc=example,dc=com]
        this/manager = \
          [uid=john,ou=people,dc=example,dc=com]/manager = uid=mary,ou=people,dc=example,dc=com
        this/manager/secretary = \
          [uid=mary,ou=people,dc=example,dc=com]/secretary = uid=jane,ou=people,dc=example,dc=co
```

The end result is that when Jane accesses John's entry, she will be granted write access to the specified attributes. Better yet, this will happen to any entry she accesses which has Mary as the manager.

This is all cool and nice, but perhaps gives too much power to secretaries. Maybe we need to further restrict it. For example, let's only allow executive secretaries to have this power:

```
        access to dn.exact="uid=john,ou=people,dc=example,dc=com"
          attrs=carLicense,homePhone,mobile,pager,telephoneNumber
          by self write
          by set="this/manager & user" write
          by set="this/manager/secretary &
                  [cn=executive,ou=group,dc=example,dc=com]/member* &
                  user" write
          by * read
```

It's almost the same ACL as before, but we now also require that the connecting user be a member of the (possibly nested) `cn=executive` group.

9. Limits

9.1. Introduction

It is usually desirable to limit the server resources that can be consumed by each LDAP client. OpenLDAP provides two sets of limits: a size limit, which can restrict the *number* of entries that a client can retrieve in a single operation, and a time limit which restricts the length of time that an operation may continue. Both types of limit can be given different values depending on who initiated the operation.

9.2. Soft and Hard limits

The server administrator can specify both *soft limits* and *hard limits*. Soft limits can be thought of as being the default limit value. Hard limits cannot be exceeded by ordinary LDAP users.

LDAP clients can specify their own size and time limits when issuing search operations. This feature has been present since the earliest version of X.500.

If the client specifies a limit then the lower of the requested value and the *hard limit* will become the limit for the operation.

If the client does not specify a limit then the server applies the *soft limit*.

Soft and Hard limits are often referred to together as *administrative limits*. Thus, if an LDAP client requests a search that would return more results than the limits allow it will get an *adminLimitExceeded* error. Note that the server will usually return some results even if the limit has been exceeded: this feature is useful to clients that just want to check for the existence of some entries without needing to see them all.

The *rootdn* is not subject to any limits.

9.3. Global Limits

Limits specified in the global part of the server configuration act as defaults which are used if no database has more specific limits set.

In a *slapd.conf*(5) configuration the keywords are `sizelimit` and `timelimit`. When using the *slapd config* backend, the corresponding attributes are `olcSizeLimit` and `olcTimeLimit`. The syntax of these values are the same in both cases.

The simple form sets both soft and hard limits to the same value:

```
        sizelimit {<integer>|unlimited}
        timelimit {<integer>|unlimited}
```

The default sizelimit is 500 entries and the default timelimit is 3600 seconds.

An extended form allows soft and hard limits to be set separately:

```
        sizelimit size[.{soft|hard}]=<integer> [...]
        timelimit time[.{soft|hard}]=<integer> [...]
```

Thus, to set a soft sizelimit of 10 entries and a hard limit of 75 entries:

```
        sizelimit size.soft=10 size.hard=75
```

9.3.1. Special Size Limits

There are other forms of size limits in addition to the soft and hard limits. Note that when using the simple *sizelimit* form, none of these special limits are changed.

9.3.1.1. Unchecked Limits

The *unchecked* keyword sets a limit on how many entries the server will examine after doing index lookups but before evaluating filter matches. If the set of candidates exceeds this limit, the search is aborted. The purpose is to avoid causing excessive workload on *slapd* if a filter uses attributes that are not properly indexed, and can be critical for very large directories.

```
        sizelimit size.unchecked={<integer>|unlimited|disabled}
```

The default is unlimited. The *disabled* setting prevents a search from being performed at all. This may be useful in the per-database limits described below, to disallow searches for a specific set of users.

9.3.1.2. Paged Results Limits

If the LDAP client adds the *pagedResultsControl* to the search operation, the hard size limit is used by default, because the request for a specific page size is considered an explicit request for a limitation on the number of entries to be returned. However, the size limit applies to the total count of entries returned within the search, and not to a single page.

Additional size limits may be enforced for paged searches.

The `size.pr` limit controls the maximum page size:

```
        sizelimit size.pr={<integer>|noEstimate|unlimited}
```

`<integer>` is the maximum page size if no explicit size is set. `noEstimate` has no effect in the current implementation as the server does not return an estimate of the result size anyway. `unlimited` indicates that no limit is applied to the maximum page size.

The `size.prtotal` limit controls the total number of entries that can be returned by a paged search. By default the limit is the same as the normal `size.hard` limit.

```
        size.prtotal={<integer>|unlimited|disabled}
```

`unlimited` removes the limit on the number of entries that can be returned by a paged search. `disabled` can be used to selectively disable paged result searches.

9.4. Per-Database Limits

Each database can have its own set of limits that override the global ones. The syntax is more flexible, and it allows different limits to be applied to different entities. Note that an *entity* is different from an *entry*: the term *entity* is used here to indicate the ID of the person or process that has initiated the LDAP operation.

In a *slapd.conf*(5) configuration the keyword is `limits`. When using the *slapd config* backend, the corresponding attribute is `olcLimits`. The syntax of the values is the same in both cases.

```
        limits <selector> <limit> [<limit> [...]]
```

The *limits* clause can be specified multiple times to apply different limits to different initiators. The server examines each clause in turn until it finds one that matches the operation's initiator or base DN. If no match is found, the global limits will be used.

9.4.1. Specify who the limits apply to

The `<selector>` part of the *limits* clause can take any of these values:

Table 9.1: Limits Entity Specifiers

Specifier	**Entities**
`*`	All, including anonymous and authenticated users
`anonymous`	Anonymous (non-authenticated) users
`users`	Authenticated users
`dn[.<type>][.<style>]=<pattern>]`	Entry or entries within a scope that match <pattern>
`group[/oc[/at]]=<pattern>`	Members of a group

Where

type can be one of self or this and

style can be one of exact, base, onelevel, subtree, children, regex, or anonymous

More information can be found in the *slapd.conf*(5) or *slapd-config*(5) manual pages.

9.4.2. Specify time limits

The syntax for time limits is

```
        time[.{soft|hard}]=<integer>
```

where integer is the number of seconds slapd will spend answering a search request.

If neither *soft* nor *hard* is specified, the value is used for both, e.g.:

```
        limits anonymous time=27
```

The value *unlimited* may be used to remove the hard time limit entirely, e.g.:

```
        limits dn.exact="cn=anyuser,dc=example,dc=org" time.hard=unlimited
```

9.4.3. Specifying size limits

The syntax for size limit is

```
        size[.{soft|hard}]=<integer>
```

where `<integer>` is the maximum number of entries slapd will return when answering a search request.

In addition to soft and hard limits, other limits are also available, with the same meanings described for the global limits configuration above.

9.5. Example Limit Configurations

9.5.1. Simple Global Limits

This simple global configuration fragment applies size and time limits to all searches by all users except *rootdn*. It limits searches to 50 results and sets an overall time limit of 10 seconds.

```
sizelimit 50
timelimit 10
```

9.5.2. Global Hard and Soft Limits

It is sometimes useful to limit the size of result sets but to allow clients to request a higher limit where needed. This can be achieved by setting separate hard and soft limits.

```
sizelimit size.soft=5 size.hard=100
```

To prevent clients from doing very inefficient non-indexed searches, add the *unchecked* limit:

```
sizelimit size.soft=5 size.hard=100 size.unchecked=100
```

9.5.3. Giving specific users larger limits

Having set appropriate default limits in the global configuration, you may want to give certain users the ability to retrieve larger result sets. Here is a way to do that in the per-database configuration:

```
limits dn.exact="cn=anyuser,dc=example,dc=org" size=100000
limits dn.exact="cn=personnel,dc=example,dc=org" size=100000
limits dn.exact="cn=dirsync,dc=example,dc=org" size=100000
```

It is generally best to avoid mentioning specific users in the server configuration. A better way is to give the higher limits to a group:

```
limits group/groupOfNames/member="cn=bigwigs,dc=example,dc=org" size=100000
```

9.5.4. Limiting who can do paged searches

It may be required that certain applications need very large result sets that they retrieve using paged searches, but that you do not want ordinary LDAP users to use the pagedResults control. The *pr* and *prtotal* limits can help:

```
limits group/groupOfNames/member="cn=dirsync,dc=example,dc=org" size.prtotal=unlimited
limits users size.soft=5 size.hard=100 size.prtotal=disabled
limits anonymous size.soft=2 size.hard=5 size.prtotal=disabled
```

9.6. Glued/Subordinate database configurations

When using subordinate databases, it is necessary for any limits that are to be applied across the parent and its subordinates to be defined in both the parent and its subordinates. Otherwise the settings on the subordinate databases are not honored.

9.7. Further Information

For further information please see *slapd.conf*(5), *ldapsearch*(1) and *slapd.access*(5)

10. Database Creation and Maintenance Tools

This section tells you how to create a slapd database from scratch, and how to do trouble shooting if you run into problems. There are two ways to create a database. First, you can create the database on-line using LDAP. With this method, you simply start up slapd and add entries using the LDAP client of your choice. This method is fine for relatively small databases (a few hundred or thousand entries, depending on your requirements). This method works for database types which support updates.

The second method of database creation is to do it off-line using special utilities provided with *slapd*(8). This method is best if you have many thousands of entries to create, which would take an unacceptably long time using the LDAP method, or if you want to ensure the database is not accessed while it is being created. Note that not all database types support these utilities.

10.1. Creating a database over LDAP

With this method, you use the LDAP client of your choice (e.g., the *ldapadd*(1)) to add entries, just like you would once the database is created. You should be sure to set the following options in the configuration file before starting *slapd*(8).

```
        suffix <dn>
```

As described in the General Database Directives section, this option defines which entries are to be held by this database. You should set this to the DN of the root of the subtree you are trying to create. For example:

```
        suffix "dc=example,dc=com"
```

You should be sure to specify a directory where the index files should be created:

```
        directory <directory>
```

For example:

```
        directory /usr/local/var/openldap-data
```

You need to create this directory with appropriate permissions such that slapd can write to it.

You need to configure slapd so that you can connect to it as a directory user with permission to add entries. You can configure the directory to support a special *super-user* or *root* user just for this purpose. This is done through the following two options in the database definition:

```
        rootdn <dn>
        rootpw <passwd>
```

For example:

```
        rootdn "cn=Manager,dc=example,dc=com"
        rootpw secret
```

These options specify a DN and password that can be used to authenticate as the *super-user* entry of the database (i.e., the entry allowed to do anything). The DN and password specified here will always work, regardless of whether the entry named actually exists or has the password given. This solves the chicken-and-egg problem of how to authenticate and add entries before any entries yet exist.

Finally, you should make sure that the database definition contains the index definitions you want:

```
index {<attrlist> | default} [pres,eq,approx,sub,none]
```

For example, to index the `cn`, `sn`, `uid` and `objectclass` attributes, the following `index` directives could be used:

```
index cn,sn,uid pres,eq,approx,sub
index objectClass eq
```

This would create presence, equality, approximate, and substring indices for the `cn`, `sn`, and `uid` attributes and an equality index for the `objectClass` attribute. Note that not all index types are available with all attribute types. See The slapd Configuration File section for more information on this option.

Once you have configured things to your liking, start up slapd, connect with your LDAP client, and start adding entries. For example, to add an organization entry and an organizational role entry using the *ldapadd* tool, you could create an LDIF file called `entries.ldif` with the contents:

```
# Organization for Example Corporation
dn: dc=example,dc=com
objectClass: dcObject
objectClass: organization
dc: example
o: Example Corporation
description: The Example Corporation

# Organizational Role for Directory Manager
dn: cn=Manager,dc=example,dc=com
objectClass: organizationalRole
cn: Manager
description: Directory Manager
```

and then use a command like this to actually create the entry:

```
ldapadd -f entries.ldif -x -D "cn=Manager,dc=example,dc=com" -w secret
```

The above command assumes settings provided in the above examples.

10.2. Creating a database off-line

The second method of database creation is to do it off-line, using the slapd database tools described below. This method is best if you have many thousands of entries to create, which would take an unacceptably long time to add using the LDAP method described above. These tools read the slapd configuration file and an input file containing a text representation of the entries to add. For database types which support the tools, they produce the database files directly (otherwise you must use the on-line method above). Also, the input file must be completely valid, as these tools do fewer consistency checks than the on-line method.

Note: this Guide is not meant to provide exhaustive documentation on the software. The tool descriptions here only list a few of the available options for each command. Read the associated manpages for complete documentation on all of the available options.

There are several important configuration options you will want to be sure and set in the config file database definition first:

```
suffix <dn>
```

As described in the General Database Directives section, this option defines which entries are to be held by this database. You should set this to the DN of the root of the subtree you are trying to create. For example:

```
suffix "dc=example,dc=com"
```

You should be sure to specify a directory where the index files should be created:

```
directory <directory>
```

For example:

```
directory /usr/local/var/openldap-data
```

Finally, you need to specify which indices you want to build. This is done by one or more index options.

```
index {<attrlist> | default} [pres,eq,approx,sub,none]
```

For example:

```
index cn,sn,uid pres,eq,approx,sub
index objectClass eq
```

This would create presence, equality, approximate, and substring indices for the `cn`, `sn`, and `uid` attributes and an equality index for the `objectClass` attribute. Note that not all index types are available with all attribute types. See The slapd Configuration File section for more information on this option.

10.2.1. The `slapadd` program

Once you've configured things to your liking, you create the primary database and associated indices by running the *slapadd*(8) program:

```
slapadd -l <inputfile> -f <slapdconfigfile>
        [-d <debuglevel>] [-n <integer>|-b <suffix>]
```

The arguments have the following meanings:

```
-l <inputfile>
```

Specifies the LDIF input file containing the entries to add in text form (described below in the The LDIF text entry format section).

```
-f <slapdconfigfile>
```

Specifies the slapd configuration file that tells where to create the indices, what indices to create, etc.

```
-F <slapdconfdirectory>
```

Specifies a config directory. If both `-f` and `-F` are specified, the config file will be read and converted to config directory format and written to the specified directory. If neither option is specified, an attempt to read the default config directory will be made before trying to use the default config file. If a valid config directory exists then the default config file is ignored. If dryrun mode is also specified, no conversion will occur.

```
-d <debuglevel>
```

Turn on debugging, as specified by `<debuglevel>`. The debug levels are the same as for slapd. See the Command-Line Options section in Running slapd.

```
-n <databasenumber>
```

An optional argument that specifies which database to modify. The first database listed in the configuration file is `1`, the second `2`, etc. By default, the first database in the configuration file is used. Should not be used in conjunction with `-b`.

```
-b <suffix>
```

An optional argument that specifies which database to modify. The provided suffix is matched against a database `suffix` directive to determine the database number. Should not be used in conjunction with `-n`.

10.2.2. The `slapindex` program

Sometimes it may be necessary to regenerate indices (such as after modifying *slapd.conf*(5)). This is possible using the *slapindex*(8) program. *slapindex* is invoked like this

```
slapindex -f <slapdconfigfile>
        [-d <debuglevel>] [-n <databasenumber>|-b <suffix>] [attr...]
```

Where the `-f`, `-d`, `-n` and `-b` options are the same as for the *slapadd*(1) program. If no specific attributes are listed, *slapindex* rebuilds all indices based upon the current database contents.

10.2.3. The `slapcat` program

The `slapcat` program is used to dump the database to an LDIF file. This can be useful when you want to make a human-readable backup of your database or when you want to edit your database off-line. The program is invoked like this:

```
slapcat -l <filename> -f <slapdconfigfile>
        [-d <debuglevel>] [-n <databasenumber>|-b <suffix>]
```

where `-n` or `-b` is used to select the database in the *slapd.conf*(5) specified using `-f`. The corresponding LDIF output is written to standard output or to the file specified using the `-l` option.

10.3. The LDIF text entry format

The LDAP Data Interchange Format (LDIF) is used to represent LDAP entries in a simple text format. This section provides a brief description of the LDIF entry format which complements *ldif*(5) and the technical specification RFC2849.

The basic form of an entry is:

```
# comment
dn: <distinguished name>
<attrdesc>: <attrvalue>
<attrdesc>: <attrvalue>

...
```

Lines starting with a '#' character are comments. An attribute description may be a simple attribute type like `cn` or `objectClass` or `1.2.3` (an OID associated with an attribute type) or may include options such as `cn;lang_en_US` or `userCertificate;binary`.

A line may be continued by starting the next line with a *single* space or tab character. For example:

```
dn: cn=Barbara J Jensen,dc=example,dc=
 com
cn: Barbara J
  Jensen
```

is equivalent to:

```
dn: cn=Barbara J Jensen,dc=example,dc=com
cn: Barbara J Jensen
```

Multiple attribute values are specified on separate lines. e.g.,

```
cn: Barbara J Jensen
cn: Babs Jensen
```

If an `<attrvalue>` contains non-printing characters or begins with a space, a colon ('`:`'), or a less than ('<'), the `<attrdesc>` is followed by a double colon and the base64 encoding of the value. For example, the value "` begins with a space`" would be encoded like this:

```
cn:: IGJlZ2lucyB3aXRoIGEgc3BhY2U=
```

You can also specify a URL containing the attribute value. For example, the following specifies the `jpegPhoto` value should be obtained from the file `/path/to/file.jpeg`.

```
jpegPhoto:< file:///path/to/file.jpeg
```

Multiple entries within the same LDIF file are separated by blank lines. Here's an example of an LDIF file containing three entries.

```
# Barbara's Entry
dn: cn=Barbara J Jensen,dc=example,dc=com
cn: Barbara J Jensen
cn: Babs Jensen
objectClass: person
sn: Jensen

# Bjorn's Entry
dn: cn=Bjorn J Jensen,dc=example,dc=com
cn: Bjorn J Jensen
cn: Bjorn Jensen
objectClass: person
sn: Jensen
# Base64 encoded JPEG photo
```

```
jpegPhoto:: /9j/4AAQSkZJRgABAAAAAQABAAD/2wBDABALD
 A4MChAODQ4SERATGCgaGBYWGDEjJR0oOjM9PDkzODdASFxOQ
 ERXRTc4UG1RV19iZ2hnPk1xeXBkeFxlZ2P/2wBDARESEhgVG

# Jennifer's Entry
dn: cn=Jennifer J Jensen,dc=example,dc=com
cn: Jennifer J Jensen
cn: Jennifer Jensen
objectClass: person
sn: Jensen
# JPEG photo from file
jpegPhoto:< file:///path/to/file.jpeg
```

Notice that the `jpegPhoto` in Bjorn's entry is base 64 encoded and the `jpegPhoto` in Jennifer's entry is obtained from the location indicated by the URL.

Note: Trailing spaces are not trimmed from values in an LDIF file. Nor are multiple internal spaces compressed. If you don't want them in your data, don't put them there.

11. Backends

Backends do the actual work of storing or retrieving data in response to LDAP requests. Backends may be compiled statically into *slapd*, or when module support is enabled, they may be dynamically loaded.

If your installation uses dynamic modules, you may need to add the relevant *moduleload* directives to the examples that follow. The name of the module for a backend is usually of the form:

```
        back_<backend name>.la
```

So for example, if you need to load the *mdb* backend, you would configure

```
        moduleload back_mdb.la
```

11.1. LDAP

11.1.1. Overview

The LDAP backend to *slapd*(8) is not an actual database; instead it acts as a proxy to forward incoming requests to another LDAP server. While processing requests it will also chase referrals, so that referrals are fully processed instead of being returned to the *slapd* client.

Sessions that explicitly *Bind* to the *back-ldap* database always create their own private connection to the remote LDAP server. Anonymous sessions will share a single anonymous connection to the remote server. For sessions bound through other mechanisms, all sessions with the same DN will share the same connection. This connection pooling strategy can enhance the proxy's efficiency by reducing the overhead of repeatedly making/breaking multiple connections.

The ldap database can also act as an information service, i.e. the identity of locally authenticated clients is asserted to the remote server, possibly in some modified form. For this purpose, the proxy binds to the remote server with some administrative identity, and, if required, authorizes the asserted identity.

It is heavily used by a lot of other Backends and Overlays.

11.1.2. back-ldap Configuration

As previously mentioned, *slapd-ldap(5)* is used behind the scenes by many other Backends and Overlays. Some of them merely provide a few configuration directive themselves, but have available to the administrator the whole of the *slapd-ldap(5)* options.

For example, the Translucent Proxy, which retrieves entries from a remote LDAP server that can be partially overridden by the defined database, has only four specific *translucent-* directives, but can be configured using any of the normal *slapd-ldap(5)* options. See *slapo-translucent(5)* for details.

Other Overlays allow you to tag directives in front of a normal *slapd-ldap(5)* directive. For example, the *slapo-chain(5)* overlay does this:

"There are very few chain overlay specific directives; however, directives related to the instances of the ldap backend that may be implicitly instantiated by the overlay may assume a special meaning when used in

conjunction with this overlay. They are described in slapd-ldap(5), and they also need to be prefixed by chain-."

You may have also seen the *slapd-ldap(5)* backend used and described in the Push Based Replication section of the guide.

It should therefore be obvious that the *slapd-ldap(5)* backend is extremely flexible and heavily used throughout the OpenLDAP Suite.

The following is a very simple example, but already the power of the *slapd-ldap(5)* backend is seen by use of a *uri list*:

```
database        ldap
suffix          "dc=suretecsystems,dc=com"
rootdn          "cn=slapd-ldap"
uri             ldap://localhost/ ldap://remotehost ldap://remotehost2
```

The URI list is space or comma-separated. Whenever the server that responds is not the first one in the list, the list is rearranged and the responsive server is moved to the head, so that it will be first contacted the next time a connection needs be created.

This feature can be used to provide a form of load balancing when using Mirror mode replication.

11.1.3. Further Information

slapd-ldap(5)

11.2. LDIF

11.2.1. Overview

The LDIF backend to *slapd*(8) is a basic storage backend that stores entries in text files in LDIF format, and exploits the filesystem to create the tree structure of the database. It is intended as a cheap, low performance easy to use backend.

When using the *cn=config* dynamic configuration database with persistent storage, the configuration data is stored using this backend. See *slapd-config*(5) for more information

11.2.2. back-ldif Configuration

Like many other backends, the LDIF backend can be instantiated with very few configuration lines:

```
include ./schema/core.schema

database  ldif
directory ./ldif
suffix    "dc=suretecsystems,dc=com"
rootdn    "cn=LDIF,dc=suretecsystems,dc=com"
rootpw    LDIF
```

If we add the *dcObject* for *dc=suretecsystems,dc=com*, you can see how this is added behind the scenes on the file system:

```
dn: dc=suretecsystems,dc=com
objectClass: dcObject
objectClass: organization
dc: suretecsystems
o: Suretec Systems Ltd
```

Now we add it to the directory:

```
ldapadd -x -H ldap://localhost:9011 -f suretec.ldif -D "cn=LDIF,dc=suretecsystems,dc=
adding new entry "dc=suretecsystems,dc=com"
```

And inside `./ldif` we have:

```
ls ./ldif
dc=suretecsystems,dc=com.ldif
```

which again contains:

```
cat ldif/dc\=suretecsystems\,dc\=com.ldif

dn: dc=suretecsystems
objectClass: dcObject
objectClass: organization
dc: suretecsystems
o: Suretec Systems Ltd.
structuralObjectClass: organization
entryUUID: 2134b714-e3a1-102c-9a15-f96ee263886d
creatorsName: cn=LDIF,dc=suretecsystems,dc=com
createTimestamp: 20080711142643Z
entryCSN: 20080711142643.661124Z#000000#000#000000
modifiersName: cn=LDIF,dc=suretecsystems,dc=com
modifyTimestamp: 20080711142643Z
```

This is the complete format you would get when exporting your directory using `slapcat` etc.

11.2.3. Further Information

slapd-ldif(5)

11.3. LMDB

11.3.1. Overview

The *mdb* backend to *slapd*(8) is the recommended primary backend for a normal *slapd* database. It uses OpenLDAP's own Lightning Memory-Mapped Database (LMDB) library to store data and replaces the BerkeleyDB backends used in older OpenLDAP releases.

It supports indexing, it uses no caching, and requires no tuning to deliver maximum search performance. It is fully hierarchical and supports subtree renames in constant time.

11.3.2. back-mdb Configuration

The *mdb* backend can be instantiated with very few configuration lines:

```
include ./schema/core.schema

database  mdb
directory ./mdb
suffix    "dc=suretecsystems,dc=com"
rootdn    "cn=mdb,dc=suretecsystems,dc=com"
rootpw    mdb
maxsize   1073741824
```

In addition to the usual parameters that a minimal configuration requires, the *mdb* backend requires a maximum size to be set. This should be the largest that the database is ever anticipated to grow (in bytes). The filesystem must also provide enough free space to accommodate this size.

11.3.3. Further Information

slapd-mdb(5)

11.4. Metadirectory

11.4.1. Overview

The meta backend to *slapd*(8) performs basic LDAP proxying with respect to a set of remote LDAP servers, called "targets". The information contained in these servers can be presented as belonging to a single Directory Information Tree (DIT).

A basic knowledge of the functionality of the *slapd-ldap*(5) backend is recommended. This backend has been designed as an enhancement of the ldap backend. The two backends share many features (actually they also share portions of code). While the ldap backend is intended to proxy operations directed to a single server, the meta backend is mainly intended for proxying of multiple servers and possibly naming context masquerading.

These features, although useful in many scenarios, may result in excessive overhead for some applications, so its use should be carefully considered.

11.4.2. back-meta Configuration

LATER

11.4.3. Further Information

slapd-meta(5)

11.5. Monitor

11.5.1. Overview

The monitor backend to *slapd*(8) is not an actual database; if enabled, it is automatically generated and dynamically maintained by slapd with information about the running status of the daemon.

To inspect all monitor information, issue a subtree search with base *cn=Monitor*, requesting that attributes "+" and "*" are returned. The monitor backend produces mostly operational attributes, and LDAP only returns operational attributes that are explicitly requested. Requesting attribute "+" is an extension which requests all operational attributes.

See the Monitoring section.

11.5.2. back-monitor Configuration

The monitor database can be instantiated only once, i.e. only one occurrence of "database monitor" can occur in the *slapd.conf(5)* file. Also the suffix is automatically set to *"cn=Monitor"*.

You can however set a *rootdn* and *rootpw*. The following is all that is needed to instantiate a monitor backend:

```
include ./schema/core.schema

database monitor
rootdn "cn=monitoring,cn=Monitor"
rootpw monitoring
```

You can also apply Access Control to this database like any other database, for example:

```
access to dn.subtree="cn=Monitor"
     by dn.exact="uid=Admin,dc=my,dc=org" write
     by users read
     by * none
```

Note: The `core.schema` must be loaded for the monitor database to work.

A small example of the data returned via *ldapsearch* would be:

```
ldapsearch -x -H ldap://localhost:9011 -b 'cn=Monitor'
# extended LDIF
#
# LDAPv3
# base <cn=Monitor> with scope subtree
# filter: (objectclass=*)
# requesting: ALL
#

# Monitor
dn: cn=Monitor
objectClass: monitorServer
cn: Monitor
description: This subtree contains monitoring/managing objects.
description: This object contains information about this server.
description: Most of the information is held in operational attributes, which
 must be explicitly requested.

# Backends, Monitor
dn: cn=Backends,cn=Monitor
objectClass: monitorContainer
cn: Backends
description: This subsystem contains information about available backends.
```

Please see the Monitoring section for complete examples of information available via this backend.

11.5.3. Further Information

slapd-monitor(5)

11.6. Null

11.6.1. Overview

The Null backend to *slapd*(8) is surely the most useful part of slapd:

- Searches return success but no entries.
- Compares return compareFalse.
- Updates return success (unless readonly is on) but do nothing.
- Binds other than as the rootdn fail unless the database option "bind on" is given.
- The slapadd(8) and slapcat(8) tools are equally exciting.

Inspired by the `/dev/null` device.

11.6.2. back-null Configuration

This has to be one of the shortest configurations you'll ever do. In order to test this, your `slapd.conf` file would look like:

```
database null
suffix "cn=Nothing"
bind on
```

bind on means:

"Allow binds as any DN in this backend's suffix, with any password. The default is "off"."

To test this backend with *ldapsearch*:

```
ldapsearch -x -H ldap://localhost:9011 -D "uid=none,cn=Nothing" -w testing -b 'cn=Nothi
# extended LDIF
#
# LDAPv3
# base <cn=Nothing> with scope subtree
# filter: (objectclass=*)
# requesting: ALL
#

# search result
search: 2
result: 0 Success

# numResponses: 1
```

11.6.3. Further Information

slapd-null(5)

11.7. Passwd

11.7.1. Overview

The PASSWD backend to *slapd*(8) serves up the user account information listed in the system *passwd*(5) file (defaulting to `/etc/passwd`).

This backend is provided for demonstration purposes only. The DN of each entry is "uid=<username>,<suffix>".

11.7.2. back-passwd Configuration

The configuration using `slapd.conf` a slightly longer, but not much. For example:

```
include ./schema/core.schema

database passwd
suffix "cn=passwd"
```

Again, testing this with *ldapsearch* would result in something like:

```
ldapsearch -x -H ldap://localhost:9011 -b 'cn=passwd'
# extended LDIF
#
# LDAPv3
# base <cn=passwd> with scope subtree
# filter: (objectclass=*)
# requesting: ALL
#

# passwd
dn: cn=passwd
cn: passwd
objectClass: organizationalUnit

# root, passwd
dn: uid=root,cn=passwd
objectClass: person
objectClass: uidObject
uid: root
cn: root
sn: root
description: root
```

11.7.3. Further Information

slapd-passwd(5)

11.8. Perl

11.8.1. Overview

The Perl backend to *slapd*(8) works by embedding a *perl*(1) interpreter into *slapd*(8). Any perl database section of the configuration file *slapd.conf*(5) must then specify what Perl module to use. Slapd then creates a new Perl object that handles all the requests for that particular instance of the backend.

11.8.2. back-perl Configuration

LATER

11.8.3. Further Information

slapd-perl(5)

11.9. Relay

11.9.1. Overview

The primary purpose of this *slapd*(8) backend is to map a naming context defined in a database running in the same *slapd*(8) instance into a virtual naming context, with attributeType and objectClass manipulation, if required. It requires the rwm overlay.

This backend and the above mentioned overlay are experimental.

11.9.2. back-relay Configuration

LATER

11.9.3. Further Information

slapd-relay(5)

11.10. SQL

11.10.1. Overview

The primary purpose of this *slapd*(8) backend is to PRESENT information stored in some RDBMS as an LDAP subtree without any programming (some SQL and maybe stored procedures can't be considered programming, anyway ;).

That is, for example, when you (some ISP) have account information you use in an RDBMS, and want to use modern solutions that expect such information in LDAP (to authenticate users, make email lookups etc.). Or you want to synchronize or distribute information between different sites/applications that use RDBMSes and/or LDAP. Or whatever else...

It is **NOT** designed as a general-purpose backend that uses RDBMS instead of LMDB (as the standard back-mdb backend does), though it can be used as such with several limitations. Please see LDAP vs RDBMS for discussion.

The idea is to use some meta-information to translate LDAP queries to SQL queries, leaving relational schema untouched, so that old applications can continue using it without any modifications. This allows SQL and LDAP applications to interoperate without replication, and exchange data as needed.

The SQL backend is designed to be tunable to virtually any relational schema without having to change source (through that meta-information mentioned). Also, it uses ODBC to connect to RDBMSes, and is highly configurable for SQL dialects RDBMSes may use, so it may be used for integration and distribution of data on different RDBMSes, OSes, hosts etc., in other words, in highly heterogeneous environments.

This backend is experimental and deprecated.

11.10.2. back-sql Configuration

This backend has to be one of the most abused and complex backends there is. Therefore, we will go through a simple, small example that comes with the OpenLDAP source and can be found in `servers/slapd/back-sql/rdbms_depend/README`

For this example we will be using PostgreSQL.

First, we add to `/etc/odbc.ini` a block of the form:

```
[example]                        <===
Description         = Example for OpenLDAP's back-sql
Driver              = PostgreSQL
Trace               = No
Database            = example    <===
Servername          = localhost
UserName            = manager    <===
Password            = secret     <===
Port                = 5432
;Protocol             = 6.4
ReadOnly            = No
RowVersioning       = No
ShowSystemTables    = No
ShowOidColumn       = No
FakeOidIndex        = No
ConnSettings        =
```

The relevant information for our test setup is highlighted with '<===' on the right above.

Next, we add to `/etc/odbcinst.ini` a block of the form:

```
[PostgreSQL]
Description     = ODBC for PostgreSQL
Driver          = /usr/lib/libodbcpsql.so
Setup           = /usr/lib/libodbcpsqlS.so
FileUsage       = 1
```

We will presume you know how to create a database and user in PostgreSQL and how to set a password. Also, we'll presume you can populate the 'example' database you've just created with the following files, as found in `servers/slapd/back-sql/rdbms_depend/pgsql`

```
backsql_create.sql, testdb_create.sql, testdb_data.sql, testdb_metadata.sql
```

Lastly, run the test:

```
[root@localhost]# cd $SOURCES/tests
[root@localhost]# SLAPD_USE_SQL=pgsql ./run sql-test000
```

Briefly, you should see something like (cut short for space):

```
Cleaning up test run directory leftover from previous run.
Running ./scripts/sql-test000-read...
running defines.sh
Starting slapd on TCP/IP port 9011...
Testing SQL backend read operations...
Waiting 5 seconds for slapd to start...
Testing correct bind... dn:cn=Mitya Kovalev,dc=example,dc=com
Testing incorrect bind (should fail)... ldap_bind: Invalid credentials (49)

......

Filtering original ldif...
Comparing filter output...
>>>>> Test succeeded
```

The test is basically readonly; this can be performed by all RDBMSes (listed above).

There is another test, sql-test900-write, which is currently enabled only for PostgreSQL and IBM db2.

Using `sql-test000`, files in `servers/slapd/back-sql/rdbms_depend/pgsql/` and the man page, you should be set.

Note: This backend is experimental and deprecated.

11.10.3. Further Information

slapd-sql(5) and `servers/slapd/back-sql/rdbms_depend/README`

12. Overlays

Overlays are software components that provide hooks to functions analogous to those provided by backends, which can be stacked on top of the backend calls and as callbacks on top of backend responses to alter their behavior.

Overlays may be compiled statically into *slapd*, or when module support is enabled, they may be dynamically loaded. Most of the overlays are only allowed to be configured on individual databases.

Some can be stacked on the `frontend` as well, for global use. This means that they can be executed after a request is parsed and validated, but right before the appropriate database is selected. The main purpose is to affect operations regardless of the database they will be handled by, and, in some cases, to influence the selection of the database by massaging the request DN.

Essentially, overlays represent a means to:

- customize the behavior of existing backends without changing the backend code and without requiring one to write a new custom backend with complete functionality
- write functionality of general usefulness that can be applied to different backend types

When using *slapd.conf*(5), overlays that are configured before any other databases are considered global, as mentioned above. In fact they are implicitly stacked on top of the `frontend` database. They can also be explicitly configured as such:

```
database frontend
overlay <overlay name>
```

Overlays are usually documented by separate specific man pages in section 5; the naming convention is

```
slapo-<overlay name>
```

All distributed core overlays have a man page. Feel free to contribute to any, if you think there is anything missing in describing the behavior of the component and the implications of all the related configuration directives.

Official overlays are located in

```
servers/slapd/overlays/
```

That directory also contains the file slapover.txt, which describes the rationale of the overlay implementation, and may serve as a guideline for the development of custom overlays.

Contribware overlays are located in

```
contrib/slapd-modules/<overlay name>/
```

along with other types of run-time loadable components; they are officially distributed, but not maintained by the project.

All the current overlays in OpenLDAP are listed and described in detail in the following sections.

12.1. Access Logging

12.1.1. Overview

This overlay can record accesses to a given backend database on another database.

This allows all of the activity on a given database to be reviewed using arbitrary LDAP queries, instead of just logging to local flat text files. Configuration options are available for selecting a subset of operation types to log, and to automatically prune older log records from the logging database. Log records are stored with audit schema to assure their readability whether viewed as LDIF or in raw form.

It is also used for delta-syncrepl replication

Note: An accesslog database is unique to a given provider. It should never be replicated.

12.1.2. Access Logging Configuration

The following is a basic example that implements Access Logging:

```
database mdb
suffix dc=example,dc=com
...
overlay accesslog
logdb cn=log
logops writes reads
logold (objectclass=person)

database mdb
suffix cn=log
...
index reqStart eq
access to *
  by dn.base="cn=admin,dc=example,dc=com" read
```

The following is an example used for delta-syncrepl replication:

```
database mdb
suffix cn=accesslog
directory /usr/local/var/openldap-accesslog
rootdn cn=accesslog
index default eq
index entryCSN,objectClass,reqEnd,reqResult,reqStart,reqDN
```

Accesslog overlay definitions for the primary db

```
database mdb
suffix dc=example,dc=com
...
overlay accesslog
logdb cn=accesslog
logops writes
logsuccess TRUE
# scan the accesslog DB every day, and purge entries older than 7 days
logpurge 07+00:00 01+00:00
```

An example search result against **cn=accesslog** might look like:

```
[ghenry@suretec ghenry]# ldapsearch -x -b cn=accesslog
# extended LDIF
#
# LDAPv3
# base <cn=accesslog> with scope subtree
# filter: (objectclass=*)
# requesting: ALL
#

# accesslog
dn: cn=accesslog
objectClass: auditContainer
cn: accesslog

# 20080110163829.000004Z, accesslog
dn: reqStart=20080110163829.000004Z,cn=accesslog
objectClass: auditModify
reqStart: 20080110163829.000004Z
reqEnd: 20080110163829.000005Z
reqType: modify
reqSession: 196696
reqAuthzID: cn=admin,dc=suretecsystems,dc=com
reqDN: uid=suretec-46022f8$,ou=Users,dc=suretecsystems,dc=com
reqResult: 0
reqMod: sambaPwdCanChange:- ###CENSORED###
reqMod: sambaPwdCanChange:+ ###CENSORED###
reqMod: sambaNTPassword:- ###CENSORED###
reqMod: sambaNTPassword:+ ###CENSORED###
reqMod: sambaPwdLastSet:- ###CENSORED###
reqMod: sambaPwdLastSet:+ ###CENSORED###
reqMod: entryCSN:= 20080110163829.095157Z#000000#000#000000
reqMod: modifiersName:= cn=admin,dc=suretecsystems,dc=com
reqMod: modifyTimestamp:= 20080110163829Z

# search result
search: 2
result: 0 Success

# numResponses: 3
# numEntries: 2
```

12.1.3. Further Information

slapo-accesslog(5) and the delta-syncrepl replication section.

12.2. Audit Logging

The Audit Logging overlay can be used to record all changes on a given backend database to a specified log file.

12.2.1. Overview

If the need arises whereby changes need to be logged as standard LDIF, then the auditlog overlay **slapo-auditlog (5)** can be used. Full examples are available in the man page **slapo-auditlog (5)**

12.2.2. Audit Logging Configuration

If the directory is running vi `slapd.d`, then the following LDIF could be used to add the overlay to the overlay list in **cn=config** and set what file the LDIF gets logged to (adjust to suit)

```
dn: olcOverlay=auditlog,olcDatabase={1}mdb,cn=config
changetype: add
objectClass: olcOverlayConfig
objectClass: olcAuditLogConfig
olcOverlay: auditlog
olcAuditlogFile: /tmp/auditlog.ldif
```

In this example for testing, we are logging changes to `/tmp/auditlog.ldif`

A typical LDIF file created by **slapo-auditlog(5)** would look like:

```
# add 1196797576 dc=suretecsystems,dc=com cn=admin,dc=suretecsystems,dc=com
dn: dc=suretecsystems,dc=com
changetype: add
objectClass: dcObject
objectClass: organization
dc: suretecsystems
o: Suretec Systems Ltd.
structuralObjectClass: organization
entryUUID: 1606f8f8-f06e-1029-8289-f0cc9d81e81a
creatorsName: cn=admin,dc=suretecsystems,dc=com
modifiersName: cn=admin,dc=suretecsystems,dc=com
createTimestamp: 20051123130912Z
modifyTimestamp: 20051123130912Z
entryCSN: 20051123130912.000000Z#000001#000#000000
auditContext: cn=accesslog
# end add 1196797576

# add 1196797577 dc=suretecsystems,dc=com cn=admin,dc=suretecsystems,dc=com
dn: ou=Groups,dc=suretecsystems,dc=com
changetype: add
objectClass: top
objectClass: organizationalUnit
ou: Groups
structuralObjectClass: organizationalUnit
entryUUID: 160aaa2a-f06e-1029-828a-f0cc9d81e81a
creatorsName: cn=admin,dc=suretecsystems,dc=com
modifiersName: cn=admin,dc=suretecsystems,dc=com
createTimestamp: 20051123130912Z
modifyTimestamp: 20051123130912Z
entryCSN: 20051123130912.000000Z#000002#000#000000
# end add 1196797577
```

12.2.3. Further Information

slapo-auditlog(5)

12.3. Chaining

12.3.1. Overview

The chain overlay provides basic chaining capability to the underlying database.

What is chaining? It indicates the capability of a DSA to follow referrals on behalf of the client, so that distributed systems are viewed as a single virtual DSA by clients that are otherwise unable to "chase" (i.e. follow) referrals by themselves.

The chain overlay is built on top of the ldap backend; it is compiled by default when **--enable-ldap**.

12.3.2. Chaining Configuration

In order to demonstrate how this overlay works, we shall discuss a typical scenario which might be one provider server and three Syncrepl replicas.

On each replica, add this near the top of the *slapd.conf*(5) file (global), before any database definitions:

```
overlay                     chain
chain-uri                   "ldap://ldapprovider.example.com"
chain-idassert-bind         bindmethod="simple"
                            binddn="cn=Manager,dc=example,dc=com"
                            credentials="<secret>"
                            mode="self"
chain-tls                   start
chain-return-error          TRUE
```

Add this below your *syncrepl* statement:

```
updateref                   "ldap://ldapprovider.example.com/"
```

The **chain-tls** statement enables TLS from the replica to the ldap provider. The DITs are exactly the same between these machines, therefore whatever user bound to the replica will also exist on the provider. If that DN does not have update privileges on the provider, nothing will happen.

You will need to restart the replica after these *slapd.conf* changes. Then, if you are using *loglevel stats* (256), you can monitor an *ldapmodify* on the replica and the provider. (If you're using *cn=config* no restart is required.)

Now start an *ldapmodify* on the replica and watch the logs. You should expect something like:

```
Sep  6 09:27:25 replica1 slapd[29274]: conn=11 fd=31 ACCEPT from IP=143.199.102.
Sep  6 09:27:25 replica1 slapd[29274]: conn=11 op=0 STARTTLS
Sep  6 09:27:25 replica1 slapd[29274]: conn=11 op=0 RESULT oid= err=0 text=
Sep  6 09:27:25 replica1 slapd[29274]: conn=11 fd=31 TLS established tls_ssf=256
Sep  6 09:27:28 replica1 slapd[29274]: conn=11 op=1 BIND dn="uid=user1,ou=people
Sep  6 09:27:28 replica1 slapd[29274]: conn=11 op=1 BIND dn="uid=user1,ou=People
Sep  6 09:27:28 replica1 slapd[29274]: conn=11 op=1 RESULT tag=97 err=0 text=
Sep  6 09:27:28 replica1 slapd[29274]: conn=11 op=2 MOD dn="uid=user1,ou=People,
Sep  6 09:27:28 replica1 slapd[29274]: conn=11 op=2 MOD attr=mail
Sep  6 09:27:28 replica1 slapd[29274]: conn=11 op=2 RESULT tag=103 err=0 text=
Sep  6 09:27:28 replica1 slapd[29274]: conn=11 op=3 UNBIND
Sep  6 09:27:28 replica1 slapd[29274]: conn=11 fd=31 closed
Sep  6 09:27:28 replica1 slapd[29274]: syncrepl_entry: LDAP_RES_SEARCH_ENTRY(LDA
Sep  6 09:27:28 replica1 slapd[29274]: syncrepl_entry: be_search (0)
Sep  6 09:27:28 replica1 slapd[29274]: syncrepl_entry: uid=user1,ou=People,dc=example,d
Sep  6 09:27:28 replica1 slapd[29274]: syncrepl_entry: be_modify (0)
```

And on the provider you will see this:

```
Sep  6 09:23:57 ldapprovider slapd[2961]: conn=55902 op=3 PROXYAUTHZ dn="uid=user1,ou=p
Sep  6 09:23:57 ldapprovider slapd[2961]: conn=55902 op=3 MOD dn="uid=user1,ou=People,d
Sep  6 09:23:57 ldapprovider slapd[2961]: conn=55902 op=3 MOD attr=mail
Sep  6 09:23:57 ldapprovider slapd[2961]: conn=55902 op=3 RESULT tag=103 err=0 text=
```

Note: You can clearly see the PROXYAUTHZ line on the provider, indicating the proper identity assertion for the update on the provider. Also note the replica immediately receiving the Syncrepl update from the provider.

12.3.3. Handling Chaining Errors

By default, if chaining fails, the original referral is returned to the client under the assumption that the client might want to try and follow the referral.

With the following directive however, if the chaining fails at the provider side, the actual error is returned to the client.

```
chain-return-error TRUE
```

12.3.4. Read-Back of Chained Modifications

Occasionally, applications want to read back the data that they just wrote. If a modification requested to a shadow server was silently chained to its provider, an immediate read could result in receiving data not yet synchronized. In those cases, clients should use the **dontusecopy** control to ensure they are directed to the authoritative source for that piece of data.

This control usually causes a referral to the actual source of the data to be returned. However, when the *slapo-chain(5)* overlay is used, it intercepts the referral being returned in response to the **dontusecopy** control, and tries to fetch the requested data.

12.3.5. Further Information

slapo-chain(5)

12.4. Constraints

12.4.1. Overview

This overlay enforces a regular expression constraint on all values of specified attributes during an LDAP modify request that contains add or modify commands. It is used to enforce a more rigorous syntax when the underlying attribute syntax is too general.

12.4.2. Constraint Configuration

Configuration via *slapd.conf*(5) would look like:

```
overlay constraint
constraint_attribute mail regex ^[[:alnum:]]+@mydomain.com$
constraint_attribute title uri
ldap:///dc=catalog,dc=example,dc=com?title?sub?(objectClass=titleCatalog)
```

A specification like the above would reject any *mail* attribute which did not look like *<alphanumeric string>@mydomain.com*.

It would also reject any title attribute whose values were not listed in the title attribute of any *titleCatalog* entries in the given scope.

An example for use with *cn=config*:

```
dn: olcOverlay=constraint,olcDatabase={1}mdb,cn=config
changetype: add
objectClass: olcOverlayConfig
objectClass: olcConstraintConfig
olcOverlay: constraint
olcConstraintAttribute: mail regex ^[[:alnum:]]+@mydomain.com$
olcConstraintAttribute: title uri ldap:///dc=catalog,dc=example,dc=com?title?sub?
```

12.4.3. Further Information

slapo-constraint(5)

12.5. Dynamic Directory Services

12.5.1. Overview

The *dds* overlay to *slapd*(8) implements dynamic objects as per RFC2589. The name *dds* stands for Dynamic Directory Services. It allows to define dynamic objects, characterized by the *dynamicObject* objectClass.

Dynamic objects have a limited lifetime, determined by a time-to-live (TTL) that can be refreshed by means of a specific refresh extended operation. This operation allows to set the Client Refresh Period (CRP), namely the period between refreshes that is required to preserve the dynamic object from expiration. The expiration time is computed by adding the requested TTL to the current time. When dynamic objects reach the end of their lifetime without being further refreshed, they are automatically *deleted*. There is no guarantee of immediate deletion, so clients should not count on it.

12.5.2. Dynamic Directory Service Configuration

A usage of dynamic objects might be to implement dynamic meetings; in this case, all the participants to the meeting are allowed to refresh the meeting object, but only the creator can delete it (otherwise it will be deleted when the TTL expires).

If we add the overlay to an example database, specifying a Max TTL of 1 day, a min of 10 seconds, with a default TTL of 1 hour. We'll also specify an interval of 120 (less than 60s might be too small) seconds between expiration checks and a tolerance of 5 second (lifetime of a dynamic object will be *entryTtl* + *tolerance*).

```
overlay dds
dds-max-ttl     1d
dds-min-ttl     10s
dds-default-ttl 1h
dds-interval    120s
dds-tolerance   5s
```

and add an index:

```
entryExpireTimestamp
```

Creating a meeting is as simple as adding the following:

```
dn: cn=OpenLDAP Documentation Meeting,ou=Meetings,dc=example,dc=com
objectClass: groupOfNames
objectClass: dynamicObject
cn: OpenLDAP Documentation Meeting
member: uid=ghenry,ou=People,dc=example,dc=com
member: uid=hyc,ou=People,dc=example,dc=com
```

12.5.2.1. Dynamic Directory Service ACLs

Allow users to start a meeting and to join it; restrict refresh to the *member*; restrict delete to the creator:

```
access to attrs=userPassword
   by self write
   by * read

access to dn.base="ou=Meetings,dc=example,dc=com"
          attrs=children
     by users write

access to dn.onelevel="ou=Meetings,dc=example,dc=com"
          attrs=entry
     by dnattr=creatorsName write
     by * read

access to dn.onelevel="ou=Meetings,dc=example,dc=com"
          attrs=participant
     by dnattr=creatorsName write
     by users selfwrite
     by * read

access to dn.onelevel="ou=Meetings,dc=example,dc=com"
          attrs=entryTtl
     by dnattr=member manage
     by * read
```

In simple terms, the user who created the *OpenLDAP Documentation Meeting* can add new attendees, refresh the meeting using (basically complete control):

```
ldapexop -x -H ldap://ldaphost "refresh" "cn=OpenLDAP Documentation Meeting,ou=Meetings,
```

Any user can join the meeting, but not add another attendee, but they can refresh the meeting. The ACLs above are quite straight forward to understand.

12.5.3. Further Information

slapo-dds(5)

12.6. Dynamic Groups

12.6.1. Overview

This overlay extends the Compare operation to detect members of a dynamic group. This overlay is now deprecated as all of its functions are available using the Dynamic Lists overlay.

12.6.2. Dynamic Group Configuration

12.7. Dynamic Lists

12.7.1. Overview

This overlay allows expansion of dynamic groups and lists. Instead of having the group members or list attributes hard coded, this overlay allows us to define an LDAP search whose results will make up the group or list.

12.7.2. Dynamic List Configuration

This module can behave both as a dynamic list and dynamic group, depending on the configuration. The syntax is as follows:

```
overlay dynlist
dynlist-attrset <group-oc> <URL-ad> [member-ad]
```

The parameters to the `dynlist-attrset` directive have the following meaning:

- `<group-oc>`: specifies which object class triggers the subsequent LDAP search. Whenever an entry with this object class is retrieved, the search is performed.
- `<URL-ad>`: is the name of the attribute which holds the search URI. It has to be a subtype of `labeledURI`. The attributes and values present in the search result are added to the entry unless `member-ad` is used (see below).
- `member-ad`: if present, changes the overlay behavior into a dynamic group. Instead of inserting the results of the search in the entry, the distinguished name of the results are added as values of this attribute.

Here is an example which will allow us to have an email alias which automatically expands to all user's emails according to our LDAP filter:

In *slapd.conf*(5):

```
overlay dynlist
dynlist-attrset nisMailAlias labeledURI
```

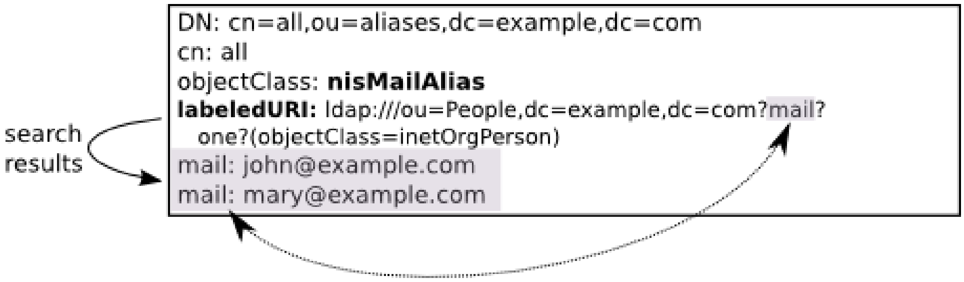
This means that whenever an entry which has the `nisMailAlias` object class is retrieved, the search specified in the `labeledURI` attribute is performed.

Let's say we have this entry in our directory:

```
cn=all,ou=aliases,dc=example,dc=com
cn: all
objectClass: nisMailAlias
labeledURI: ldap:///ou=People,dc=example,dc=com?mail?one?(objectClass=inetOrgPerson)
```

If this entry is retrieved, the search specified in `labeledURI` will be performed and the results will be added to the entry just as if they have always been there. In this case, the search filter selects all entries directly under `ou=People` that have the `inetOrgPerson` object class and retrieves the `mail` attribute, if it exists.

This is what gets added to the entry when we have two users under `ou=People` that match the filter:



```
DN: cn=all,ou=aliases,dc=example,dc=com
cn: all
objectClass: nisMailAlias
labeledURI: ldap:///ou=People,dc=example,dc=com?mail?
  one?(objectClass=inetOrgPerson)
mail: john@example.com
mail: mary@example.com
```

Figure X.Y: Dynamic List for all emails

The configuration for a dynamic group is similar. Let's see an example which would automatically populate an `allusers` group with all the user accounts in the directory.

In `slapd.conf`(5):

```
include /path/to/dyngroup.schema
...
overlay dynlist
dynlist-attrset groupOfURLs labeledURI member
```

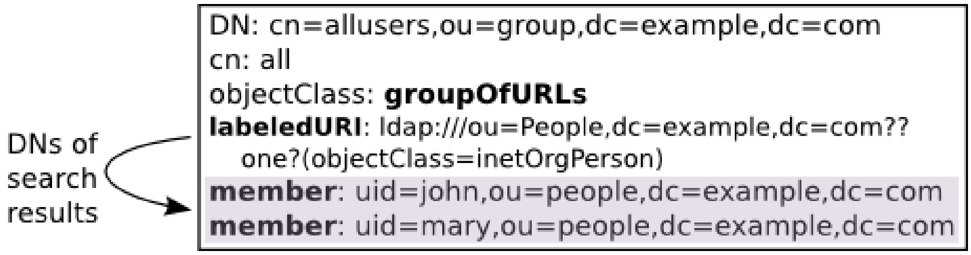
Note: We must include the `dyngroup.schema` file that defines the `groupOfURLs` objectClass used in this example.

Let's apply it to the following entry:

```
cn=allusers,ou=group,dc=example,dc=com
cn: all
objectClass: groupOfURLs
labeledURI: ldap:///ou=people,dc=example,dc=com??one?(objectClass=inetOrgPerson)
```

The behavior is similar to the dynamic list configuration we had before: whenever an entry with the `groupOfURLs` object class is retrieved, the search specified in the `labeledURI` attribute is performed. But this time, only the distinguished names of the results are added, and as values of the `member` attribute.

This is what we get:



```
DN: cn=allusers,ou=group,dc=example,dc=com
cn: all
objectClass: groupOfURLs
labeledURI: ldap:///ou=People,dc=example,dc=com??
   one?(objectClass=inetOrgPerson)
member: uid=john,ou=people,dc=example,dc=com
member: uid=mary,ou=people,dc=example,dc=com
```

Figure X.Y: Dynamic Group for all users

Note that a side effect of this scheme of dynamic groups is that the members need to be specified as full DNs. So, if you are planning in using this for `posixGroups`, be sure to use RFC2307bis and some attribute which can hold distinguished names. The `memberUid` attribute used in the `posixGroup` object class can hold only names, not DNs, and is therefore not suitable for dynamic groups.

12.7.3. Further Information

slapo-dynlist(5)

12.8. Reverse Group Membership Maintenance

12.8.1. Overview

In some scenarios, it may be desirable for a client to be able to determine which groups an entry is a member of, without performing an additional search. Examples of this are applications using the DIT for access control based on group authorization.

The **memberof** overlay updates an attribute (by default **memberOf**) whenever changes occur to the membership attribute (by default **member**) of entries of the objectclass (by default **groupOfNames**) configured to trigger updates.

Thus, it provides maintenance of the list of groups an entry is a member of, when usual maintenance of groups is done by modifying the members on the group entry.

12.8.2. Member Of Configuration

The typical use of this overlay requires just enabling the overlay for a specific database. For example, with the following minimal slapd.conf:

```
include /usr/share/openldap/schema/core.schema
include /usr/share/openldap/schema/cosine.schema

authz-regexp "gidNumber=0\\\+uidNumber=0,cn=peercred,cn=external,cn=auth"
        "cn=Manager,dc=example,dc=com"
database        mdb
suffix          "dc=example,dc=com"
rootdn          "cn=Manager,dc=example,dc=com"
rootpw          secret
directory       /var/lib/ldap2.5
checkpoint 256 5
index   objectClass   eq
index   uid           eq,sub
```

```
        overlay memberof
```

adding the following ldif:

```
        cat memberof.ldif
        dn: dc=example,dc=com
        objectclass: domain
        dc: example

        dn: ou=Group,dc=example,dc=com
        objectclass: organizationalUnit
        ou: Group

        dn: ou=People,dc=example,dc=com
        objectclass: organizationalUnit
        ou: People

        dn: uid=test1,ou=People,dc=example,dc=com
        objectclass: account
        uid: test1

        dn: cn=testgroup,ou=Group,dc=example,dc=com
        objectclass: groupOfNames
        cn: testgroup
        member: uid=test1,ou=People,dc=example,dc=com
```

Results in the following output from a search on the test1 user:

```
# ldapsearch -LL -Y EXTERNAL -H ldapi:/// "(uid=test1)" -b dc=example,dc=com memberOf
SASL/EXTERNAL authentication started
SASL username: gidNumber=0+uidNumber=0,cn=peercred,cn=external,cn=auth
SASL SSF: 0
version: 1

dn: uid=test1,ou=People,dc=example,dc=com
memberOf: cn=testgroup,ou=Group,dc=example,dc=com
```

Note that the **memberOf** attribute is an operational attribute, so it must be requested explicitly.

12.8.3. Further Information

slapo-memberof(5)

12.9. The Proxy Cache Engine

LDAP servers typically hold one or more subtrees of a DIT. Replica (or shadow) servers hold shadow copies of entries held by one or more provider servers. Changes are propagated from the provider server to replica servers using LDAP Sync replication. An LDAP cache is a special type of replica which holds entries corresponding to search filters instead of subtrees.

12.9.1. Overview

The proxy cache extension of slapd is designed to improve the responsiveness of the ldap and meta backends. It handles a search request (query) by first determining whether it is contained in any cached search filter.

Contained requests are answered from the proxy cache's local database. Other requests are passed on to the underlying ldap or meta backend and processed as usual.

E.g. `(shoesize>=9)` is contained in `(shoesize>=8)` and `(sn=Richardson)` is contained in `(sn=Richards*)`

Correct matching rules and syntaxes are used while comparing assertions for query containment. To simplify the query containment problem, a list of cacheable "templates" (defined below) is specified at configuration time. A query is cached or answered only if it belongs to one of these templates. The entries corresponding to cached queries are stored in the proxy cache local database while its associated meta information (filter, scope, base, attributes) is stored in main memory.

A template is a prototype for generating LDAP search requests. Templates are described by a prototype search filter and a list of attributes which are required in queries generated from the template. The representation for prototype filter is similar to RFC4515, except that the assertion values are missing. Examples of prototype filters are: (sn=),(&(sn=)(givenname=)) which are instantiated by search filters (sn=Doe) and (&(sn=Doe)(givenname=John)) respectively.

The cache replacement policy removes the least recently used (LRU) query and entries belonging to only that query. Queries are allowed a maximum time to live (TTL) in the cache thus providing weak consistency. A background task periodically checks the cache for expired queries and removes them.

The Proxy Cache paper (http://www.openldap.org/pub/kapurva/proxycaching.pdf) provides design and implementation details.

12.9.2. Proxy Cache Configuration

The cache configuration specific directives described below must appear after a `overlay pcache` directive within a `"database meta"` or `"database ldap"` section of the server's *slapd.conf*(5) file.

12.9.2.1. Setting cache parameters

```
        pcache <DB> <maxentries> <nattrsets> <entrylimit> <period>
```

This directive enables proxy caching and sets general cache parameters. The <DB> parameter specifies which underlying database is to be used to hold cached entries. It should be set to `mdb`. The <maxentries> parameter specifies the total number of entries which may be held in the cache. The <nattrsets> parameter specifies the total number of attribute sets (as specified by the `pcacheAttrset` directive) that may be defined. The <entrylimit> parameter specifies the maximum number of entries in a cacheable query. The <period> specifies the consistency check period (in seconds). In each period, queries with expired TTLs are removed.

12.9.2.2. Defining attribute sets

```
        pcacheAttrset <index> <attrs...>
```

Used to associate a set of attributes to an index. Each attribute set is associated with an index number from 0 to <numattrsets>-1. These indices are used by the pcacheTemplate directive to define cacheable templates.

12.9.2.3. Specifying cacheable templates

```
        pcacheTemplate <prototype_string> <attrset_index> <TTL>
```

Specifies a cacheable template and the "time to live" (in sec) <TTL> for queries belonging to the template. A template is described by its prototype filter string and set of required attributes identified by <attrset_index>.

12.9.2.4. Example for slapd.conf

An example *slapd.conf*(5) database section for a caching server which proxies for the `"dc=example,dc=com"` subtree held at server `ldap.example.com`.

```
            database        ldap
            suffix          "dc=example,dc=com"
            rootdn          "dc=example,dc=com"
            uri             ldap://ldap.example.com/
            overlay pcache
            pcache         mdb 100000 1 1000 100
            pcacheAttrset  0 mail postaladdress telephonenumber
            pcacheTemplate (sn=) 0 3600
            pcacheTemplate (&(sn=)(givenName=)) 0 3600
            pcacheTemplate (&(departmentNumber=)(secretary=*)) 0 3600

            directory ./testrun/db.2.a
            maxsize   1073741824
            index       objectClass eq
            index       cn,sn,uid,mail  pres,eq,sub
```

12.9.2.5. Example for slapd-config

The same example as a LDIF file for back-config for a caching server which proxies for the `"dc=example,dc=com"` subtree held at server `ldap.example.com`.

```
         dn: olcDatabase={2}ldap,cn=config
         objectClass: olcDatabaseConfig
         objectClass: olcLDAPConfig
         olcDatabase: {2}ldap
         olcSuffix: dc=example,dc=com
         olcRootDN: dc=example,dc=com
         olcDbURI: "ldap://ldap.example.com"

         dn: olcOverlay={0}pcache,olcDatabase={2}ldap,cn=config
         objectClass: olcOverlayConfig
         objectClass: olcPcacheConfig
         olcOverlay: {0}pcache
         olcPcache: mdb 100000 1 1000 100
         olcPcacheAttrset: 0 mail postalAddress telephoneNumber
         olcPcacheTemplate: "(sn=)" 0 3600 0 0 0
         olcPcacheTemplate: "(&(sn=)(givenName=))" 0 3600 0 0 0
         olcPcacheTemplate: "(&(departmentNumber=)(secretary=))" 0 3600

         dn: olcDatabase={0}mdb,olcOverlay={0}pcache,olcDatabase={2}ldap,cn=config
         objectClass: olcMdbConfig
         objectClass: olcPcacheDatabase
         olcDatabase: {0}mdb
         olcDbDirectory: ./testrun/db.2.a
         olcDbMaxSize: 1073741824
         olcDbIndex: objectClass eq
```

```
        olcDbIndex: cn,sn,uid,mail  pres,eq,sub
```

12.9.2.5.1. Cacheable Queries

A LDAP search query is cacheable when its filter matches one of the templates as defined in the "pcacheTemplate" statements and when it references only the attributes specified in the corresponding attribute set. In the example above the attribute set number 0 defines that only the attributes: `mail postaladdress telephonenumber` are cached for the following pcacheTemplates.

12.9.2.5.2. Examples:

```
        Filter: (&(sn=Richard*)(givenName=jack))
        Attrs: mail telephoneNumber
```

is cacheable, because it matches the template `(&(sn=)(givenName=))` and its attributes are contained in pcacheAttrset 0.

```
        Filter: (&(sn=Richard*)(telephoneNumber))
        Attrs: givenName
```

is not cacheable, because the filter does not match the template, nor is the attribute givenName stored in the cache

```
        Filter: (|(sn=Richard*)(givenName=jack))
        Attrs: mail telephoneNumber
```

is not cacheable, because the filter does not match the template (logical OR "|" condition instead of logical AND "&")

12.9.3. Further Information

slapo-pcache(5)

12.10. Password Policies

12.10.1. Overview

This overlay follows the specifications contained in the draft RFC titled draft-behera-ldap-password-policy-09. While the draft itself is expired, it has been implemented in several directory servers, including slapd. Nonetheless, it is important to note that it is a draft, meaning that it is subject to change and is a work-in-progress.

The key abilities of the password policy overlay are as follows:

- Enforce a minimum length for new passwords
- Make sure passwords are not changed too frequently
- Cause passwords to expire, provide warnings before they need to be changed, and allow a fixed number of 'grace' logins to allow them to be changed after they have expired
- Maintain a history of passwords to prevent password re-use
- Prevent password guessing by locking a password for a specified period of time after repeated authentication failures

- Force a password to be changed at the next authentication
- Set an administrative lock on an account
- Support multiple password policies on a default or a per-object basis.
- Perform arbitrary quality checks using an external loadable module. This is a non-standard extension of the draft RFC.

12.10.2. Password Policy Configuration

Instantiate the module in the database where it will be used, after adding the new ppolicy schema and loading the ppolicy module. The following example shows the ppolicy module being added to the database that handles the naming context "dc=example,dc=com". In this example we are also specifying the DN of a policy object to use if none other is specified in a user's object.

```
database mdb
suffix "dc=example,dc=com"
[...additional database configuration directives go here...]

overlay ppolicy
ppolicy_default "cn=default,ou=policies,dc=example,dc=com"
```

Now we need a container for the policy objects. In our example the password policy objects are going to be placed in a section of the tree called "ou=policies,dc=example,dc=com":

```
dn: ou=policies,dc=example,dc=com
objectClass: organizationalUnit
objectClass: top
ou: policies
```

The default policy object that we are creating defines the following policies:

- The user is allowed to change his own password. Note that the directory ACLs for this attribute can also affect this ability (pwdAllowUserChange: TRUE).
- The name of the password attribute is "userPassword" (pwdAttribute: userPassword). Note that this is the only value that is accepted by OpenLDAP for this attribute.
- The server will check the syntax of the password. If the server is unable to check the syntax (i.e., it was hashed or otherwise encoded by the client) it will return an error refusing the password (pwdCheckQuality: 2).
- When a client includes the Password Policy Request control with a bind request, the server will respond with a password expiration warning if it is going to expire in ten minutes or less (pwdExpireWarning: 600). The warnings themselves are returned in a Password Policy Response control.
- When the password for a DN has expired, the server will allow five additional "grace" logins (pwdGraceAuthNLimit: 5).
- The server will maintain a history of the last five passwords that were used for a DN (pwdInHistory: 5).
- The server will lock the account after the maximum number of failed bind attempts has been exceeded (pwdLockout: TRUE).
- When the server has locked an account, the server will keep it locked until an administrator unlocks it (pwdLockoutDuration: 0)
- The server will reset its failed bind count after a period of 30 seconds.
- Passwords will not expire (pwdMaxAge: 0).
- Passwords can be changed as often as desired (pwdMinAge: 0).

- Passwords must be at least 5 characters in length (pwdMinLength: 5).
- The password does not need to be changed at the first bind or when the administrator has reset the password (pwdMustChange: FALSE)
- The current password does not need to be included with password change requests (pwdSafeModify: FALSE)
- The server will only allow five failed binds in a row for a particular DN (pwdMaxFailure: 5).

The actual policy would be:

```
dn: cn=default,ou=policies,dc=example,dc=com
cn: default
objectClass: pwdPolicy
objectClass: namedPolicy
objectClass: top
pwdAllowUserChange: TRUE
pwdAttribute: userPassword
pwdCheckQuality: 2
pwdExpireWarning: 600
pwdFailureCountInterval: 30
pwdGraceAuthNLimit: 5
pwdInHistory: 5
pwdLockout: TRUE
pwdLockoutDuration: 0
pwdMaxAge: 0
pwdMaxFailure: 5
pwdMinAge: 0
pwdMinLength: 5
pwdMustChange: FALSE
pwdSafeModify: FALSE
```

You can create additional policy objects as needed.

The namedPolicy object class is present because the policy entry requires a structural object class.

There are two ways password policy can be applied to individual objects:

1. The pwdPolicySubentry in a user's object - If a user's object has a pwdPolicySubEntry attribute specifying the DN of a policy object, then the policy defined by that object is applied.

2. Default password policy - If there is no specific pwdPolicySubentry set for an object, and the password policy module was configured with the DN of a default policy object and if that object exists, then the policy defined in that object is applied.

Please see *slapo-ppolicy(5)* for a complete explanation of its features.

A guiding philosophy for OpenLDAP and directory servers in general has been that they always hand back exactly what they were given, without modification. For example, if the cn attribute of an object was set to fOObaR, the server will return that exact string during a search. Values of attributes of a sensitive nature, such as userPassword, are often hashed to conceal their values. Since the userPassword values are used internally by the directory server to authenticate users, any hash algorithm that is applied to the value must be compatible with the directory server. Historically this problem has been solved by making the LDAP client application be able to hash the userPassword attribute value in a way that is compatible with the directory server, but this solution has the obvious drawback of requiring tight coupling between the LDAP client and server, and limits the choices of usable hashing algorithms to those that are accommodated by both. This is clearly a sub-optimal solution.

In 2001 RFC 3062 became a standard that specified an LDAP extended operation for cases like this. Extended operations are not bound by the return-what-you-are-given philosophy and so are free to do things to attribute values that the add and modify operations cannot. The change password extended operation accepts a plaintext password and hashes it based on a specification that is contained in the server. This allows the server to be in control of the hashing algorithm which, in turn, ensures that any hashes applied to userPassword attribute values will not prevent users from being authenticated.

The password policy module's ppolicy_hash_cleartext flag addresses this problem by intercepting LDAP modify operations that include the userPassword attribute and converting them to change password extended operations so they can be hashed according to the specification contained in slapd's configuration. When this flag is set, LDAP applications that modify the userPassword attribute can send the password in cleartext form to the server using a standard LDAP modify command and the server will hash the value according to the password-hash directive before storing it. It goes without saying that steps need to be taken to protect the cleartext password in transit, such as using SSL, TLS, or some other link encryption method.

The following example shows the ppolicy module configured to hash cleartext passwords:

```
database mdb
suffix "dc=example,dc=com"
[...additional database configuration directives go here...]

overlay ppolicy
ppolicy_default "cn=default,ou=policies,dc=example,dc=com"
ppolicy_hash_cleartext
```

12.10.3. Further Information

slapo-ppolicy(5)

12.11. Referential Integrity

12.11.1. Overview

This overlay can be used with a backend database such as slapd-mdb(5) to maintain the cohesiveness of a schema which utilizes reference attributes.

Whenever a *modrdn* or *delete* is performed, that is, when an entry's DN is renamed or an entry is removed, the server will search the directory for references to this DN (in selected attributes: see below) and update them accordingly. If it was a *delete* operation, the reference is deleted. If it was a *modrdn* operation, then the reference is updated with the new DN.

For example, a very common administration task is to maintain group membership lists, specially when users are removed from the directory. When an user account is deleted or renamed, all groups this user is a member of have to be updated. LDAP administrators usually have scripts for that. But we can use the `refint` overlay to automate this task. In this example, if the user is removed from the directory, the overlay will take care to remove the user from all the groups he/she was a member of. No more scripting for this.

12.11.2. Referential Integrity Configuration

The configuration for this overlay is as follows:

```
overlay refint
refint_attributes <attribute [attribute ...]>
refint_nothing <string>
```

- `refint_attributes`: this parameter specifies a space separated list of attributes which will have the referential integrity maintained. When an entry is removed or has its DN renamed, the server will do an internal search for any of the `refint_attributes` that point to the affected DN and update them accordingly. IMPORTANT: the attributes listed here must have the `distinguishedName` syntax, that is, hold DNs as values.
- `refint_nothing`: some times, while trying to maintain the referential integrity, the server has to remove the last attribute of its kind from an entry. This may be prohibited by the schema: for example, the `groupOfNames` object class requires at least one member. In these cases, the server will add the attribute value specified in `refint_nothing` to the entry.

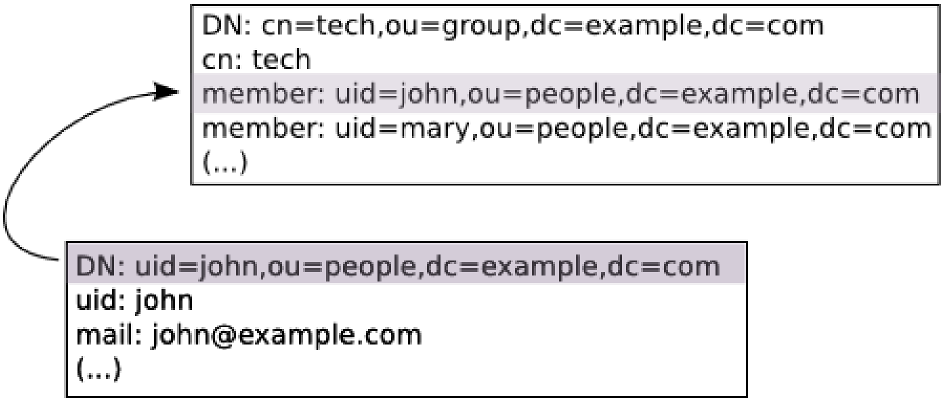
To illustrate this overlay, we will use the group membership scenario.

In `slapd.conf`:

```
overlay refint
refint_attributes member
refint_nothing "cn=admin,dc=example,dc=com"
```

This configuration tells the overlay to maintain the referential integrity of the `member` attribute. This attribute is used in the `groupOfNames` object class which always needs a member, so we add the `refint_nothing` directive to fill in the group with a standard member should all the members vanish.

If we have the following group membership, the refint overlay will automatically remove `john` from the group if his entry is removed from the directory:



```
DN: cn=tech,ou=group,dc=example,dc=com
cn: tech
member: uid=john,ou=people,dc=example,dc=com
member: uid=mary,ou=people,dc=example,dc=com
(...)
```

```
DN: uid=john,ou=people,dc=example,dc=com
uid: john
mail: john@example.com
(...)
```

Figure X.Y: Maintaining referential integrity in groups

Notice that if we rename (`modrdn`) the `john` entry to, say, `jsmith`, the refint overlay will also rename the reference in the `member` attribute, so the group membership stays correct.

If we removed all users from the directory who are a member of this group, then the end result would be a single member in the group: `cn=admin,dc=example,dc=com`. This is the `refint_nothing` parameter kicking into action so that the schema is not violated.

The *rootdn* must be set for the database as refint runs as the *rootdn* to gain access to make its updates. The *rootpw* does not need to be set.

12.11.3. Further Information

slapo-refint(5)

12.12. Return Code

12.12.1. Overview

This overlay is useful to test the behavior of clients when server-generated erroneous and/or unusual responses occur, for example; error codes, referrals, excessive response times and so on.

This would be classed as a debugging tool whilst developing client software or additional Overlays.

For detailed information, please see the *slapo-retcode(5)* man page.

12.12.2. Return Code Configuration

The retcode overlay utilizes the "return code" schema described in the man page. This schema is specifically designed for use with this overlay and is not intended to be used otherwise.

Note: The necessary schema is loaded automatically by the overlay.

An example configuration might be:

```
overlay         retcode
retcode-parent  "ou=RetCodes,dc=example,dc=com"
include         ./retcode.conf

retcode-item    "cn=Unsolicited"                0x00 unsolicited="0"
retcode-item    "cn=Notice of Disconnect"       0x00 unsolicited="1.3.6.1.4.1.1466.20036
retcode-item    "cn=Pre-disconnect"             0x34 flags="pre-disconnect"
retcode-item    "cn=Post-disconnect"            0x34 flags="post-disconnect"
```

Note: *retcode.conf* can be found in the openldap source at: `tests/data/retcode.conf`

An excerpt of a `retcode.conf` would be something like:

```
retcode-item    "cn=success"                            0x00

retcode-item    "cn=success w/ delay"                   0x00    sleeptime=2

retcode-item    "cn=operationsError"                    0x01
retcode-item    "cn=protocolError"                      0x02
retcode-item    "cn=timeLimitExceeded"                  0x03    op=search
retcode-item    "cn=sizeLimitExceeded"                  0x04    op=search
retcode-item    "cn=compareFalse"                       0x05    op=compare
```

```
retcode-item    "cn=compareTrue"                    0x06    op=compare
retcode-item    "cn=authMethodNotSupported"         0x07
retcode-item    "cn=strongAuthNotSupported"         0x07    text="same as aut
retcode-item    "cn=strongAuthRequired"             0x08
retcode-item    "cn=strongerAuthRequired"           0x08    text="same as str
```

Please see `tests/data/retcode.conf` for a complete `retcode.conf`

12.12.3. Further Information

slapo-retcode(5)

12.13. Rewrite/Remap

12.13.1. Overview

It performs basic DN/data rewrite and objectClass/attributeType mapping. Its usage is mostly intended to provide virtual views of existing data either remotely, in conjunction with the proxy backend described in *slapd-ldap(5)*, or locally, in conjunction with the relay backend described in *slapd-relay(5)*.

This overlay is extremely configurable and advanced, therefore recommended reading is the *slapo-rwm(5)* man page.

12.13.2. Rewrite/Remap Configuration

12.13.3. Further Information

slapo-rwm(5)

12.14. Sync Provider

12.14.1. Overview

This overlay implements the provider-side support for the LDAP Content Synchronization (RFC4533) as well as syncrepl replication support, including persistent search functionality.

12.14.2. Sync Provider Configuration

There is very little configuration needed for this overlay, in fact for many situations merely loading the overlay will suffice.

However, because the overlay creates a contextCSN attribute in the root entry of the database which is updated for every write operation performed against the database and only updated in memory, it is recommended to configure a checkpoint so that the contextCSN is written into the underlying database to minimize recovery time after an unclean shutdown:

```
overlay syncprov
syncprov-checkpoint 100 10
```

For every 100 operations or 10 minutes, which ever is sooner, the contextCSN will be checkpointed.

The four configuration directives available are **syncprov-checkpoint**, **syncprov-sessionlog**, **syncprov-nopresent** and **syncprov-reloadhint** which are covered in the man page discussing various other scenarios where this overlay can be used.

12.14.3. Further Information

The *slapo-syncprov(5)* man page and the Configuring the different replication types section

12.15. Translucent Proxy

12.15.1. Overview

This overlay can be used with a backend database such as *slapd-mdb*(5) to create a "translucent proxy".

Entries retrieved from a remote LDAP server may have some or all attributes overridden, or new attributes added, by entries in the local database before being presented to the client.

A search operation is first populated with entries from the remote LDAP server, the attributes of which are then overridden with any attributes defined in the local database. Local overrides may be populated with the add, modify, and modrdn operations, the use of which is restricted to the root user of the translucent local database.

A compare operation will perform a comparison with attributes defined in the local database record (if any) before any comparison is made with data in the remote database.

12.15.2. Translucent Proxy Configuration

There are various options available with this overlay, but for this example we will demonstrate adding new attributes to a remote entry and also searching against these newly added local attributes. For more information about overriding remote entries and search configuration, please see *slapo-translucent(5)*

Note: The Translucent Proxy overlay will disable schema checking in the local database, so that an entry consisting of overlay attributes need not adhere to the complete schema.

First we configure the overlay in the normal manner:

```
include     /usr/local/etc/openldap/schema/core.schema
include     /usr/local/etc/openldap/schema/cosine.schema
include     /usr/local/etc/openldap/schema/nis.schema
include     /usr/local/etc/openldap/schema/inetorgperson.schema

pidfile     ./slapd.pid
argsfile    ./slapd.args

database    mdb
suffix      "dc=suretecsystems,dc=com"
rootdn      "cn=trans,dc=suretecsystems,dc=com"
rootpw      secret
directory   ./openldap-data

index       objectClass eq
```

```
overlay     translucent
translucent_local carLicense

uri         ldap://192.168.X.X:389
lastmod     off
acl-bind    binddn="cn=admin,dc=suretecsystems,dc=com" credentials="blahblah"
```

You will notice the overlay directive and a directive to say what attribute we want to be able to search against in the local database. We must also load the ldap backend which will connect to the remote directory server.

Now we take an example LDAP group:

```
# itsupport, Groups, suretecsystems.com
dn: cn=itsupport,ou=Groups,dc=suretecsystems,dc=com
objectClass: posixGroup
objectClass: sambaGroupMapping
cn: itsupport
gidNumber: 1000
sambaSID: S-1-5-21-XXX
sambaGroupType: 2
displayName: itsupport
memberUid: ghenry
memberUid: joebloggs
```

and create an LDIF file we can use to add our data to the local database, using some pretty strange choices of new attributes for demonstration purposes:

```
[ghenry@suretec test_configs]$ cat test-translucent-add.ldif
dn: cn=itsupport,ou=Groups,dc=suretecsystems,dc=com
businessCategory: frontend-override
carLicense: LIVID
employeeType: special
departmentNumber: 9999999
roomNumber: 41L-535
```

Searching against the proxy gives:

```
[ghenry@suretec test_configs]$ ldapsearch -x -H ldap://127.0.0.1:9001 "(cn=itsuppo
# itsupport, Groups, OxObjects, suretecsystems.com
dn: cn=itsupport,ou=Groups,ou=OxObjects,dc=suretecsystems,dc=com
objectClass: posixGroup
objectClass: sambaGroupMapping
cn: itsupport
gidNumber: 1003
SAMBASID: S-1-5-21-XXX
SAMBAGROUPTYPE: 2
displayName: itsupport
memberUid: ghenry
memberUid: joebloggs
roomNumber: 41L-535
departmentNumber: 9999999
employeeType: special
carLicense: LIVID
businessCategory: frontend-override
```

Here we can see that the 5 new attributes are added to the remote entry before being returned to the our client.

Because we have configured a local attribute to search against:

```
overlay     translucent
translucent_local carLicense
```

we can also search for that to return the completely fabricated entry:

```
ldapsearch -x -H ldap://127.0.0.1:9001 (carLicense=LIVID)
```

This is an extremely useful feature because you can then extend a remote directory server locally and also search against the local entries.

Note: Because the translucent overlay does not perform any DN rewrites, the local and remote database instances must have the same suffix. Other configurations will probably fail with No Such Object and other errors

---

12.15.3. Further Information

slapo-translucent(5)

12.16. Attribute Uniqueness

12.16.1. Overview

This overlay can be used with a backend database such as *slapd-mdb(5)* to enforce the uniqueness of some or all attributes within a subtree.

12.16.2. Attribute Uniqueness Configuration

This overlay is only effective on new data from the point the overlay is enabled. To check uniqueness for existing data, you can export and import your data again via the LDAP Add operation, which will not be suitable for large amounts of data, unlike **slapcat**.

For the following example, if uniqueness were enforced for the **mail** attribute, the subtree would be searched for any other records which also have a **mail** attribute containing the same value presented with an **add**, **modify** or **modrdn** operation which are unique within the configured scope. If any are found, the request is rejected.

Note: If no attributes are specified, for example **ldap:///??sub?**, then the URI applies to all non-operational attributes. However, the keyword **ignore** can be specified to exclude certain non-operational attributes.

To search at the base dn of the current backend database ensuring uniqueness of the **mail** attribute, we simply add the following configuration:

```
overlay unique
unique_uri ldap:///?mail?sub?
```

For an existing entry of:

```
dn: cn=gavin,dc=suretecsystems,dc=com
objectClass: top
objectClass: inetorgperson
cn: gavin
```

```
sn: henry
mail: ghenry@suretecsystems.com
```

and we then try to add a new entry of:

```
dn: cn=robert,dc=suretecsystems,dc=com
objectClass: top
objectClass: inetorgperson
cn: robert
sn: jones
mail: ghenry@suretecsystems.com
```

would result in an error like so:

```
adding new entry "cn=robert,dc=example,dc=com"
ldap_add: Constraint violation (19)
        additional info: some attributes not unique
```

The overlay can have multiple URIs specified within a domain, allowing complex selections of objects and also have multiple **unique_uri** statements or **olcUniqueURI** attributes which will create independent domains.

For more information and details about the **strict** and **ignore** keywords, please see the *slapo-unique(5)* man page.

12.16.3. Further Information

slapo-unique(5)

12.17. Value Sorting

12.17.1. Overview

The Value Sorting overlay can be used with a backend database to sort the values of specific multi-valued attributes within a subtree. The sorting occurs whenever the attributes are returned in a search response.

12.17.2. Value Sorting Configuration

Sorting can be specified in ascending or descending order, using either numeric or alphanumeric sort methods. Additionally, a "weighted" sort can be specified, which uses a numeric weight prepended to the attribute values.

The weighted sort is always performed in ascending order, but may be combined with the other methods for values that all have equal weights. The weight is specified by prepending an integer weight {<weight>} in front of each value of the attribute for which weighted sorting is desired. This weighting factor is stripped off and never returned in search results.

Here are a few examples:

```
loglevel    sync stats

database    mdb
```

```
suffix      "dc=suretecsystems,dc=com"
directory   /usr/local/var/openldap-data

......

overlay valsort
valsort-attr memberUid ou=Groups,dc=suretecsystems,dc=com alpha-ascend
```

For example, ascend:

```
# sharedemail, Groups, suretecsystems.com
dn: cn=sharedemail,ou=Groups,dc=suretecsystems,dc=com
objectClass: posixGroup
objectClass: top
cn: sharedemail
gidNumber: 517
memberUid: admin
memberUid: dovecot
memberUid: laura
memberUid: suretec
```

For weighted, we change our data to:

```
# sharedemail, Groups, suretecsystems.com
dn: cn=sharedemail,ou=Groups,dc=suretecsystems,dc=com
objectClass: posixGroup
objectClass: top
cn: sharedemail
gidNumber: 517
memberUid: {4}admin
memberUid: {2}dovecot
memberUid: {1}laura
memberUid: {3}suretec
```

and change the config to:

```
overlay valsort
valsort-attr memberUid ou=Groups,dc=suretecsystems,dc=com weighted
```

Searching now results in:

```
# sharedemail, Groups, OxObjects, suretecsystems.com
dn: cn=sharedemail,ou=Groups,ou=OxObjects,dc=suretecsystems,dc=com
objectClass: posixGroup
objectClass: top
cn: sharedemail
gidNumber: 517
memberUid: laura
memberUid: dovecot
memberUid: suretec
memberUid: admin
```

12.17.3. Further Information

slapo-valsort(5)

12.18. Overlay Stacking

12.18.1. Overview

Overlays can be stacked, which means that more than one overlay can be instantiated for each database, or for the `frontend`. As a consequence, each overlays function is called, if defined, when overlay execution is invoked. Multiple overlays are executed in reverse order (as a stack) with respect to their definition in slapd.conf (5), or with respect to their ordering in the config database, as documented in slapd-config (5).

12.18.2. Example Scenarios

12.18.2.1. Samba

13. Schema Specification

This chapter describes how to extend the user schema used by *slapd*(8). The chapter assumes the reader is familiar with the LDAP/X.500 information model.

The first section, Distributed Schema Files details optional schema definitions provided in the distribution and where to obtain other definitions. The second section, Extending Schema, details how to define new schema items.

This chapter does not discuss how to extend system schema used by *slapd*(8) as this requires source code modification. System schema includes all operational attribute types or any object class which allows or requires an operational attribute (directly or indirectly).

13.1. Distributed Schema Files

OpenLDAP Software is distributed with a set of schema specifications for your use. Each set is defined in a file suitable for inclusion (using the `include` directive) in your *slapd.conf*(5) file. These schema files are normally installed in the `/usr/local/etc/openldap/schema` directory.

Table 8.1: Provided Schema Specifications

File	Description
`core.schema`	OpenLDAP *core* (required)
`cosine.schema`	Cosine and Internet X.500 (useful)
`inetorgperson.schema`	InetOrgPerson (useful)
`misc.schema`	Assorted (experimental)
`nis.schema`	Network Information Services (FYI)
`openldap.schema`	OpenLDAP Project (experimental)

To use any of these schema files, you only need to include the desired file in the global definitions portion of your *slapd.conf*(5) file. For example:

```
# include schema
include /usr/local/etc/openldap/schema/core.schema
include /usr/local/etc/openldap/schema/cosine.schema
include /usr/local/etc/openldap/schema/inetorgperson.schema
```

Additional files may be available. Please consult the OpenLDAP FAQ (http://www.openldap.org/faq/).

Note: You should not modify any of the schema items defined in provided files.

13.2. Extending Schema

Schema used by *slapd*(8) may be extended to support additional syntaxes, matching rules, attribute types, and object classes. This chapter details how to add user application attribute types and object classes using the syntaxes and matching rules already supported by slapd. slapd can also be extended to support additional syntaxes, matching rules and system schema, but this requires some programming and hence is not discussed here.

There are five steps to defining new schema:

1. obtain Object Identifier
2. choose a name prefix
3. create local schema file
4. define custom attribute types (if necessary)
5. define custom object classes

13.2.1. Object Identifiers

Each schema element is identified by a globally unique Object Identifier (OID). OIDs are also used to identify other objects. They are commonly found in protocols described by ASN.1. In particular, they are heavily used by the Simple Network Management Protocol (SNMP). As OIDs are hierarchical, your organization can obtain one OID and branch it as needed. For example, if your organization were assigned OID `1.1`, you could branch the tree as follows:

Table 8.2: Example OID hierarchy

OID	**Assignment**
`1.1`	Organization's OID
`1.1.1`	SNMP Elements
`1.1.2`	LDAP Elements
`1.1.2.1`	AttributeTypes
`1.1.2.1.1`	x-my-Attribute
`1.1.2.2`	ObjectClasses
`1.1.2.2.1`	x-my-ObjectClass

You are, of course, free to design a hierarchy suitable to your organizational needs under your organization's OID. No matter what hierarchy you choose, you should maintain a registry of assignments you make. This can be a simple flat file or something more sophisticated such as the *OpenLDAP OID Registry* (http://www.openldap.org/faq/index.cgi?file=197).

For more information about Object Identifiers (and a listing service) see http://www.alvestrand.no/objectid/.

Under no circumstances should you hijack OID namespace!

To obtain a registered OID at *no cost*, apply for a OID under the Internet Assigned Numbers Authority (ORG:IANA) maintained *Private Enterprise* arc. Any private enterprise (organization) may request a Private Enterprise Number (PEN) to be assigned under this arc. Just fill out the IANA form at http://pen.iana.org/pen/PenApplication.page and your official PEN will be sent to you usually within a few days. Your base OID will be something like `1.3.6.1.4.1.X` where `X` is an integer.

Note: PENs obtained using this form may be used for any purpose including identifying LDAP schema elements.

Alternatively, OID name space may be available from a national authority (e.g., ANSI, BSI).

13.2.2. Naming Elements

In addition to assigning a unique object identifier to each schema element, you should provide at least one textual name for each element. Names should be registered with the IANA or prefixed with "x-" to place in the "private use" name space.

The name should be both descriptive and not likely to clash with names of other schema elements. In particular, any name you choose should not clash with present or future Standard Track names (this is assured if you registered names or use names beginning with "x-").

It is noted that you can obtain your own registered name prefix so as to avoid having to register your names individually. See RFC4520 for details.

In the examples below, we have used a short prefix '`x-my-`'. Such a short prefix would only be suitable for a very large, global organization. In general, we recommend something like '`x-de-Firm-`' (German company) or '`x-com-Example`' (elements associated with organization associated with `example.com`).

13.2.3. Local schema file

The `objectclass` and `attributeTypes` configuration file directives can be used to define schema rules on entries in the directory. It is customary to create a file to contain definitions of your custom schema items. We recommend you create a file `local.schema` in `/usr/local/etc/openldap/schema/local.schema` and then include this file in your *slapd.conf*(5) file immediately after other schema `include` directives.

```
        # include schema
        include /usr/local/etc/openldap/schema/core.schema
        include /usr/local/etc/openldap/schema/cosine.schema
        include /usr/local/etc/openldap/schema/inetorgperson.schema
        # include local schema
        include /usr/local/etc/openldap/schema/local.schema
```

13.2.4. Attribute Type Specification

The *attributetype* directive is used to define a new attribute type. The directive uses the same Attribute Type Description (as defined in RFC4512) used by the attributeTypes attribute found in the subschema subentry, e.g.:

```
        attributetype <RFC4512 Attribute Type Description>
```

where Attribute Type Description is defined by the following ABNF:

```
      AttributeTypeDescription = "(" whsp
            numericoid whsp              ; AttributeType identifier
          [ "NAME" qdescrs ]             ; name used in AttributeType
          [ "DESC" qdstring ]            ; description
          [ "OBSOLETE" whsp ]
          [ "SUP" woid ]                 ; derived from this other
                                         ; AttributeType
          [ "EQUALITY" woid              ; Matching Rule name
          [ "ORDERING" woid              ; Matching Rule name
          [ "SUBSTR" woid ]              ; Matching Rule name
          [ "SYNTAX" whsp noidlen whsp ] ; Syntax OID
```

```
        [ "SINGLE-VALUE" whsp ]        ; default multi-valued
        [ "COLLECTIVE" whsp ]          ; default not collective
        [ "NO-USER-MODIFICATION" whsp ]; default user modifiable
        [ "USAGE" whsp AttributeUsage ]; default userApplications
        whsp ")"

    AttributeUsage =
        "userApplications"     /
        "directoryOperation"   /
        "distributedOperation" / ; DSA-shared
        "dSAOperation"          ; DSA-specific, value depends on server
```

where whsp is a space (' '), numericoid is a globally unique OID in dotted-decimal form (e.g. `1.1.0`), qdescrs is one or more names, woid is either the name or OID optionally followed by a length specifier (e.g `{10}`).

For example, the attribute types `name` and `cn` are defined in `core.schema` as:

```
        attributeType ( 2.5.4.41 NAME 'name'
                DESC 'name(s) associated with the object'
                EQUALITY caseIgnoreMatch
                SUBSTR caseIgnoreSubstringsMatch
                SYNTAX 1.3.6.1.4.1.1466.115.121.1.15{32768} )
        attributeType ( 2.5.4.3 NAME ( 'cn' 'commonName' )
                DESC 'common name(s) associated with the object'
                SUP name )
```

Notice that each defines the attribute's OID, provides a short name, and a brief description. Each name is an alias for the OID. *slapd*(8) returns the first listed name when returning results.

The first attribute, `name`, holds values of `directoryString` (UTF-8 encoded Unicode) syntax. The syntax is specified by OID (1.3.6.1.4.1.1466.115.121.1.15 identifies the directoryString syntax). A length recommendation of 32768 is specified. Servers should support values of this length, but may support longer values. The field does NOT specify a size constraint, so is ignored on servers (such as slapd) which don't impose such size limits. In addition, the equality and substring matching uses case ignore rules. Below are tables listing commonly used syntax and matching rules (*slapd*(8) supports these and many more).

Table 8.3: Commonly Used Syntaxes

Name	**OID**	**Description**
`boolean`	`1.3.6.1.4.1.1466.115.121.1.7`	boolean value
`directoryString`	`1.3.6.1.4.1.1466.115.121.1.15`	Unicode (UTF-8) string
`distinguishedName`	`1.3.6.1.4.1.1466.115.121.1.12`	LDAP DN
`integer`	`1.3.6.1.4.1.1466.115.121.1.27`	integer
`numericString`	`1.3.6.1.4.1.1466.115.121.1.36`	numeric string
`OID`	`1.3.6.1.4.1.1466.115.121.1.38`	object identifier
`octetString`	`1.3.6.1.4.1.1466.115.121.1.40`	arbitrary octets

Table 8.4: Commonly Used Matching Rules

Name	**Type**	**Description**

booleanMatch	equality	boolean
caseIgnoreMatch	equality	case insensitive, space insensitive
caseIgnoreOrderingMatch	ordering	case insensitive, space insensitive
caseIgnoreSubstringsMatch	substrings	case insensitive, space insensitive
caseExactMatch	equality	case sensitive, space insensitive
caseExactOrderingMatch	ordering	case sensitive, space insensitive
caseExactSubstringsMatch	substrings	case sensitive, space insensitive
distinguishedNameMatch	equality	distinguished name
integerMatch	equality	integer
integerOrderingMatch	ordering	integer
numericStringMatch	equality	numerical
numericStringOrderingMatch	ordering	numerical
numericStringSubstringsMatch	substrings	numerical
octetStringMatch	equality	octet string
octetStringOrderingMatch	ordering	octet string
octetStringSubstringsMatch ordering	octet st	ring
objectIdentiferMatch	equality	object identifier

The second attribute, cn, is a subtype of name hence it inherits the syntax, matching rules, and usage of name. commonName is an alternative name.

Neither attribute is restricted to a single value. Both are meant for usage by user applications. Neither is obsolete nor collective.

The following subsections provide a couple of examples.

13.2.4.1. x-my-UniqueName

Many organizations maintain a single unique name for each user. Though one could use displayName (RFC2798), this attribute is really meant to be controlled by the user, not the organization. We could just copy the definition of displayName from inetorgperson.schema and replace the OID, name, and description, e.g:

```
attributetype ( 1.1.2.1.1 NAME 'x-my-UniqueName'
        DESC 'unique name with my organization'
        EQUALITY caseIgnoreMatch
        SUBSTR caseIgnoreSubstringsMatch
        SYNTAX 1.3.6.1.4.1.1466.115.121.1.15
        SINGLE-VALUE )
```

However, if we want this name to be used in name assertions, e.g. (name=*Jane*), the attribute could alternatively be defined as a subtype of name, e.g.:

```
attributetype ( 1.1.2.1.1 NAME 'x-my-UniqueName'
        DESC 'unique name with my organization'
        SUP name )
```

13.2.4.2. x-my-Photo

Many organizations maintain a photo of each each user. A `x-my-Photo` attribute type could be defined to hold a photo. Of course, one could use just use `jpegPhoto` (RFC2798) (or a subtype) to hold the photo. However, you can only do this if the photo is in *JPEG File Interchange Format*. Alternatively, an attribute type which uses the *Octet String* syntax can be defined, e.g.:

```
        attributetype ( 1.1.2.1.2 NAME 'x-my-Photo'
                DESC 'a photo (application defined format)'
                SYNTAX 1.3.6.1.4.1.1466.115.121.1.40
                SINGLE-VALUE )
```

In this case, the syntax doesn't specify the format of the photo. It's assumed (maybe incorrectly) that all applications accessing this attribute agree on the handling of values.

If you wanted to support multiple photo formats, you could define a separate attribute type for each format, prefix the photo with some typing information, or describe the value using ASN.1 and use the `;binary` transfer option.

Another alternative is for the attribute to hold a URI pointing to the photo. You can model such an attribute after `labeledURI` (RFC2079) or simply create a subtype, e.g.:

```
        attributetype ( 1.1.2.1.3 NAME 'x-my-PhotoURI'
                DESC 'URI and optional label referring to a photo'
                SUP labeledURI )
```

13.2.5. Object Class Specification

The *objectclasses* directive is used to define a new object class. The directive uses the same Object Class Description (as defined in RFC4512) used by the objectClasses attribute found in the subschema subentry, e.g.:

```
        objectclass <RFC4512 Object Class Description>
```

where Object Class Description is defined by the following ABNF:

```
        ObjectClassDescription = "(" whsp
                numericoid whsp      ; ObjectClass identifier
                [ "NAME" qdescrs ]
                [ "DESC" qdstring ]
                [ "OBSOLETE" whsp ]
                [ "SUP" oids ]       ; Superior ObjectClasses
                [ ( "ABSTRACT" / "STRUCTURAL" / "AUXILIARY" ) whsp ]
                        ; default structural
                [ "MUST" oids ]      ; AttributeTypes
                [ "MAY" oids ]       ; AttributeTypes
                whsp ")"
```

where whsp is a space (' '), numericoid is a globally unique OID in dotted-decimal form (e.g. `1.1.0`), qdescrs is one or more names, and oids is one or more names and/or OIDs.

13.2.5.1. x-my-PhotoObject

To define an *auxiliary* object class which allows x-my-Photo to be added to any existing entry.

```
        objectclass ( 1.1.2.2.1 NAME 'x-my-PhotoObject'
                DESC 'mixin x-my-Photo'
                AUXILIARY
                MAY x-my-Photo )
```

13.2.5.2. x-my-Person

If your organization would like have a private *structural* object class to instantiate users, you can subclass one of the existing person classes, such as `inetOrgPerson` (RFC2798), and add any additional attributes which you desire.

```
        objectclass ( 1.1.2.2.2 NAME 'x-my-Person'
                DESC 'my person'
                SUP inetOrgPerson
                MUST ( x-my-UniqueName $ givenName )
                MAY x-my-Photo )
```

The object class inherits the required/allowed attribute types of `inetOrgPerson` but requires `x-my-UniqueName` and `givenName` and allows `x-my-Photo`.

13.2.6. OID Macros

To ease the management and use of OIDs, *slapd*(8) supports *Object Identifier* macros. The `objectIdentifier` directive is used to equate a macro (name) with a OID. The OID may possibly be derived from a previously defined OID macro. The *slapd.conf*(5) syntax is:

```
        objectIdentifier <name> { <oid> | <name>[:<suffix>] }
```

The following demonstrates definition of a set of OID macros and their use in defining schema elements:

```
        objectIdentifier myOID  1.1
        objectIdentifier mySNMP myOID:1
        objectIdentifier myLDAP myOID:2
        objectIdentifier myAttributeType        myLDAP:1
        objectIdentifier myObjectClass  myLDAP:2
        attributetype ( myAttributeType:3 NAME 'x-my-PhotoURI'
                DESC 'URI and optional label referring to a photo'
                SUP labeledURI )
        objectclass ( myObjectClass:1 NAME 'x-my-PhotoObject'
                DESC 'mixin x-my-Photo'
                AUXILIARY
                MAY x-my-Photo )
```

14. Security Considerations

OpenLDAP Software is designed to run in a wide variety of computing environments from tightly-controlled closed networks to the global Internet. Hence, OpenLDAP Software supports many different security mechanisms. This chapter describes these mechanisms and discusses security considerations for using OpenLDAP Software.

14.1. Network Security

14.1.1. Selective Listening

By default, *slapd*(8) will listen on both the IPv4 and IPv6 "any" addresses. It is often desirable to have *slapd* listen on select address/port pairs. For example, listening only on the IPv4 address `127.0.0.1` will disallow remote access to the directory server. E.g.:

```
        slapd -h ldap://127.0.0.1
```

While the server can be configured to listen on a particular interface address, this doesn't necessarily restrict access to the server to only those networks accessible via that interface. To selective restrict remote access, it is recommend that an IP Firewall be used to restrict access.

See Command-line Options and *slapd*(8) for more information.

14.1.2. IP Firewall

IP firewall capabilities of the server system can be used to restrict access based upon the client's IP address and/or network interface used to communicate with the client.

Generally, *slapd*(8) listens on port 389/tcp for ldap:// sessions and port 636/tcp for ldaps://) sessions. *slapd*(8) may be configured to listen on other ports.

As specifics of how to configure IP firewall are dependent on the particular kind of IP firewall used, no examples are provided here. See the document associated with your IP firewall.

14.1.3. TCP Wrappers

slapd(8) supports TCP Wrappers. TCP Wrappers provide a rule-based access control system for controlling TCP/IP access to the server. For example, the *host_options*(5) rule:

```
        slapd: 10.0.0.0/255.0.0.0 127.0.0.1 : ALLOW
        slapd: ALL : DENY
```

allows only incoming connections from the private network `10.0.0.0` and localhost (`127.0.0.1`) to access the directory service.

Note: IP addresses are used as *slapd*(8) is not normally configured to perform reverse lookups.

It is noted that TCP wrappers require the connection to be accepted. As significant processing is required just to deny a connection, it is generally advised that IP firewall protection be used instead of TCP wrappers.

See *hosts_access*(5) for more information on TCP wrapper rules.

14.2. Data Integrity and Confidentiality Protection

Transport Layer Security (TLS) can be used to provide data integrity and confidentiality protection. OpenLDAP supports negotiation of TLS (SSL) via both StartTLS and ldaps://. See the Using TLS chapter for more information. StartTLS is the standard track mechanism.

A number of Simple Authentication and Security Layer (SASL) mechanisms, such as DIGEST-MD5 and GSSAPI, also provide data integrity and confidentiality protection. See the Using SASL chapter for more information.

14.2.1. Security Strength Factors

The server uses Security Strength Factors (SSF) to indicate the relative strength of protection. A SSF of zero (0) indicates no protections are in place. A SSF of one (1) indicates integrity protection are in place. A SSF greater than one (>1) roughly correlates to the effective encryption key length. For example, DES is 56, 3DES is 112, and AES 128, 192, or 256.

A number of administrative controls rely on SSFs associated with TLS and SASL protection in place on an LDAP session.

`security` controls disallow operations when appropriate protections are not in place. For example:

```
        security ssf=1 update_ssf=112
```

requires integrity protection for all operations and encryption protection, 3DES equivalent, for update operations (e.g. add, delete, modify, etc.). See *slapd.conf*(5) for details.

For fine-grained control, SSFs may be used in access controls. See the Access Control section for more information.

14.3. Authentication Methods

14.3.1. "simple" method

The LDAP "simple" method has three modes of operation:

- anonymous,
- unauthenticated, and
- user/password authenticated.

Anonymous access is requested by providing no name and no password to the "simple" bind operation. Unauthenticated access is requested by providing a name but no password. Authenticated access is requested by providing a valid name and password.

An anonymous bind results in an *anonymous* authorization association. Anonymous bind mechanism is enabled by default, but can be disabled by specifying "`disallow bind_anon`" in *slapd.conf*(5).

Note: Disabling the anonymous bind mechanism does not prevent anonymous access to the directory. To require authentication to access the directory, one should instead specify "`require authc`".

An unauthenticated bind also results in an *anonymous* authorization association. Unauthenticated bind mechanism is disabled by default, but can be enabled by specifying "`allow bind_anon_cred`" in *slapd.conf*(5). As a number of LDAP applications mistakenly generate unauthenticated bind request when authenticated access was intended (that is, they do not ensure a password was provided), this mechanism should generally remain disabled.

A successful user/password authenticated bind results in a user authorization identity, the provided name, being associated with the session. User/password authenticated bind is enabled by default. However, as this mechanism itself offers no eavesdropping protection (e.g., the password is set in the clear), it is recommended that it be used only in tightly controlled systems or when the LDAP session is protected by other means (e.g., TLS, IPsec). Where the administrator relies on TLS to protect the password, it is recommended that unprotected authentication be disabled. This is done using the `security` directive's `simple_bind` option, which provides fine grain control over the level of confidential protection to require for *simple* user/password authentication. E.g., using `security simple_bind=56` would require *simple* binds to use encryption of DES equivalent or better.

The user/password authenticated bind mechanism can be completely disabled by setting "`disallow bind_simple`".

Note: An unsuccessful bind always results in the session having an *anonymous* authorization association.

14.3.2. SASL method

The LDAP SASL method allows the use of any SASL authentication mechanism. The Using SASL section discusses the use of SASL.

14.4. Password Storage

LDAP passwords are normally stored in the *userPassword* attribute. RFC4519 specifies that passwords are not stored in encrypted (or hashed) form. This allows a wide range of password-based authentication mechanisms, such as `DIGEST-MD5` to be used. This is also the most interoperable storage scheme.

However, it may be desirable to store a hash of password instead. *slapd*(8) supports a variety of storage schemes for the administrator to choose from.

Note: Values of password attributes, regardless of storage scheme used, should be protected as if they were clear text. Hashed passwords are subject to *dictionary attacks* and *brute-force attacks*.

The *userPassword* attribute is allowed to have more than one value, and it is possible for each value to be stored in a different form. During authentication, *slapd* will iterate through the values until it finds one that matches the offered password or until it runs out of values to inspect. The storage scheme is stored as a prefix on the value, so a hashed password using the Salted SHA1 (`SSHA`) scheme looks like:

```
        userPassword: {SSHA}DkMTwBl+a/3DQTxCYEApdUtNXGgdUac3
```

The advantage of hashed passwords is that an attacker which discovers the hash does not have direct access to the actual password. Unfortunately, as dictionary and brute force attacks are generally quite easy for attackers to successfully mount, this advantage is marginal at best (this is why all modern Unix systems use shadow password files).

The disadvantages of hashed storage is that they are non-standard, may cause interoperability problem, and generally preclude the use of stronger than Simple (or SASL/PLAIN) password-based authentication mechanisms such as `DIGEST-MD5`.

14.4.1. SSHA password storage scheme

This is the salted version of the SHA scheme. It is believed to be the most secure password storage scheme supported by *slapd*.

These values represent the same password:

```
        userPassword: {SSHA}DkMTwBl+a/3DQTxCYEApdUtNXGgdUac3
        userPassword: {SSHA}d0Q0626PSH9VUld7yWpR0k6BlpQmtczb
```

14.4.2. CRYPT password storage scheme

This scheme uses the operating system's *crypt(3)* hash function. It normally produces the traditional Unix-style 13 character hash, but on systems with `glibc2` it can also generate the more secure 34-byte MD5 hash.

```
        userPassword: {CRYPT}aUihad99hmev6
        userPassword: {CRYPT}$1$czBJdDqS$TmkzUAb836oMxg/BmIwN.1
```

The advantage of the CRYPT scheme is that passwords can be transferred to or from an existing Unix password file without having to know the cleartext form. Both forms of *crypt* include salt so they have some resistance to dictionary attacks.

Note: Since this scheme uses the operating system's *crypt(3)* hash function, it is therefore operating system specific.

14.4.3. MD5 password storage scheme

This scheme simply takes the MD5 hash of the password and stores it in base64 encoded form:

```
        userPassword: {MD5}Xr4ilOzQ4PCOq3aQ0qbuaQ==
```

Although safer than cleartext storage, this is not a very secure scheme. The MD5 algorithm is fast, and because there is no salt the scheme is vulnerable to a dictionary attack.

14.4.4. SMD5 password storage scheme

This improves on the basic MD5 scheme by adding salt (random data which means that there are many possible representations of a given plaintext password). For example, both of these values represent the same password:

```
        userPassword: {SMD5}4QWGWZpj9GCmfuqEvm8HtZhZS6E=
        userPassword: {SMD5}g2/J/7D5EO6+oPdklp5p8YtNFk4=
```

14.4.5. SHA password storage scheme

Like the MD5 scheme, this simply feeds the password through an SHA hash process. SHA is thought to be more secure than MD5, but the lack of salt leaves the scheme exposed to dictionary attacks.

```
        userPassword: {SHA}5en6G6MezRroT3XKqkdPOmY/BfQ=
```

14.4.6. SASL password storage scheme

This is not really a password storage scheme at all. It uses the value of the *userPassword* attribute to delegate password verification to another process. See below for more information.

Note: This is not the same as using SASL to authenticate the LDAP session.

14.5. Pass-Through authentication

Since OpenLDAP 2.0 *slapd* has had the ability to delegate password verification to a separate process. This uses the *sasl_checkpass(3)* function so it can use any back-end server that Cyrus SASL supports for checking passwords. The choice is very wide, as one option is to use *saslauthd(8)* which in turn can use local files, Kerberos, an IMAP server, another LDAP server, or anything supported by the PAM mechanism.

The server must be built with the `--enable-spasswd` configuration option to enable pass-through authentication.

Note: This is not the same as using a SASL mechanism to authenticate the LDAP session.

Pass-Through authentication works only with plaintext passwords, as used in the "simple bind" and "SASL PLAIN" authentication mechanisms.

Pass-Through authentication is selective: it only affects users whose *userPassword* attribute has a value marked with the "{SASL}" scheme. The format of the attribute is:

```
        userPassword: {SASL}username@realm
```

The *username* and *realm* are passed to the SASL authentication mechanism and are used to identify the account whose password is to be verified. This allows arbitrary mapping between entries in OpenLDAP and accounts known to the backend authentication service.

It would be wise to use access control to prevent users from changing their passwords through LDAP where they have pass-through authentication enabled.

14.5.1. Configuring slapd to use an authentication provider

Where an entry has a "{SASL}" password value, OpenLDAP delegates the whole process of validating that entry's password to Cyrus SASL. All the configuration is therefore done in SASL config files.

The first file to be considered is confusingly named *slapd.conf* and is typically found in the SASL library directory, often `/usr/lib/sasl2/slapd.conf` This file governs the use of SASL when talking LDAP to *slapd* as well as the use of SASL backends for pass-through authentication. See `options.html` in the

Cyrus SASL docs for full details. Here is a simple example for a server that will use *saslauthd* to verify passwords:

```
        mech_list: plain
        pwcheck_method: saslauthd
        saslauthd_path: /var/run/sasl2/mux
```

14.5.2. Configuring saslauthd

saslauthd is capable of using many different authentication services: see *saslauthd(8)* for details. A common requirement is to delegate some or all authentication to another LDAP server. Here is a sample `saslauthd.conf` that uses Microsoft Active Directory (AD):

```
        ldap_servers: ldap://dc1.example.com/ ldap://dc2.example.com/

        ldap_search_base: cn=Users,DC=ad,DC=example,DC=com
        ldap_filter: (userPrincipalName=%u)

        ldap_bind_dn: cn=saslauthd,cn=Users,DC=ad,DC=example,DC=com
        ldap_password: secret
```

In this case, *saslauthd* is run with the `ldap` authentication mechanism and is set to combine the SASL realm with the login name:

```
        saslauthd -a ldap -r
```

This means that the "username@realm" string from the *userPassword* attribute ends up being used to search AD for "userPrincipalName=username@realm" - the password is then verified by attempting to bind to AD using the entry found by the search and the password supplied by the LDAP client.

14.5.3. Testing pass-through authentication

It is usually best to start with the back-end authentication provider and work through *saslauthd* and *slapd* towards the LDAP client.

In the AD example above, first check that the DN and password that *saslauthd* will use when it connects to AD are valid:

```
        ldapsearch -x -H ldap://dc1.example.com/ \
             -D cn=saslauthd,cn=Users,DC=ad,DC=example,DC=com \
             -w secret \
             -b '' \
             -s base
```

Next check that a sample AD user can be found:

```
        ldapsearch -x -H ldap://dc1.example.com/ \
             -D cn=saslauthd,cn=Users,DC=ad,DC=example,DC=com \
             -w secret \
             -b cn=Users,DC=ad,DC=example,DC=com \
             "(userPrincipalName=user@ad.example.com)"
```

Check that the user can bind to AD:

```
ldapsearch -x -H ldap://dc1.example.com/ \
     -D cn=user,cn=Users,DC=ad,DC=example,DC=com \
     -w userpassword \
     -b cn=user,cn=Users,DC=ad,DC=example,DC=com \
     -s base \
       "(objectclass=*)"
```

If all that works then *saslauthd* should be able to do the same:

```
testsaslauthd -u user@ad.example.com -p userpassword
testsaslauthd -u user@ad.example.com -p wrongpassword
```

Now put the magic token into an entry in OpenLDAP:

```
userPassword: {SASL}user@ad.example.com
```

It should now be possible to bind to OpenLDAP using the DN of that entry and the password of the AD user.

15. Using SASL

OpenLDAP clients and servers are capable of authenticating via the Simple Authentication and Security Layer (SASL) framework, which is detailed in RFC4422. This chapter describes how to make use of SASL in OpenLDAP.

There are several industry standard authentication mechanisms that can be used with SASL, including GSSAPI for Kerberos V, DIGEST-MD5, and PLAIN and EXTERNAL for use with Transport Layer Security (TLS).

The standard client tools provided with OpenLDAP Software, such as *ldapsearch*(1) and *ldapmodify*(1), will by default attempt to authenticate the user to the LDAP directory server using SASL. Basic authentication service can be set up by the LDAP administrator with a few steps, allowing users to be authenticated to the slapd server as their LDAP entry. With a few extra steps, some users and services can be allowed to exploit SASL's proxy authorization feature, allowing them to authenticate themselves and then switch their identity to that of another user or service.

This chapter assumes you have read *Cyrus SASL for System Administrators*, provided with the Cyrus SASL package (in `doc/sysadmin.html`) and have a working Cyrus SASL installation. You should use the Cyrus SASL `sample_client` and `sample_server` to test your SASL installation before attempting to make use of it with OpenLDAP Software.

Note that in the following text the term *user* is used to describe a person or application entity who is connecting to the LDAP server via an LDAP client, such as *ldapsearch*(1). That is, the term *user* not only applies to both an individual using an LDAP client, but to an application entity which issues LDAP client operations without direct user control. For example, an e-mail server which uses LDAP operations to access information held in an LDAP server is an application entity.

15.1. SASL Security Considerations

SASL offers many different authentication mechanisms. This section briefly outlines security considerations.

Some mechanisms, such as PLAIN and LOGIN, offer no greater security over LDAP *simple* authentication. Like LDAP *simple* authentication, such mechanisms should not be used unless you have adequate security protections in place. It is recommended that these mechanisms be used only in conjunction with Transport Layer Security (TLS). Use of PLAIN and LOGIN are not discussed further in this document.

The DIGEST-MD5 mechanism is the mandatory-to-implement authentication mechanism for LDAPv3. Though DIGEST-MD5 is not a strong authentication mechanism in comparison with trusted third party authentication systems (such as Kerberos or public key systems), it does offer significant protections against a number of attacks. Unlike the CRAM-MD5 mechanism, it prevents chosen plaintext attacks. DIGEST-MD5 is favored over the use of plaintext password mechanisms. The CRAM-MD5 mechanism is deprecated in favor of DIGEST-MD5. Use of DIGEST-MD5 is discussed below.

The GSSAPI mechanism utilizes GSS-API Kerberos V to provide secure authentication services. The KERBEROS_V4 mechanism is available for those using Kerberos IV. Kerberos is viewed as a secure, distributed authentication system suitable for both small and large enterprises. Use of GSSAPI and KERBEROS_V4 are discussed below.

The EXTERNAL mechanism utilizes authentication services provided by lower level network services such as Transport Layer Security (TLS). When used in conjunction with TLS X.509-based public key technology, EXTERNAL offers strong authentication. TLS is discussed in the Using TLS chapter.

EXTERNAL can also be used with the `ldapi:///` transport, as Unix-domain sockets can report the UID and GID of the client process.

There are other strong authentication mechanisms to choose from, including OTP (one time passwords) and SRP (secure remote passwords). These mechanisms are not discussed in this document.

15.2. SASL Authentication

Getting basic SASL authentication running involves a few steps. The first step configures your slapd server environment so that it can communicate with client programs using the security system in place at your site. This usually involves setting up a service key, a public key, or other form of secret. The second step concerns mapping authentication identities to LDAP DN's, which depends on how entries are laid out in your directory. An explanation of the first step will be given in the next section using Kerberos V4 as an example mechanism. The steps necessary for your site's authentication mechanism will be similar, but a guide to every mechanism available under SASL is beyond the scope of this chapter. The second step is described in the section Mapping Authentication Identities.

15.2.1. GSSAPI

This section describes the use of the SASL GSSAPI mechanism and Kerberos V with OpenLDAP. It will be assumed that you have Kerberos V deployed, you are familiar with the operation of the system, and that your users are trained in its use. This section also assumes you have familiarized yourself with the use of the GSSAPI mechanism by reading *Configuring GSSAPI and Cyrus SASL* (provided with Cyrus SASL in the `doc/gssapi` file) and successfully experimented with the Cyrus provided `sample_server` and `sample_client` applications. General information about Kerberos is available at http://web.mit.edu/kerberos/www/.

To use the GSSAPI mechanism with *slapd*(8) one must create a service key with a principal for *ldap* service within the realm for the host on which the service runs. For example, if you run *slapd* on `directory.example.com` and your realm is `EXAMPLE.COM`, you need to create a service key with the principal:

```
        ldap/directory.example.com@EXAMPLE.COM
```

When *slapd*(8) runs, it must have access to this key. This is generally done by placing the key into a keytab file, `/etc/krb5.keytab`. See your Kerberos and Cyrus SASL documentation for information regarding keytab location settings.

To use the GSSAPI mechanism to authenticate to the directory, the user obtains a Ticket Granting Ticket (TGT) prior to running the LDAP client. When using OpenLDAP client tools, the user may mandate use of the GSSAPI mechanism by specifying `-Y GSSAPI` as a command option.

For the purposes of authentication and authorization, *slapd*(8) associates an authentication request DN of the form:

```
        uid=<primary[/instance][@realm]>,cn=gssapi,cn=auth
```

The realm is omitted by Cyrus SASL if it's equal to the default realm of the server in `/etc/krb5.conf`.

Continuing our example, a user with the Kerberos principal `kurt@EXAMPLE.COM` would have the associated DN:

```
uid=kurt,cn=gssapi,cn=auth
```

and the principal `ursula/admin@FOREIGN.REALM` would have the associated DN:

```
uid=ursula/admin@foreign.realm,cn=gssapi,cn=auth
```

The authentication request DN can be used directly in ACLs and `groupOfNames` "member" attributes, since it is of legitimate LDAP DN format. Or alternatively, the authentication DN could be mapped before use. See the section Mapping Authentication Identities for details.

If you configure the *olcSaslRealm* then it will be inserted as an extra component in the authorization DN, regardless of any Kerberos realms in use. For example, if you set olcSaslRealm to `example.com` then you will get:

```
uid=kurt,cn=example.com,cn=gssapi,cn=auth
uid=ursula/admin@foreign.realm,cn=example.com,cn=gssapi,cn=auth
```

15.2.2. KERBEROS_V4

This section describes the use of the SASL KERBEROS_V4 mechanism with OpenLDAP. It will be assumed that you are familiar with the workings of the Kerberos IV security system, and that your site has Kerberos IV deployed. Your users should be familiar with authentication policy, how to receive credentials in a Kerberos ticket cache, and how to refresh expired credentials.

Note: KERBEROS_V4 and Kerberos IV are deprecated in favor of GSSAPI and Kerberos V.

Client programs will need to be able to obtain a session key for use when connecting to your LDAP server. This allows the LDAP server to know the identity of the user, and allows the client to know it is connecting to a legitimate server. If encryption layers are to be used, the session key can also be used to help negotiate that option.

The slapd server runs the service called "*ldap*", and the server will require a srvtab file with a service key. SASL aware client programs will be obtaining an "ldap" service ticket with the user's ticket granting ticket (TGT), with the instance of the ticket matching the hostname of the OpenLDAP server. For example, if your realm is named `EXAMPLE.COM` and the slapd server is running on the host named `directory.example.com`, the `/etc/srvtab` file on the server will have a service key

```
ldap.directory@EXAMPLE.COM
```

When an LDAP client is authenticating a user to the directory using the KERBEROS_IV mechanism, it will request a session key for that same principal, either from the ticket cache or by obtaining a new one from the Kerberos server. This will require the TGT to be available and valid in the cache as well. If it is not present or has expired, the client may print out the message:

```
ldap_sasl_interactive_bind_s: Local error
```

When the service ticket is obtained, it will be passed to the LDAP server as proof of the user's identity. The server will extract the identity and realm out of the service ticket using SASL library calls, and convert them into an *authentication request DN* of the form

```
uid=<username>,cn=<realm>,cn=<mechanism>,cn=auth
```

So in our above example, if the user's name were "adamson", the authentication request DN would be:

```
uid=adamson,cn=example.com,cn=kerberos_v4,cn=auth
```

This authentication request DN can be used directly ACLs or, alternatively, mapped prior to use. See the section Mapping Authentication Identities for details.

15.2.3. DIGEST-MD5

This section describes the use of the SASL DIGEST-MD5 mechanism using secrets stored either in the directory itself or in Cyrus SASL's own database. DIGEST-MD5 relies on the client and the server sharing a "secret", usually a password. The server generates a challenge and the client a response proving that it knows the shared secret. This is much more secure than simply sending the secret over the wire.

Cyrus SASL supports several shared-secret mechanisms. To do this, it needs access to the plaintext password (unlike mechanisms which pass plaintext passwords over the wire, where the server can store a hashed version of the password).

The server's copy of the shared-secret may be stored in Cyrus SASL's own *sasldb* database, in an external system accessed via *saslauthd*, or in LDAP database itself. In either case it is very important to apply file access controls and LDAP access controls to prevent exposure of the passwords. The configuration and commands discussed in this section assume the use of Cyrus SASL 2.1.

To use secrets stored in *sasldb*, simply add users with the *saslpasswd2* command:

```
saslpasswd2 -c <username>
```

The passwords for such users must be managed with the *saslpasswd2* command.

To use secrets stored in the LDAP directory, place plaintext passwords in the `userPassword` attribute. It will be necessary to add an option to `slapd.conf` to make sure that passwords set using the LDAP Password Modify Operation are stored in plaintext:

```
password-hash   {CLEARTEXT}
```

Passwords stored in this way can be managed either with *ldappasswd*(1) or by simply modifying the `userPassword` attribute. Regardless of where the passwords are stored, a mapping will be needed from authentication request DN to user's DN.

The DIGEST-MD5 mechanism produces authentication IDs of the form:

```
uid=<username>,cn=<realm>,cn=digest-md5,cn=auth
```

If the default realm is used, the realm name is omitted from the ID, giving:

```
uid=<username>,cn=digest-md5,cn=auth
```

See Mapping Authentication Identities below for information on optional mapping of identities.

With suitable mappings in place, users can specify SASL IDs when performing LDAP operations, and the password stored in *sasldb* or in the directory itself will be used to verify the authentication. For example, the user identified by the directory entry:

```
dn: cn=Andrew Findlay+uid=u000997,dc=example,dc=com
objectclass: inetOrgPerson
objectclass: person
sn: Findlay
uid: u000997
userPassword: secret
```

can issue commands of the form:

```
ldapsearch -Y DIGEST-MD5 -U u000997 ...
```

Note: in each of the above cases, no authorization identity (e.g. `-X`) was provided. Unless you are attempting SASL Proxy Authorization, no authorization identity should be specified. The server will infer an authorization identity from authentication identity (as described below).

15.2.4. EXTERNAL

The SASL EXTERNAL mechanism makes use of an authentication performed by a lower-level protocol: usually TLS or Unix IPC

Each transport protocol returns Authentication Identities in its own format:

15.2.4.1. TLS Authentication Identity Format

This is the Subject DN from the client-side certificate. Note that DNs are displayed differently by LDAP and by X.509, so a certificate issued to

```
C=gb, O=The Example Organisation, CN=A Person
```

will produce an authentication identity of:

```
cn=A Person,o=The Example Organisation,c=gb
```

Note that you must set a suitable value for TLSVerifyClient to make the server request the use of a client-side certificate. Without this, the SASL EXTERNAL mechanism will not be offered. Refer to the Using TLS chapter for details.

15.2.4.2. IPC (ldapi:///) Identity Format

This is formed from the Unix UID and GID of the client process:

```
gidNumber=<number>+uidNumber=<number>,cn=peercred,cn=external,cn=auth
```

Thus, a client process running as `root` will be:

```
gidNumber=0+uidNumber=0,cn=peercred,cn=external,cn=auth
```

15.2.5. Mapping Authentication Identities

The authentication mechanism in the slapd server will use SASL library calls to obtain the authenticated user's "username", based on whatever underlying authentication mechanism was used. This username is in the namespace of the authentication mechanism, and not in the normal LDAP namespace. As stated in the sections above, that username is reformatted into an authentication request DN of the form

```
        uid=<username>,cn=<realm>,cn=<mechanism>,cn=auth
```

or

```
        uid=<username>,cn=<mechanism>,cn=auth
```

depending on whether or not <mechanism> employs the concept of "realms". Note also that the realm part will be omitted if the default realm was used in the authentication.

The *ldapwhoami*(1) command may be used to determine the identity associated with the user. It is very useful for determining proper function of mappings.

It is not intended that you should add LDAP entries of the above form to your LDAP database. Chances are you have an LDAP entry for each of the persons that will be authenticating to LDAP, laid out in your directory tree, and the tree does not start at cn=auth. But if your site has a clear mapping between the "username" and an LDAP entry for the person, you will be able to configure your LDAP server to automatically map a authentication request DN to the user's *authentication DN*.

Note: it is not required that the authentication request DN nor the user's authentication DN resulting from the mapping refer to an entry held in the directory. However, additional capabilities become available (see below).

The LDAP administrator will need to tell the slapd server how to map an authentication request DN to a user's authentication DN. This is done by adding one or more `authz-regexp` directives to the *slapd.conf*(5) file. This directive takes two arguments:

```
        authz-regexp   <search pattern>   <replacement pattern>
```

The authentication request DN is compared to the search pattern using the regular expression functions *regcomp*() and *regexec*(), and if it matches, it is rewritten as the replacement pattern. If there are multiple `authz-regexp` directives, only the first whose search pattern matches the authentication identity is used. The string that is output from the replacement pattern should be the authentication DN of the user or an LDAP URL. If replacement string produces a DN, the entry named by this DN need not be held by this server. If the replace string produces an LDAP URL, that LDAP URL must evaluate to one and only one entry held by this server.

The search pattern can contain any of the regular expression characters listed in *regexec*(3C). The main characters of note are dot ".", asterisk "*", and the open and close parenthesis "(" and ")". Essentially, the dot matches any character, the asterisk allows zero or more repeats of the immediately preceding character or pattern, and terms in parenthesis are remembered for the replacement pattern.

The replacement pattern will produce either a DN or URL referring to the user. Anything from the authentication request DN that matched a string in parenthesis in the search pattern is stored in the variable "$1". That variable "$1" can appear in the replacement pattern, and will be replaced by the string from the authentication request DN. If there were multiple sets of parentheses in the search pattern, the variables $2, $3, etc are used.

15.2.6. Direct Mapping

Where possible, direct mapping of the authentication request DN to the user's DN is generally recommended. Aside from avoiding the expense of searching for the user's DN, it allows mapping to DNs which refer to entries not held by this server.

Suppose the authentication request DN is written as:

```
uid=adamson,cn=example.com,cn=gssapi,cn=auth
```

and the user's actual LDAP entry is:

```
uid=adamson,ou=people,dc=example,dc=com
```

then the following `authz-regexp` directive in *slapd.conf*(5) would provide for direct mapping.

```
authz-regexp
  uid=([^,]*),cn=example.com,cn=gssapi,cn=auth
  uid=$1,ou=people,dc=example,dc=com
```

An even more lenient rule could be written as

```
authz-regexp
  uid=([^,]*),cn=[^,]*,cn=auth
  uid=$1,ou=people,dc=example,dc=com
```

Be careful about setting the search pattern too leniently, however, since it may mistakenly allow persons to become authenticated as a DN to which they should not have access. It is better to write several strict directives than one lenient directive which has security holes. If there is only one authentication mechanism in place at your site, and zero or one realms in use, you might be able to map between authentication identities and LDAP DN's with a single `authz-regexp` directive.

Don't forget to allow for the case where the realm is omitted as well as the case with an explicitly specified realm. This may well require a separate `authz-regexp` directive for each case, with the explicit-realm entry being listed first.

15.2.7. Search-based mappings

There are a number of cases where mapping to a LDAP URL may be appropriate. For instance, some sites may have person objects located in multiple areas of the LDAP tree, such as if there were an `ou=accounting` tree and an `ou=engineering` tree, with persons interspersed between them. Or, maybe the desired mapping must be based upon information in the user's information. Consider the need to map the above authentication request DN to user whose entry is as follows:

```
dn: cn=Mark Adamson,ou=People,dc=Example,dc=COM
objectclass: person
cn: Mark Adamson
uid: adamson
```

The information in the authentication request DN is insufficient to allow the user's DN to be directly derived, instead the user's DN must be searched for. For these situations, a replacement pattern which produces a LDAP URL can be used in the `authz-regexp` directives. This URL will then be used to perform an internal search of the LDAP database to find the person's authentication DN.

An LDAP URL, similar to other URL's, is of the form

```
ldap://<host>/<base>?<attrs>?<scope>?<filter>
```

This contains all of the elements necessary to perform an LDAP search: the name of the server <host>, the LDAP DN search base <base>, the LDAP attributes to retrieve <attrs>, the search scope <scope> which is one of the three options "base", "one", or "sub", and lastly an LDAP search filter <filter>. Since the search is for an LDAP DN within the current server, the <host> portion should be empty. The <attrs> field is also ignored since only the DN is of concern. These two elements are left in the format of the URL to maintain the clarity of what information goes where in the string.

Suppose that the person in the example from above did in fact have an authentication username of "adamson" and that information was kept in the attribute "uid" in their LDAP entry. The `authz-regexp` directive might be written as

```
authz-regexp
  uid=([^,]*),cn=example.com,cn=gssapi,cn=auth
  ldap:///ou=people,dc=example,dc=com??one?(uid=$1)
```

This will initiate an internal search of the LDAP database inside the slapd server. If the search returns exactly one entry, it is accepted as being the DN of the user. If there are more than one entries returned, or if there are zero entries returned, the authentication fails and the user's connection is left bound as the authentication request DN.

The attributes that are used in the search filter <filter> in the URL should be indexed to allow faster searching. If they are not, the authentication step alone can take uncomfortably long periods, and users may assume the server is down.

A more complex site might have several realms in use, each mapping to a different subtree in the directory. These can be handled with statements of the form:

```
# Match Engineering realm
authz-regexp
   uid=([^,]*),cn=engineering.example.com,cn=digest-md5,cn=auth
   ldap:///dc=eng,dc=example,dc=com??one?(&(uid=$1)(objectClass=person))

# Match Accounting realm
authz-regexp
   uid=([^,].*),cn=accounting.example.com,cn=digest-md5,cn=auth
   ldap:///dc=accounting,dc=example,dc=com??one?(&(uid=$1)(objectClass=person))

# Default realm is customers.example.com
authz-regexp
   uid=([^,]*),cn=digest-md5,cn=auth
   ldap:///dc=customers,dc=example,dc=com??one?(&(uid=$1)(objectClass=person))
```

Note that the explicitly-named realms are handled first, to avoid the realm name becoming part of the UID. Also note the use of scope and filters to limit matching to desirable entries.

Note as well that `authz-regexp` internal search are subject to access controls. Specifically, the authentication identity must have `auth` access.

See *slapd.conf*(5) for more detailed information.

15.3. SASL Proxy Authorization

The SASL offers a feature known as *proxy authorization*, which allows an authenticated user to request that they act on the behalf of another user. This step occurs after the user has obtained an authentication DN, and involves sending an authorization identity to the server. The server will then make a decision on whether or not to allow the authorization to occur. If it is allowed, the user's LDAP connection is switched to have a binding DN derived from the authorization identity, and the LDAP session proceeds with the access of the new authorization DN.

The decision to allow an authorization to proceed depends on the rules and policies of the site where LDAP is running, and thus cannot be made by SASL alone. The SASL library leaves it up to the server to make the decision. The LDAP administrator sets the guidelines of who can authorize to what identity by adding information into the LDAP database entries. By default, the authorization features are disabled, and must be explicitly configured by the LDAP administrator before use.

The rules governing proxy authorization are not just used for SASL: they also control the use of the LDAP Proxied Authorization Control (RFC 4370).

15.3.1. Uses of Proxy Authorization

This sort of service is useful when one entity needs to act on the behalf of many other users. For example, users may be directed to a web page to make changes to their personal information in their LDAP entry. The users authenticate to the web server to establish their identity, but the web server CGI cannot authenticate to the LDAP server as that user to make changes for them. Instead, the web server authenticates itself to the LDAP server as a service identity, say,

```
        cn=WebUpdate,dc=example,dc=com
```

and then it will SASL authorize to the DN of the user. Once so authorized, the CGI makes changes to the LDAP entry of the user, and as far as the slapd server can tell for its ACLs, it is the user themself on the other end of the connection. The user could have connected to the LDAP server directly and authenticated as themself, but that would require the user to have more knowledge of LDAP clients, knowledge which the web page provides in an easier format.

Proxy authorization can also be used to limit access to an account that has greater access to the database. Such an account, perhaps even the root DN specified in *slapd.conf*(5), can have a strict list of people who can authorize to that DN. Changes to the LDAP database could then be only allowed by that DN, and in order to become that DN, users must first authenticate as one of the persons on the list. This allows for better auditing of who made changes to the LDAP database. If people were allowed to authenticate directly to the privileged account, possibly through the `rootpw` *slapd.conf*(5) directive or through a `userPassword` attribute, then auditing becomes more difficult.

Note that after a successful proxy authorization, the original authentication DN of the LDAP connection is overwritten by the new DN from the authorization request. If a service program is able to authenticate itself as its own authentication DN and then authorize to other DN's, and it is planning on switching to several different identities during one LDAP session, it will need to authenticate itself each time before authorizing to another DN (or use a different proxy authorization mechanism). The slapd server does not keep record of the service program's ability to switch to other DN's. On authentication mechanisms like Kerberos this will not require multiple connections being made to the Kerberos server, since the user's TGT and "ldap" session key are valid for multiple uses for the several hours of the ticket lifetime.

15.3.2. SASL Authorization Identities

The SASL authorization identity is sent to the LDAP server via the `-X` switch for *ldapsearch*(1) and other tools, or in the `*authzid` parameter to the *lutil_sasl_defaults*() call. The identity can be in one of two forms, either

```
        u:<username>
```

or

```
        dn:<dn>
```

In the first form, the <username> is from the same namespace as the authentication identities above. It is the user's username as it is referred to by the underlying authentication mechanism. Authorization identities of this form are converted into a DN format by the same function that the authentication process used, producing an *authorization request DN* of the form

```
        uid=<username>,cn=<realm>,cn=<mechanism>,cn=auth
```

That authorization request DN is then run through the same `authz-regexp` process to convert it into a legitimate authorization DN from the database. If it cannot be converted due to a failed search from an LDAP URL, the authorization request fails with "inappropriate access". Otherwise, the DN string is now a legitimate authorization DN ready to undergo approval.

If the authorization identity was provided in the second form, with a `"dn:"` prefix, the string after the prefix is already in authorization DN form, ready to undergo approval.

15.3.3. Proxy Authorization Rules

Once slapd has the authorization DN, the actual approval process begins. There are two attributes that the LDAP administrator can put into LDAP entries to allow authorization:

```
        authzTo
        authzFrom
```

Both can be multivalued. The `authzTo` attribute is a source rule, and it is placed into the entry associated with the authentication DN to tell what authorization DNs the authenticated DN is allowed to assume. The second attribute is a destination rule, and it is placed into the entry associated with the requested authorization DN to tell which authenticated DNs may assume it.

The choice of which authorization policy attribute to use is up to the administrator. Source rules are checked first in the person's authentication DN entry, and if none of the `authzTo` rules specify the authorization is permitted, the `authzFrom` rules in the authorization DN entry are then checked. If neither case specifies that the request be honored, the request is denied. Since the default behavior is to deny authorization requests, rules only specify that a request be allowed; there are no negative rules telling what authorizations to deny.

The value(s) in the two attributes are of the same form as the output of the replacement pattern of a `authz-regexp` directive: either a DN or an LDAP URL. For example, if a `authzTo` value is a DN, that DN is one the authenticated user can authorize to. On the other hand, if the `authzTo` value is an LDAP URL, the URL is used as an internal search of the LDAP database, and the authenticated user can become ANY DN returned by the search. If an LDAP entry looked like:

```
dn: cn=WebUpdate,dc=example,dc=com
authzTo: ldap:///dc=example,dc=com??sub?(objectclass=person)
```

then any user who authenticated as `cn=WebUpdate,dc=example,dc=com` could authorize to any other LDAP entry under the search base `dc=example,dc=com` which has an objectClass of `Person`.

15.3.3.1. Notes on Proxy Authorization Rules

An LDAP URL in a `authzTo` or `authzFrom` attribute will return a set of DNs. Each DN returned will be checked. Searches which return a large set can cause the authorization process to take an uncomfortably long time. Also, searches should be performed on attributes that have been indexed by slapd.

To help produce more sweeping rules for `authzFrom` and `authzTo`, the values of these attributes are allowed to be DNs with regular expression characters in them. This means a source rule like

```
authzTo: dn.regex:^uid=[^,]*,dc=example,dc=com$
```

would allow that authenticated user to authorize to any DN that matches the regular expression pattern given. This regular expression comparison can be evaluated much faster than an LDAP search for `(uid=*)`.

Also note that the values in an authorization rule must be one of the two forms: an LDAP URL or a DN (with or without regular expression characters). Anything that does not begin with "`ldap://`" is taken as a DN. It is not permissible to enter another authorization identity of the form "`u:<username>`" as an authorization rule.

15.3.3.2. Policy Configuration

The decision of which type of rules to use, `authzFrom` or `authzTo`, will depend on the site's situation. For example, if the set of people who may become a given identity can easily be written as a search filter, then a single destination rule could be written. If the set of people is not easily defined by a search filter, and the set of people is small, it may be better to write a source rule in the entries of each of those people who should be allowed to perform the proxy authorization.

By default, processing of proxy authorization rules is disabled. The `authz-policy` directive must be set in the *slapd.conf*(5) file to enable authorization. This directive can be set to `none` for no rules (the default), `to` for source rules, `from` for destination rules, or `both` for both source and destination rules.

Source rules are extremely powerful. If ordinary users have access to write the `authzTo` attribute in their own entries, then they can write rules that would allow them to authorize as anyone else. As such, when using source rules, the `authzTo` attribute should be protected with an ACL that only allows privileged users to set its values.

15.3.3.3. Access Control requirements

When checking whether a particular DN may authorize as another DN, the server applies access control rules to the `authzTo` and `authzFrom` attributes. The `auth` privilege is required for an attribute to be used.

For example, suppose Alice has authenticated using her own ID and password, and wants to perform an LDAP operation using Bob's permissions. If authorization is granted by an `authzTo` attribute in Alice's entry then Alice needs the `auth` privilege on that attribute. Similarly, if authorization is granted by an `authzFrom` attribute in Bob's entry then Alice needs the `auth` privilege on that. Alice does not need any other access privilege to do a proxy operation.

16. Using TLS

OpenLDAP clients and servers are capable of using the Transport Layer Security (TLS) framework to provide integrity and confidentiality protections and to support LDAP authentication using the SASL EXTERNAL mechanism. TLS is defined in RFC4346.

Note: For generating certificates, please reference http://www.openldap.org/faq/data/cache/185.html

16.1. TLS Certificates

TLS uses X.509 certificates to carry client and server identities. All servers are required to have valid certificates, whereas client certificates are optional. Clients must have a valid certificate in order to authenticate via SASL EXTERNAL. For more information on creating and managing certificates, see the OpenSSL or GnuTLS documentation, depending on which TLS implementation libraries you are using.

16.1.1. Server Certificates

The DN of a server certificate must use the `CN` attribute to name the server, and the `CN` must carry the server's fully qualified domain name. Additional alias names and wildcards may be present in the `subjectAltName` certificate extension. More details on server certificate names are in RFC4513.

16.1.2. Client Certificates

The DN of a client certificate can be used directly as an authentication DN. Since X.509 is a part of the X.500 standard and LDAP is also based on X.500, both use the same DN formats and generally the DN in a user's X.509 certificate should be identical to the DN of their LDAP entry. However, sometimes the DNs may not be exactly the same, and so the mapping facility described in Mapping Authentication Identities can be applied to these DNs as well.

16.2. TLS Configuration

After obtaining the required certificates, a number of options must be configured on both the client and the server to enable TLS and make use of the certificates. At a minimum, the clients must be configured with the name of the file containing all of the Certificate Authority (CA) certificates it will trust. The server must be configured with the CA certificates and also its own server certificate and private key.

Typically a single CA will have issued the server certificate and all of the trusted client certificates, so the server only needs to trust that one signing CA. However, a client may wish to connect to a variety of secure servers managed by different organizations, with server certificates generated by many different CAs. As such, a client is likely to need a list of many different trusted CAs in its configuration.

16.2.1. Server Configuration

The configuration directives for slapd belong in the global directives section of *slapd.conf*(5).

16.2.1.1. TLSCACertificateFile <filename>

This directive specifies the PEM-format file containing certificates for the CA's that slapd will trust. The certificate for the CA that signed the server certificate must be included among these certificates. If the signing CA was not a top-level (root) CA, certificates for the entire sequence of CA's from the signing CA to the top-level CA should be present. Multiple certificates are simply appended to the file; the order is not significant.

16.2.1.2. TLSCACertificatePath <path>

This directive specifies the path of a directory that contains individual CA certificates in separate files. In addition, this directory must be specially managed using the OpenSSL *rehash* command. When using this feature, the OpenSSL library will attempt to locate certificate files based on a hash of their name and serial number. The OpenSSL *rehash* command is used to generate symbolic links with the hashed names that point to the actual certificate files. As such, this option can only be used with a filesystem that actually supports symbolic links. In general, it is simpler to use the `TLSCACertificateFile` directive instead.

16.2.1.3. TLSCertificateFile <filename>

This directive specifies the file that contains the slapd server certificate. Certificates are generally public information and require no special protection.

16.2.1.4. TLSCertificateKeyFile <filename>

This directive specifies the file that contains the private key that matches the certificate stored in the `TLSCertificateFile` file. Private keys themselves are sensitive data and are usually password encrypted for protection. However, the current implementation doesn't support encrypted keys so the key must not be encrypted and the file itself must be protected carefully.

16.2.1.5. TLSCipherSuite <cipher-suite-spec>

This directive configures what ciphers will be accepted and the preference order. `<cipher-suite-spec>` should be a cipher specification for OpenSSL. You can use the command

```
            openssl ciphers -v ALL
```

to obtain a verbose list of available cipher specifications.

Besides the individual cipher names, the specifiers `HIGH`, `MEDIUM`, `LOW`, `EXPORT`, and `EXPORT40` may be helpful, along with `TLSv1`, `SSLv3`, and `SSLv2`.

To obtain the list of ciphers in GnuTLS use:

```
            gnutls-cli -l
```

16.2.1.6. TLSRandFile <filename>

This directive specifies the file to obtain random bits from when `/dev/urandom` is not available. If the system provides `/dev/urandom` then this option is not needed, otherwise a source of random data must be configured. Some systems (e.g. Linux) provide `/dev/urandom` by default, while others (e.g. Solaris) require the installation of a patch to provide it, and others may not support it at all. In the latter case, EGD or

PRNGD should be installed, and this directive should specify the name of the EGD/PRNGD socket. The environment variable `RANDFILE` can also be used to specify the filename. Also, in the absence of these options, the `.rnd` file in the slapd user's home directory may be used if it exists. To use the `.rnd` file, just create the file and copy a few hundred bytes of arbitrary data into the file. The file is only used to provide a seed for the pseudo-random number generator, and it doesn't need very much data to work.

This directive is ignored with GnuTLS.

16.2.1.7. TLSDHParamFile <filename>

This directive specifies the file that contains parameters for Diffie-Hellman ephemeral key exchange. This is required in order to use DHE-based cipher suites, including all DSA-based suites (i.e. `TLSCertificateKeyFile` points to a DSA key), and RSA when the 'key encipherment' key usage is not specified in the certificate. Parameters can be generated using the following command

```
openssl dhparam [-dsaparam] -out <filename> <numbits> or
certtool --generate-dh-params --bits <numbits> --outfile <filename>
```

16.2.1.8. TLSECName <name>

This directive specifies the curve to use for Elliptic Curve Diffie-Hellman ephemeral key exchange. This option is only needed to use ECDHE-based cipher suites in OpenSSL. The names of supported curves may be shown using the following command

```
openssl ecparam -list_curves
```

See the OpenSSL documentation for details. This directive is not used for GnuTLS. For GnuTLS the curves may be specified in the ciphersuite.

16.2.1.9. TLSVerifyClient { never | allow | try | demand }

This directive specifies what checks to perform on client certificates in an incoming TLS session, if any. This option is set to `never` by default, in which case the server never asks the client for a certificate. With a setting of `allow` the server will ask for a client certificate; if none is provided the session proceeds normally. If a certificate is provided but the server is unable to verify it, the certificate is ignored and the session proceeds normally, as if no certificate had been provided. With a setting of `try` the certificate is requested, and if none is provided, the session proceeds normally. If a certificate is provided and it cannot be verified, the session is immediately terminated. With a setting of `demand` the certificate is requested and a valid certificate must be provided, otherwise the session is immediately terminated.

Note: The server must request a client certificate in order to use the SASL EXTERNAL authentication mechanism with a TLS session. As such, a non-default `TLSVerifyClient` setting must be configured before SASL EXTERNAL authentication may be attempted, and the SASL EXTERNAL mechanism will only be offered to the client if a valid client certificate was received.

16.2.2. Client Configuration

Most of the client configuration directives parallel the server directives. The names of the directives are different, and they go into *ldap.conf*(5) instead of *slapd.conf*(5), but their functionality is mostly the same. Also, while most of these options may be configured on a system-wide basis, they may all be overridden by individual users in their *.ldaprc* files.

The LDAP Start TLS operation is used in LDAP to initiate TLS negotiation. All OpenLDAP command line tools support a `-Z` and `-ZZ` flag to indicate whether a Start TLS operation is to be issued. The latter flag indicates that the tool is to cease processing if TLS cannot be started while the former allows the command to continue.

In LDAPv2 environments, TLS is normally started using the LDAP Secure URI scheme (`ldaps://`) instead of the normal LDAP URI scheme (`ldap://`). OpenLDAP command line tools allow either scheme to used with the `-H` flag and with the `URI` *ldap.conf*(5) option.

16.2.2.1. TLS_CACERT <filename>

This is equivalent to the server's `TLSCACertificateFile` option. As noted in the TLS Configuration section, a client typically may need to know about more CAs than a server, but otherwise the same considerations apply.

16.2.2.2. TLS_CACERTDIR <path>

This is equivalent to the server's `TLSCACertificatePath` option. The specified directory must be managed with the OpenSSL *rehash* command as well.

16.2.2.3. TLS_CERT <filename>

This directive specifies the file that contains the client certificate. This is a user-only directive and can only be specified in a user's *.ldaprc* file.

16.2.2.4. TLS_KEY <filename>

This directive specifies the file that contains the private key that matches the certificate stored in the `TLS_CERT` file. The same constraints mentioned for `TLSCertificateKeyFile` apply here. This is also a user-only directive.

16.2.2.5. TLS_RANDFILE <filename>

This directive is the same as the server's `TLSRandFile` option.

16.2.2.6. TLS_REQCERT { never | allow | try | demand }

This directive is equivalent to the server's `TLSVerifyClient` option. However, for clients the default value is `demand` and there generally is no good reason to change this setting.

17. Constructing a Distributed Directory Service

For many sites, running one or more *slapd*(8) that hold an entire subtree of data is sufficient. But often it is desirable to have one *slapd* refer to other directory services for a certain part of the tree (which may or may not be running *slapd*).

slapd supports *subordinate* and *superior* knowledge information. Subordinate knowledge information is held in `referral` objects (RFC3296).

17.1. Subordinate Knowledge Information

Subordinate knowledge information may be provided to delegate a subtree. Subordinate knowledge information is maintained in the directory as a special *referral* object at the delegate point. The referral object acts as a delegation point, gluing two services together. This mechanism allows for hierarchical directory services to be constructed.

A referral object has a structural object class of `referral` and has the same Distinguished Name as the delegated subtree. Generally, the referral object will also provide the auxiliary object class `extensibleObject`. This allows the entry to contain appropriate Relative Distinguished Name values. This is best demonstrated by example.

If the server `a.example.net` holds `dc=example,dc=net` and wished to delegate the subtree `ou=subtree,dc=example,dc=net` to another server `b.example.net`, the following named referral object would be added to `a.example.net`:

```
dn: dc=subtree,dc=example,dc=net
objectClass: referral
objectClass: extensibleObject
dc: subtree
ref: ldap://b.example.net/dc=subtree,dc=example,dc=net
```

The server uses this information to generate referrals and search continuations to subordinate servers.

For those familiar with X.500, a *named referral* object is similar to an X.500 knowledge reference held in a *subr* DSE.

17.2. Superior Knowledge Information

Superior knowledge information may be specified using the `referral` directive. The value is a list of URIs referring to superior directory services. For servers without immediate superiors, such as for `a.example.net` in the example above, the server can be configured to use a directory service with *global knowledge*, such as the *OpenLDAP Root Service* (http://www.openldap.org/faq/index.cgi?file=393).

```
referral        ldap://root.openldap.org/
```

However, as `a.example.net` is the *immediate superior* to `b.example.net`, *b.example.net* would be configured as follows:

```
referral        ldap://a.example.net/
```

The server uses this information to generate referrals for operations acting upon entries not within or subordinate to any of the naming contexts held by the server.

For those familiar with X.500, this use of the `ref` attribute is similar to an X.500 knowledge reference held in a *Supr* DSE.

17.3. The ManageDsaIT Control

Adding, modifying, and deleting referral objects is generally done using *ldapmodify*(1) or similar tools which support the ManageDsaIT control. The ManageDsaIT control informs the server that you intend to manage the referral object as a regular entry. This keeps the server from sending a referral result for requests which interrogate or update referral objects.

The ManageDsaIT control should not be specified when managing regular entries.

The `-M` option of *ldapmodify*(1) (and other tools) enables ManageDsaIT. For example:

```
ldapmodify -M -f referral.ldif -x -D "cn=Manager,dc=example,dc=net" -W
```

or with *ldapsearch*(1):

```
ldapsearch -M -b "dc=example,dc=net" -x "(objectclass=referral)" '*' ref
```

Note: the `ref` attribute is operational and must be explicitly requested when desired in search results.

Note: the use of referrals to construct a Distributed Directory Service is extremely clumsy and not well supported by common clients. If an existing installation has already been built using referrals, the use of the *chain* overlay to hide the referrals will greatly improve the usability of the Directory system. A better approach would be to use explicitly defined local and proxy databases in *subordinate* configurations to provide a seamless view of the Distributed Directory.

Note: LDAP operations, even subtree searches, normally access only one database. That can be changed by gluing databases together with the **subordinate/olcSubordinate** keyword. Please see *slapd.conf*(5) and *slapd-config*(5).

18. Replication

Replicated directories are a fundamental requirement for delivering a resilient enterprise deployment.

OpenLDAP has various configuration options for creating a replicated directory. In previous releases, replication was discussed in terms of a *master* server and some number of *slave* servers. A master accepted directory updates from other clients, and a slave only accepted updates from a (single) master. The replication structure was rigidly defined and any particular database could only fulfill a single role, either master or slave. Another historic term introduced with OpenLDAP 2.4 was multimaster.

As OpenLDAP now supports a wide variety of replication topologies, these terms have been deprecated in favor of *provider*/*multi-provider* and *consumer*: A provider can accept external write operations and make them available for retrieval by consumers; consumers request replication updates from providers. Unlike the rigidly defined master/slave relationships, provider/consumer roles are quite fluid: replication updates received in a consumer can be further propagated by that consumer to other servers, so a consumer can also act simultaneously as a provider. Also, a consumer need not be an actual LDAP server; it may be just an LDAP client.

The following sections will describe the replication technology and discuss the various replication options that are available.

18.1. Replication Technology

18.1.1. LDAP Sync Replication

The LDAP Sync Replication engine, syncrepl for short, is a consumer-side replication engine that enables the consumer LDAP server to maintain a shadow copy of a DIT fragment. A syncrepl engine resides at the consumer and executes as one of the *slapd*(8) threads. It creates and maintains a replica by connecting to the replication provider to perform the initial DIT content load followed either by periodic content polling or by timely updates upon content changes.

Syncrepl uses the LDAP Content Synchronization protocol (or LDAP Sync for short) as the consumer synchronization protocol. LDAP Sync provides a stateful replication which supports both pull-based and push-based synchronization and does not mandate the use of a history store. In pull-based replication the consumer periodically polls the provider for updates. In push-based replication the consumer listens for updates that are sent by the provider in realtime. Since the protocol does not require a history store, the provider does not need to maintain any log of updates it has received (Note that the syncrepl engine is extensible and additional replication protocols may be supported in the future.).

Syncrepl keeps track of the status of the replication content by maintaining and exchanging synchronization cookies. Because the syncrepl consumer and provider maintain their content status, the consumer can poll the provider content to perform incremental synchronization by asking for the entries required to make the consumer up-to-date with the provider content. Syncrepl also enables convenient management of consumers by maintaining replication status. The consumer database can be constructed from a consumer-side or a provider-side backup at any synchronization status. Syncrepl can automatically resynchronize the consumer database to be up-to-date with the current provider content.

Syncrepl supports both pull-based and push-based synchronization. In its basic refreshOnly synchronization mode, the provider uses pull-based synchronization where the consumer servers need not be tracked and no history information is maintained. The information required for the provider to process periodic polling requests is contained in the synchronization cookie of the request itself. To optimize the pull-based synchronization, syncrepl utilizes the present phase of the LDAP Sync protocol as well as its delete phase, instead of falling back on frequent full reloads. To further optimize the pull-based synchronization, the provider can maintain a per-scope session log as a history store. In its refreshAndPersist mode of synchronization, the provider uses a push-based synchronization. The provider keeps track of the consumer servers that have requested a persistent search and sends them necessary updates as the provider replication content gets modified.

With syncrepl, a consumer can create a replication agreement without changing the provider's configurations and without restarting the provider server, if the consumer server has appropriate access privileges for the DIT fragment to be replicated. The consumer server can stop the replication also without the need for provider-side changes and restart.

Syncrepl supports both types of partial replication: sparse and fractional The shadow DIT fragment is defined by a general search criteria consisting of base, scope, filter, and attribute list. The consumer content is also subject to the access privileges of the bind identity of the syncrepl replication connection.

Fractional replication uses explicit attribute lists to replicate only a subset of the provider's attributes and sparse replication uses base/scope/filter to replicate only a subset of the provider's entries. Both cases are just refinements of the general search criteria.

18.1.1.1. The LDAP Content Synchronization Protocol

The LDAP Sync protocol allows a client to maintain a synchronized copy of a DIT fragment. The LDAP Sync operation is defined as a set of controls and other protocol elements which extend the LDAP search operation. This section introduces the LDAP Content Sync protocol only briefly. For more information, refer to RFC4533.

The LDAP Sync protocol supports both polling and listening for changes by defining two respective synchronization operations: *refreshOnly* and *refreshAndPersist*. Polling is implemented by the *refreshOnly* operation. The consumer polls the provider using an LDAP Search request with an LDAP Sync control attached. The consumer copy is synchronized to the provider copy at the time of polling using the information returned in the search. The provider finishes the search operation by returning *SearchResultDone* at the end of the search operation as in the normal search. Listening is implemented by the *refreshAndPersist* operation. As the name implies, it begins with a search, like refreshOnly. Instead of finishing the search after returning all entries currently matching the search criteria, the synchronization search remains persistent in the provider. Subsequent updates to the synchronization content in the provider cause additional entry updates to be sent to the consumer.

The *refreshOnly* operation and the refresh stage of the *refreshAndPersist* operation can be performed with a present phase or a delete phase.

In the present phase, the provider sends the consumer the entries updated within the search scope since the last synchronization. The provider sends all requested attributes, be they changed or not, of the updated entries. For each unchanged entry which remains in the scope, the provider sends a present message consisting only of the name of the entry and the synchronization control representing state present. The present message does not contain any attributes of the entry. After the consumer receives all update and present entries, it can reliably determine the new consumer copy by adding the entries added to the provider, by replacing the entries modified at the provider, and by deleting entries in the consumer copy which have not been updated nor specified as being present at the provider.

The transmission of the updated entries in the delete phase is the same as in the present phase. The provider sends all the requested attributes of the entries updated within the search scope since the last synchronization to the consumer. In the delete phase, however, the provider sends a delete message for each entry deleted from the search scope, instead of sending present messages. The delete message consists only of the name of the entry and the synchronization control representing state delete. The new consumer copy can be determined by adding, modifying, and removing entries according to the synchronization control attached to the *SearchResultEntry* message.

In the case that the LDAP Sync provider maintains a history store and can determine which entries are scoped out of the consumer copy since the last synchronization time, the provider can use the delete phase. If the provider does not maintain any history store, cannot determine the scoped-out entries from the history store, or the history store does not cover the outdated synchronization state of the consumer, the provider should use the present phase. The use of the present phase is much more efficient than a full content reload in terms of the synchronization traffic. To reduce the synchronization traffic further, the LDAP Sync protocol also provides several optimizations such as the transmission of the normalized `entryUUIDs` and the transmission of multiple `entryUUIDs` in a single *syncIdSet* message.

At the end of the *refreshOnly* synchronization, the provider sends a synchronization cookie to the consumer as a state indicator of the consumer copy after the synchronization is completed. The consumer will present the received cookie when it requests the next incremental synchronization to the provider.

When *refreshAndPersist* synchronization is used, the provider sends a synchronization cookie at the end of the refresh stage by sending a Sync Info message with refreshDone=TRUE. It also sends a synchronization cookie by attaching it to *SearchResultEntry* messages generated in the persist stage of the synchronization search. During the persist stage, the provider can also send a Sync Info message containing the synchronization cookie at any time the provider wants to update the consumer-side state indicator.

In the LDAP Sync protocol, entries are uniquely identified by the `entryUUID` attribute value. It can function as a reliable identifier of the entry. The DN of the entry, on the other hand, can be changed over time and hence cannot be considered as the reliable identifier. The `entryUUID` is attached to each *SearchResultEntry* or *SearchResultReference* as a part of the synchronization control.

18.1.1.2. Syncrepl Details

The syncrepl engine utilizes both the *refreshOnly* and the *refreshAndPersist* operations of the LDAP Sync protocol. If a syncrepl specification is included in a database definition, *slapd*(8) launches a syncrepl engine as a *slapd*(8) thread and schedules its execution. If the *refreshOnly* operation is specified, the syncrepl engine will be rescheduled at the interval time after a synchronization operation is completed. If the *refreshAndPersist* operation is specified, the engine will remain active and process the persistent synchronization messages from the provider.

The syncrepl engine utilizes both the present phase and the delete phase of the refresh synchronization. It is possible to configure a session log in the provider which stores the `entryUUIDs` of a finite number of entries deleted from a database. Multiple consumers share the same session log. The syncrepl engine uses the delete phase if the session log is present and the state of the consumer server is recent enough that no session log entries are truncated after the last synchronization of the client. The syncrepl engine uses the present phase if no session log is configured for the replication content or if the consumer is too outdated to be covered by the session log. The current design of the session log store is memory based, so the information contained in the session log is not persistent over multiple provider invocations. It is not currently supported to access the session log store by using LDAP operations. It is also not currently supported to impose access control to the session log.

As a further optimization, even in the case the synchronization search is not associated with any session log, no entries will be transmitted to the consumer server when there has been no update in the replication context.

The syncrepl engine, which is a consumer-side replication engine, can work with any backends. The LDAP Sync provider can be configured as an overlay on any backend, but works best with the *back-mdb* backend.

The LDAP Sync provider maintains a `contextCSN` for each database as the current synchronization state indicator of the provider content. It is the largest `entryCSN` in the provider context such that no transactions for an entry having smaller `entryCSN` value remains outstanding. The `contextCSN` could not just be set to the largest issued `entryCSN` because `entryCSN` is obtained before a transaction starts and transactions are not committed in the issue order.

The provider stores the `contextCSN` of a context in the `contextCSN` attribute of the context suffix entry. The attribute is not written to the database after every update operation though; instead it is maintained primarily in memory. At database start time the provider reads the last saved `contextCSN` into memory and uses the in-memory copy exclusively thereafter. By default, changes to the `contextCSN` as a result of database updates will not be written to the database until the server is cleanly shut down. A checkpoint facility exists to cause the `contextCSN` to be written out more frequently if desired.

Note that at startup time, if the provider is unable to read a `contextCSN` from the suffix entry, it will scan the entire database to determine the value, and this scan may take quite a long time on a large database. When a `contextCSN` value is read, the database will still be scanned for any `entryCSN` values greater than it, to make sure the `contextCSN` value truly reflects the greatest committed `entryCSN` in the database. On databases which support inequality indexing, setting an eq index on the `entryCSN` attribute and configuring *contextCSN* checkpoints will greatly speed up this scanning step.

If no `contextCSN` can be determined by reading and scanning the database, a new value will be generated. Also, if scanning the database yielded a greater `entryCSN` than was previously recorded in the suffix entry's `contextCSN` attribute, a checkpoint will be immediately written with the new value.

The consumer also stores its replication state, which is the provider's `contextCSN` received as a synchronization cookie, in the `contextCSN` attribute of the suffix entry. The replication state maintained by a consumer server is used as the synchronization state indicator when it performs subsequent incremental synchronization with the provider server. It is also used as a provider-side synchronization state indicator when it functions as a secondary provider server in a cascading replication configuration. Since the consumer and provider state information are maintained in the same location within their respective databases, any consumer can be promoted to a provider (and vice versa) without any special actions.

Because a general search filter can be used in the syncrepl specification, some entries in the context may be omitted from the synchronization content. The syncrepl engine creates a glue entry to fill in the holes in the consumer context if any part of the consumer content is subordinate to the holes. The glue entries will not be returned in the search result unless *ManageDsaIT* control is provided.

Also as a consequence of the search filter used in the syncrepl specification, it is possible for a modification to remove an entry from the replication scope even though the entry has not been deleted on the provider. Logically the entry must be deleted on the consumer but in *refreshOnly* mode the provider cannot detect and propagate this change without the use of the session log on the provider.

For configuration, please see the Syncrepl section.

18.2. Deployment Alternatives

While the LDAP Sync specification only defines a narrow scope for replication, the OpenLDAP implementation is extremely flexible and supports a variety of operating modes to handle other scenarios not explicitly addressed in the spec.

18.2.1. Delta-syncrepl replication

- Disadvantages of LDAP Sync replication:

LDAP Sync replication is an object-based replication mechanism. When any attribute value in a replicated object is changed on the provider, each consumer fetches and processes the complete changed object, including **both the changed and unchanged attribute values** during replication. One advantage of this approach is that when multiple changes occur to a single object, the precise sequence of those changes need not be preserved; only the final state of the entry is significant. But this approach may have drawbacks when the usage pattern involves single changes to multiple objects.

For example, suppose you have a database consisting of 102,400 objects of 1 KB each. Further, suppose you routinely run a batch job to change the value of a single two-byte attribute value that appears in each of the 102,400 objects on the provider. Not counting LDAP and TCP/IP protocol overhead, each time you run this job each consumer will transfer and process **100 MB** of data to process **200KB of changes!**

99.98% of the data that is transmitted and processed in a case like this will be redundant, since it represents values that did not change. This is a waste of valuable transmission and processing bandwidth and can cause an unacceptable replication backlog to develop. While this situation is extreme, it serves to demonstrate a very real problem that is encountered in some LDAP deployments.

- Where Delta-syncrepl comes in:

Delta-syncrepl, a changelog-based variant of syncrepl, is designed to address situations like the one described above. Delta-syncrepl works by maintaining a changelog of a selectable depth in a separate database on the provider. The replication consumer checks the changelog for the changes it needs and, as long as the changelog contains the needed changes, the consumer fetches the changes from the changelog and applies them to its database. If, however, a consumer is too far out of sync (or completely empty), conventional syncrepl is used to bring it up to date and replication then switches back to the delta-syncrepl mode.

Note: since the database state is stored in both the changelog DB and the main DB on the provider, it is important to backup/restore both the changelog DB and the main DB using slapcat/slapadd when restoring a DB or copying it to another machine.

For configuration, please see the Delta-syncrepl section.

18.2.2. N-Way Multi-Provider Replication

Multi-Provider replication is a replication technique using Syncrepl to replicate data to multiple provider ("Provider") Directory servers.

18.2.2.1. Valid Arguments for Multi-Provider replication

- If any provider fails, other providers will continue to accept updates
- Avoids a single point of failure
- Providers can be located in several physical sites i.e. distributed across the network/globe.
- Good for Automatic failover/High Availability

18.2.2.2. Invalid Arguments for Multi-Provider replication

(These are often claimed to be advantages of Multi-Provider replication but those claims are false):

- It has **NOTHING** to do with load balancing
- Providers **must** propagate writes to **all** the other servers, which means the network traffic and write load spreads across all of the servers the same as for single-provider.
- Server utilization and performance are at best identical for Multi-Provider and Single-Provider replication; at worst Single-Provider is superior because indexing can be tuned differently to optimize for the different usage patterns between the provider and the consumers.

18.2.2.3. Arguments against Multi-Provider replication

- Breaks the data consistency guarantees of the directory model
- http://www.openldap.org/faq/data/cache/1240.html
- If connectivity with a provider is lost because of a network partition, then "automatic failover" can just compound the problem
- Typically, a particular machine cannot distinguish between losing contact with a peer because that peer crashed, or because the network link has failed
- If a network is partitioned and multiple clients start writing to each of the "providers" then reconciliation will be a pain; it may be best to simply deny writes to the clients that are partitioned from the single provider

For configuration, please see the N-Way Multi-Provider section below

18.2.3. Mirror mode replication

Mirror mode is a hybrid configuration that provides all of the consistency guarantees of single-provider replication, while also providing the high availability of multi-provider. In Mirror mode two providers are set up to replicate from each other (as a multi-provider configuration), but an external frontend is employed to direct all writes to only one of the two servers. The second provider will only be used for writes if the first provider crashes, at which point the frontend will switch to directing all writes to the second provider. When a crashed provider is repaired and restarted it will automatically catch up to any changes on the running provider and resync.

18.2.3.1. Arguments for Mirror mode

- Provides a high-availability (HA) solution for directory writes (replicas handle reads)
- As long as one provider is operational, writes can safely be accepted
- Provider nodes replicate from each other, so they are always up to date and can be ready to take over (hot standby)
- Syncrepl also allows the provider nodes to re-synchronize after any downtime

18.2.3.2. Arguments against Mirror mode

- Mirror mode is not what is termed as a Multi-Provider solution. This is because writes have to go to just one of the mirror nodes at a time
- Mirror mode can be termed as Active-Active Hot-Standby, therefore an external server (slapd in proxy mode) or device (hardware load balancer) is needed to manage which provider is currently active
- Backups are managed slightly differently

For configuration, please see the Mirror mode section below

18.2.4. Syncrepl Proxy Mode

While the LDAP Sync protocol supports both pull- and push-based replication, the push mode (refreshAndPersist) must still be initiated from the consumer before the provider can begin pushing changes. In some network configurations, particularly where firewalls restrict the direction in which connections can be made, a provider-initiated push mode may be needed.

This mode can be configured with the aid of the LDAP Backend (Backends and *slapd-ldap(8)*). Instead of running the syncrepl engine on the actual consumer, a slapd-ldap proxy is set up near (or collocated with) the provider that points to the consumer, and the syncrepl engine runs on the proxy.

For configuration, please see the Syncrepl Proxy section.

18.3. Configuring the different replication types

18.3.1. Syncrepl

18.3.1.1. Syncrepl configuration

Because syncrepl is a consumer-side replication engine, the syncrepl specification is defined in *slapd.conf*(5) of the consumer server, not in the provider server's configuration file. The initial loading of the consumer content can be performed either by starting the syncrepl engine with no synchronization cookie or by populating the consumer by loading an LDIF file dumped as a backup at the provider.

When loading from a backup, it is not required to perform the initial loading from the up-to-date backup of the provider content. The syncrepl engine will automatically synchronize the initial consumer to the current provider content. As a result, it is not required to stop the provider server in order to avoid the replication inconsistency caused by the updates to the provider content during the content backup and loading process.

When replicating a large scale directory, especially in a bandwidth constrained environment, it is advised to load the consumer from a backup instead of performing a full initial load using syncrepl.

18.3.1.2. Set up the provider slapd

The provider is implemented as an overlay, so the overlay itself must first be configured in *slapd.conf*(5) before it can be used. The provider has two primary configuration directives and two secondary directives for when delta-syncrepl is being used. Because the LDAP Sync search is subject to access control, proper access control privileges should be set up for the replicated content.

The two primary options to configure are the checkpoint and sessionlog behaviors.

The `contextCSN` checkpoint is configured by the

```
        syncprov-checkpoint <ops> <minutes>
```

directive. Checkpoints are only tested after successful write operations. If <*ops*> operations or more than <*minutes*> time has passed since the last checkpoint, a new checkpoint is performed. Checkpointing is disabled by default.

The session log is configured by the

```
        syncprov-sessionlog <ops>
```

directive, where <*ops*> is the maximum number of session log entries the session log can record. All write operations (except Adds) are recorded in the log.

Note that using the session log requires searching on the *entryUUID* attribute. Setting an eq index on this attribute will greatly benefit the performance of the session log on the provider.

The reloadhint option is configured by the

```
        syncprov-reloadhint <TRUE|FALSE>
```

directive. It must be set TRUE when using the accesslog overlay for delta-based syncrepl replication support. The default is FALSE.

The nonpresent option is configured by the

```
        syncprov-nopresent <TRUE|FALSE>
```

directive. This value should only be set TRUE for a syncprov instance on top of a log database (such as one managed by the accesslog overlay). The default is FALSE.

A more complete example of the *slapd.conf*(5) content is thus:

```
        database mdb
        maxsize 1073741824
        suffix dc=Example,dc=com
        rootdn dc=Example,dc=com
        directory /var/ldap/db
        index objectclass,entryCSN,entryUUID eq

        overlay syncprov
        syncprov-checkpoint 100 10
        syncprov-sessionlog 100
```

18.3.1.3. Set up the consumer slapd

The syncrepl directive is specified in the database section of *slapd.conf*(5) for the consumer context. The syncrepl engine is backend independent and the directive can be defined with any database type.

```
        database mdb
        maxsize 1073741824
```

```
suffix dc=Example,dc=com
rootdn dc=Example,dc=com
directory /var/ldap/db
index objectclass,entryCSN,entryUUID eq

syncrepl rid=123
        provider=ldap://provider.example.com:389
        type=refreshOnly
        interval=01:00:00:00
        searchbase="dc=example,dc=com"
        filter="(objectClass=organizationalPerson)"
        scope=sub
        attrs="cn,sn,ou,telephoneNumber,title,l"
        schemachecking=off
        bindmethod=simple
        binddn="cn=syncuser,dc=example,dc=com"
        credentials=secret
```

In this example, the consumer will connect to the provider *slapd*(8) at port 389 of ldap://provider.example.com to perform a polling (*refreshOnly*) mode of synchronization once a day. It will bind as `cn=syncuser,dc=example,dc=com` using simple authentication with password "secret". Note that the access control privilege of `cn=syncuser,dc=example,dc=com` should be set appropriately in the provider to retrieve the desired replication content. Also the search limits must be high enough on the provider to allow the syncuser to retrieve a complete copy of the requested content. The consumer uses the rootdn to write to its database so it always has full permissions to write all content.

The synchronization search in the above example will search for the entries whose objectClass is organizationalPerson in the entire subtree rooted at `dc=example,dc=com`. The requested attributes are `cn`, `sn`, `ou`, `telephoneNumber`, `title`, and `l`. The schema checking is turned off, so that the consumer *slapd*(8) will not enforce entry schema checking when it processes updates from the provider *slapd*(8).

For more detailed information on the syncrepl directive, see the syncrepl section of The slapd Configuration File chapter of this admin guide.

18.3.1.4. Start the provider and the consumer slapd

The provider *slapd*(8) is not required to be restarted. *contextCSN* is automatically generated as needed: it might be originally contained in the LDIF file, generated by *slapadd* (8), generated upon changes in the context, or generated when the first LDAP Sync search arrives at the provider. If an LDIF file is being loaded which did not previously contain the *contextCSN*, the *-w* option should be used with *slapadd* (8) to cause it to be generated. This will allow the server to startup a little quicker the first time it runs.

When starting a consumer *slapd*(8), it is possible to provide a synchronization cookie as the *-c cookie* command line option in order to start the synchronization from a specific state. The cookie is a comma separated list of name=value pairs. Currently supported syncrepl cookie fields are *csn=<csn>* and *rid=<rid>*. *<csn>* represents the current synchronization state of the consumer. *<rid>* identifies a consumer locally within the consumer server. It is used to relate the cookie to the syncrepl definition in *slapd.conf*(5) which has the matching *<rid>*. The *<rid>* must have no more than 3 decimal digits. The command line cookie overrides the synchronization cookie stored in the consumer database.

18.3.2. Delta-syncrepl

18.3.2.1. Delta-syncrepl Provider configuration

Setting up delta-syncrepl requires configuration changes on both the provider and replica servers:

```
# Give the replicator DN unlimited read access.  This ACL needs to be
# merged with other ACL statements, and/or moved within the scope
# of a database.  The "by * break" portion causes evaluation of
# subsequent rules.  See slapd.access(5) for details.
access to *
   by dn.base="cn=replicator,dc=example,dc=com" read
   by * break

# Set the module path location
modulepath /opt/symas/lib/openldap

# Load the mdb backend
moduleload back_mdb.la

# Load the accesslog overlay
moduleload accesslog.la

#Load the syncprov overlay
moduleload syncprov.la

# Accesslog database definitions
database mdb
suffix cn=accesslog
directory /db/accesslog
rootdn cn=accesslog
index default eq
index entryCSN,objectClass,reqEnd,reqResult,reqStart,reqDN

overlay syncprov
syncprov-nopresent TRUE
syncprov-reloadhint TRUE

# Let the replicator DN have limitless searches
limits dn.exact="cn=replicator,dc=example,dc=com" time.soft=unlimited time.hard=unlimited

# Primary database definitions
database mdb
suffix "dc=symas,dc=com"
rootdn "cn=manager,dc=symas,dc=com"

## Whatever other configuration options are desired

# syncprov specific indexing
index entryCSN eq
index entryUUID eq

# syncrepl Provider for primary db
overlay syncprov
syncprov-checkpoint 1000 60

# accesslog overlay definitions for primary db
overlay accesslog
logdb cn=accesslog
logops writes
logsuccess TRUE
# scan the accesslog DB every day, and purge entries older than 7 days
```

```
logpurge 07+00:00 01+00:00

# Let the replicator DN have limitless searches
limits dn.exact="cn=replicator,dc=example,dc=com" time.soft=unlimited time.hard=unl
```

For more information, always consult the relevant man pages (*slapo-accesslog*(5) and *slapd.conf*(5))

18.3.2.2. Delta-syncrepl Consumer configuration

```
# Replica database configuration
database mdb
suffix "dc=symas,dc=com"
rootdn "cn=manager,dc=symas,dc=com"

## Whatever other configuration bits for the replica, like indexing
## that you want

# syncrepl specific indices
index entryUUID eq

# syncrepl directives
syncrepl  rid=0
          provider=ldap://ldapprovider.example.com:389
          bindmethod=simple
          binddn="cn=replicator,dc=example,dc=com"
          credentials=secret
          searchbase="dc=example,dc=com"
          logbase="cn=accesslog"
          logfilter="(&(objectClass=auditWriteObject)(reqResult=0))"
          schemachecking=on
          type=refreshAndPersist
          retry="60 +"
          syncdata=accesslog

# Refer updates to the provider
updateref               ldap://ldapprovider.example.com
```

The above configuration assumes that you have a replicator identity defined in your database that can be used to bind to the provider.

Note: An accesslog database is unique to a given provider. It should never be replicated.

18.3.3. N-Way Multi-Provider

For the following example we will be using 3 Provider nodes. Keeping in line with **test050-syncrepl-multiprovider** of the OpenLDAP test suite, we will be configuring *slapd(8)* via **cn=config**

This sets up the config database:

```
dn: cn=config
objectClass: olcGlobal
cn: config
olcServerID: 1

dn: olcDatabase={0}config,cn=config
objectClass: olcDatabaseConfig
olcDatabase: {0}config
```

```
        olcRootPW: secret
```

Each server must have a unique server ID (`SID`), so second and third servers will have a different `olcServerID` obviously:

```
        dn: cn=config
        objectClass: olcGlobal
        cn: config
        olcServerID: 2

        dn: olcDatabase={0}config,cn=config
        objectClass: olcDatabaseConfig
        olcDatabase: {0}config
        olcRootPW: secret
```

This sets up syncrepl as a provider (since these are all providers):

```
        dn: cn=module,cn=config
        objectClass: olcModuleList
        cn: module
        olcModulePath: /usr/local/libexec/openldap
        olcModuleLoad: syncprov.la
```

Now we setup the first Provider Node (replace $URI1, $URI2 and $URI3 etc. with your actual ldap urls):

```
        dn: cn=config
        changetype: modify
        replace: olcServerID
        olcServerID: 1 $URI1
        olcServerID: 2 $URI2
        olcServerID: 3 $URI3

        dn: olcOverlay=syncprov,olcDatabase={0}config,cn=config
        changetype: add
        objectClass: olcOverlayConfig
        objectClass: olcSyncProvConfig
        olcOverlay: syncprov

        dn: olcDatabase={0}config,cn=config
        changetype: modify
        add: olcSyncRepl
        olcSyncRepl: rid=001 provider=$URI1 binddn="cn=config" bindmethod=simple
          credentials=secret searchbase="cn=config" type=refreshAndPersist
          retry="5 5 300 5" timeout=1
        olcSyncRepl: rid=002 provider=$URI2 binddn="cn=config" bindmethod=simple
          credentials=secret searchbase="cn=config" type=refreshAndPersist
          retry="5 5 300 5" timeout=1
        olcSyncRepl: rid=003 provider=$URI3 binddn="cn=config" bindmethod=simple
          credentials=secret searchbase="cn=config" type=refreshAndPersist
          retry="5 5 300 5" timeout=1
        -
        add: olcMultiProvider
        olcMultiProvider: TRUE
```

Now start up the provider and a consumer/s, also add the above LDIF to the first consumer, second consumer etc. It will then replicate **cn=config**. You now have N-Way Multi-Provider on the config database.

We still have to replicate the actual data, not just the config, so add to the provider (all active and configured consumers/providers will pull down this config, as they are all syncing). Also, replace all *${}* variables with whatever is applicable to your setup:

```
dn: olcDatabase={1}$BACKEND,cn=config
objectClass: olcDatabaseConfig
objectClass: olc${BACKEND}Config
olcDatabase: {1}$BACKEND
olcSuffix: $BASEDN
olcDbDirectory: ./db
olcRootDN: $MANAGERDN
olcRootPW: $PASSWD
olcLimits: dn.exact="$MANAGERDN" time.soft=unlimited time.hard=unlimited
  size.soft=unlimited size.hard=unlimited
olcSyncRepl: rid=004 provider=$URI1 binddn="$MANAGERDN" bindmethod=simple
  credentials=$PASSWD searchbase="$BASEDN" type=refreshOnly
  interval=00:00:00:10 retry="5 5 300 5" timeout=1
olcSyncRepl: rid=005 provider=$URI2 binddn="$MANAGERDN" bindmethod=simple
  credentials=$PASSWD searchbase="$BASEDN" type=refreshOnly
  interval=00:00:00:10 retry="5 5 300 5" timeout=1
olcSyncRepl: rid=006 provider=$URI3 binddn="$MANAGERDN" bindmethod=simple
  credentials=$PASSWD searchbase="$BASEDN" type=refreshOnly
  interval=00:00:00:10 retry="5 5 300 5" timeout=1
olcMultiProvider: TRUE

dn: olcOverlay=syncprov,olcDatabase={1}${BACKEND},cn=config
changetype: add
objectClass: olcOverlayConfig
objectClass: olcSyncProvConfig
olcOverlay: syncprov
```

Note: All of your servers' clocks must be tightly synchronized using e.g. NTP http://www.ntp.org/, atomic clock, or some other reliable time reference.

Note: As stated in *slapd-config*(5), URLs specified in *olcSyncRepl* directives are the URLs of the servers from which to replicate. These must exactly match the URLs *slapd* listens on (*-h* in Command-Line Options). Otherwise slapd may attempt to replicate from itself, causing a loop.

Note: The *entryCSN* and *contextCSN* attributes are used to track changes to an entry and naming context, respectively. The `SID` which must be unique for each replication provider is a component of these CSNs. If you're using *slapadd* to load a database and there are no entryCSNs already present in the input LDIF, *slapadd* will generate them with a *SID* of `000`. This is not a valid *SID* for multi-provider replication, and you should use the `-S` option of *slapadd* (8) to specify a valid *SID* for these generated CSNs. If there are existing entryCSNs in the input LDIF, *slapadd* will not change them.

18.3.4. Mirror mode

Mirror mode configuration is actually very easy. If you have ever setup a normal slapd syncrepl provider, then the only change is the following two directives:

```
multiprovider  on
serverID    1
```

Note: You need to make sure that the *serverID* of each provider node is different and add it as a global configuration option.

18.3.4.1. Mirror Node Configuration

The first step is to configure the syncrepl provider the same as in the Set up the provider slapd section.

Here's a specific cut down example using LDAP Sync Replication in *refreshAndPersist* mode:

Mirror mode node 1:

```
# Global section
serverID    1
# database section

# syncrepl directive
syncrepl      rid=001
              provider=ldap://ldap-sid2.example.com
              bindmethod=simple
              binddn="cn=mirrormode,dc=example,dc=com"
              credentials=mirrormode
              searchbase="dc=example,dc=com"
              schemachecking=on
              type=refreshAndPersist
              retry="60 +"

multiprovider on
```

Mirror mode node 2:

```
# Global section
serverID    2
# database section

# syncrepl directive
syncrepl      rid=001
              provider=ldap://ldap-sid1.example.com
              bindmethod=simple
              binddn="cn=mirrormode,dc=example,dc=com"
              credentials=mirrormode
              searchbase="dc=example,dc=com"
              schemachecking=on
              type=refreshAndPersist
              retry="60 +"

multiprovider on
```

It's simple really; each Mirror mode node is setup **exactly** the same, except that the *serverID* is unique, and each consumer is pointed to the other server.

18.3.4.1.1. Failover Configuration

There are generally 2 choices for this; 1. Hardware proxies/load-balancing or dedicated proxy software, 2. using a Back-LDAP proxy as a syncrepl provider

A typical enterprise example might be:

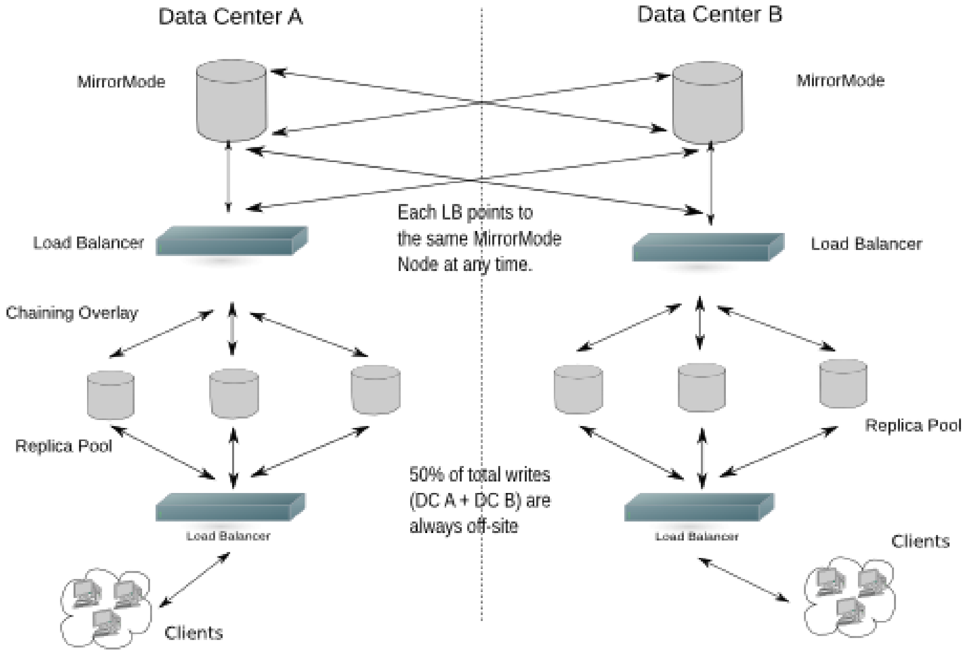


Figure X.Y: Mirror mode in a Dual Data Center Configuration

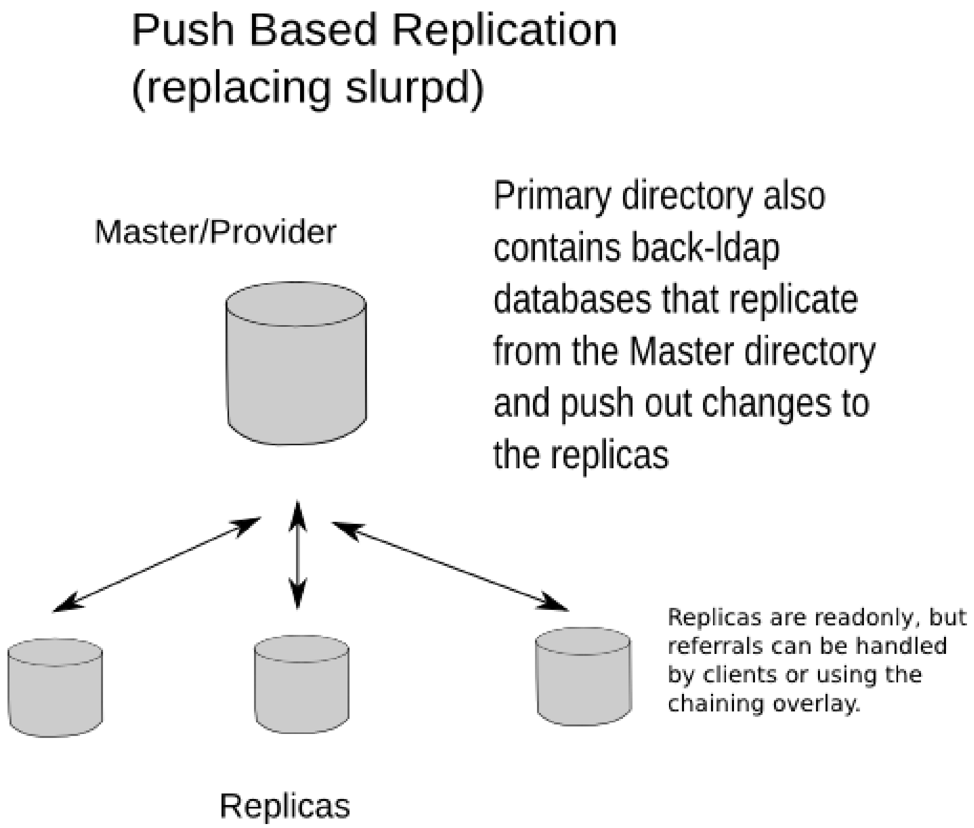
18.3.4.1.2. Normal Consumer Configuration

This is exactly the same as the Set up the consumer slapd section. It can either setup in normal syncrepl replication mode, or in delta-syncrepl replication mode.

18.3.4.2. Mirror mode Summary

You will now have a directory architecture that provides all of the consistency guarantees of single-provider replication, while also providing the high availability of multi-provider replication.

18.3.5. Syncrepl Proxy


Push Based Replication
(replacing slurpd)

Primary directory also contains back-ldap databases that replicate from the Master directory and push out changes to the replicas

Replicas are readonly, but referrals can be handled by clients or using the chaining overlay.

Figure X.Y: Replacing slurpd

The following example is for a self-contained push-based replication solution:

```
#######################################################################
# Standard OpenLDAP Provider
#######################################################################

include     /usr/local/etc/openldap/schema/core.schema
include     /usr/local/etc/openldap/schema/cosine.schema
include     /usr/local/etc/openldap/schema/nis.schema
include     /usr/local/etc/openldap/schema/inetorgperson.schema

include     /usr/local/etc/openldap/slapd.acl

modulepath  /usr/local/libexec/openldap
moduleload  back_mdb.la
moduleload  syncprov.la
moduleload  back_ldap.la

pidfile     /usr/local/var/slapd.pid
argsfile    /usr/local/var/slapd.args

loglevel    sync stats

database    mdb
suffix      "dc=suretecsystems,dc=com"
directory   /usr/local/var/openldap-data

checkpoint      1024 5
```

```
index       objectClass eq
# rest of indexes
index       default     sub

rootdn          "cn=admin,dc=suretecsystems,dc=com"
rootpw          testing

# syncprov specific indexing
index entryCSN eq
index entryUUID eq

# syncrepl Provider for primary db
overlay syncprov
syncprov-checkpoint 1000 60

# Let the replicator DN have limitless searches
limits dn.exact="cn=replicator,dc=suretecsystems,dc=com" time.soft=unlimited tim

database    monitor

database    config
rootpw          testing

##############################################################################
# Consumer Proxy that pulls in data via Syncrepl and pushes out via slapd-ldap
##############################################################################

database        ldap
# ignore conflicts with other databases, as we need to push out to same suffix
hidden              on
suffix          "dc=suretecsystems,dc=com"
rootdn          "cn=slapd-ldap"
uri             ldap://localhost:9012/

lastmod         on

# We don't need any access to this DSA
restrict        all

acl-bind        bindmethod=simple
                binddn="cn=replicator,dc=suretecsystems,dc=com"
                credentials=testing

syncrepl        rid=001
                provider=ldap://localhost:9011/
                binddn="cn=replicator,dc=suretecsystems,dc=com"
                bindmethod=simple
                credentials=testing
                searchbase="dc=suretecsystems,dc=com"
                type=refreshAndPersist
                retry="5 5 300 5"

overlay         syncprov
```

A replica configuration for this type of setup could be:

```
#######################################################################
# Standard OpenLDAP Replica without Syncrepl
#######################################################################

include     /usr/local/etc/openldap/schema/core.schema
include     /usr/local/etc/openldap/schema/cosine.schema
include     /usr/local/etc/openldap/schema/nis.schema
include     /usr/local/etc/openldap/schema/inetorgperson.schema

include     /usr/local/etc/openldap/slapd.acl

modulepath  /usr/local/libexec/openldap
moduleload  back_mdb.la
moduleload  syncprov.la
moduleload  back_ldap.la

pidfile     /usr/local/var/slapd.pid
argsfile    /usr/local/var/slapd.args

loglevel    sync stats

database    mdb
suffix      "dc=suretecsystems,dc=com"
directory   /usr/local/var/openldap-consumer/data

maxsize         85899345920
checkpoint      1024 5

index       objectClass eq
# rest of indexes
index       default     sub

rootdn          "cn=admin,dc=suretecsystems,dc=com"
rootpw          testing

# Let the replicator DN have limitless searches
limits dn.exact="cn=replicator,dc=suretecsystems,dc=com" time.soft=unlimited time.hard=

updatedn "cn=replicator,dc=suretecsystems,dc=com"

# Refer updates to the provider
updateref   ldap://localhost:9011

database    monitor

database    config
rootpw          testing
```

You can see we use the *updatedn* directive here and example ACLs (`usr/local/etc/openldap/slapd.acl`) for this could be:

```
# Give the replicator DN unlimited read access.  This ACL may need to be
# merged with other ACL statements.

access to *
     by dn.base="cn=replicator,dc=suretecsystems,dc=com" write
     by * break

access to dn.base=""
        by * read

access to dn.base="cn=Subschema"
        by * read

access to dn.subtree="cn=Monitor"
```

```
    by dn.exact="uid=admin,dc=suretecsystems,dc=com" write
    by users read
    by * none

access to *
        by self write
        by * read
```

In order to support more replicas, just add more *database ldap* sections and increment the *syncrepl rid* number accordingly.

Note: You must populate the Provider and Replica directories with the same data, unlike when using normal Syncrepl

If you do not have access to modify the provider directory configuration you can configure a standalone ldap proxy, which might look like:

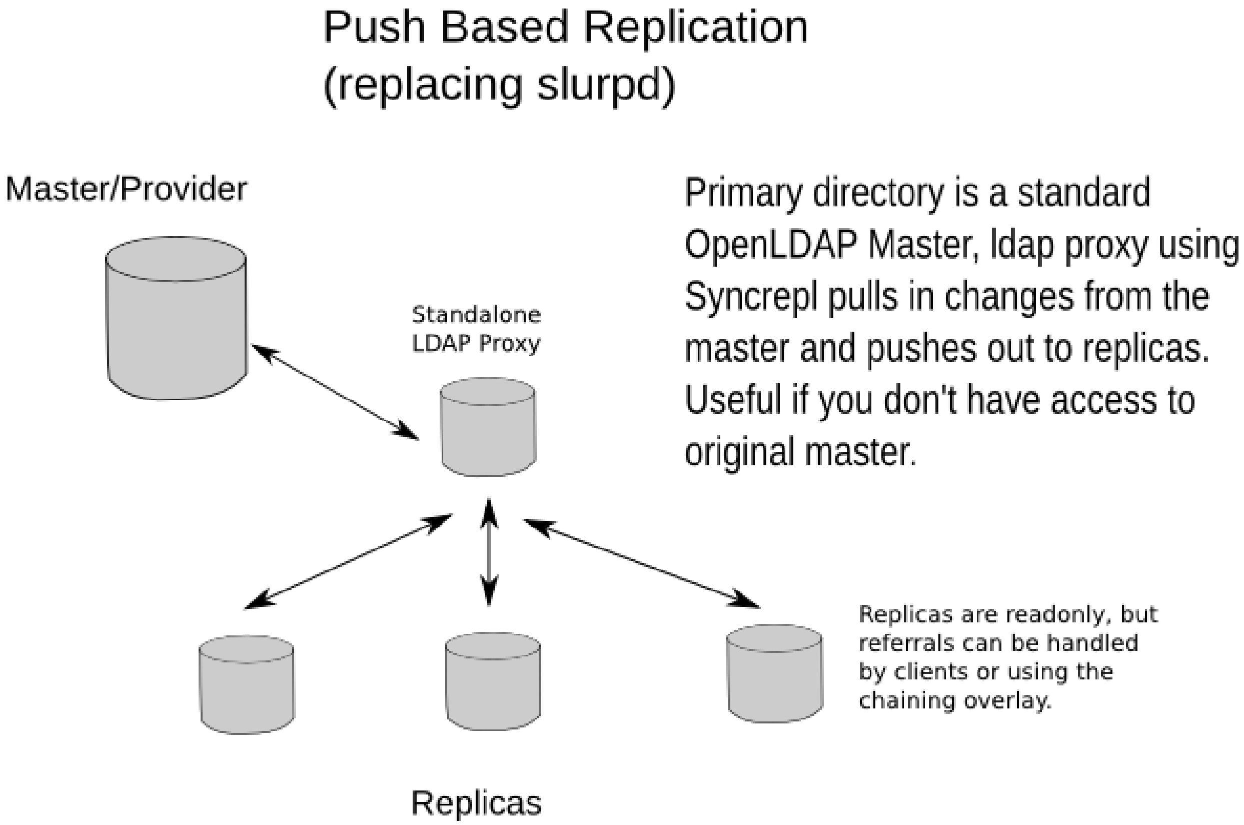

Push Based Replication
(replacing slurpd)
Master/Provider
Standalone
LDAP Proxy
Primary directory is a standard OpenLDAP Master, ldap proxy using Syncrepl pulls in changes from the master and pushes out to replicas. Useful if you don't have access to original master.
Replicas are readonly, but referrals can be handled by clients or using the chaining overlay.
Replicas

Figure X.Y: Replacing slurpd with a standalone version

The following configuration is an example of a standalone LDAP Proxy:

```
include     /usr/local/etc/openldap/schema/core.schema
include     /usr/local/etc/openldap/schema/cosine.schema
include     /usr/local/etc/openldap/schema/nis.schema
include     /usr/local/etc/openldap/schema/inetorgperson.schema

include     /usr/local/etc/openldap/slapd.acl

modulepath  /usr/local/libexec/openldap
```

```
moduleload  syncprov.la
moduleload  back_ldap.la

##############################################################################
# Consumer Proxy that pulls in data via Syncrepl and pushes out via slapd-ldap
##############################################################################

database        ldap
# ignore conflicts with other databases, as we need to push out to same suffix
hidden              on
suffix          "dc=suretecsystems,dc=com"
rootdn          "cn=slapd-ldap"
uri             ldap://localhost:9012/

lastmod         on

# We don't need any access to this DSA
restrict        all

acl-bind        bindmethod=simple
                binddn="cn=replicator,dc=suretecsystems,dc=com"
                credentials=testing

syncrepl        rid=001
                provider=ldap://localhost:9011/
                binddn="cn=replicator,dc=suretecsystems,dc=com"
                bindmethod=simple
                credentials=testing
                searchbase="dc=suretecsystems,dc=com"
                type=refreshAndPersist
                retry="5 5 300 5"

overlay         syncprov
```

As you can see, you can let your imagination go wild using Syncrepl and *slapd-ldap(8)* tailoring your replication to fit your specific network topology.

19. Maintenance

System Administration is all about maintenance, so it is only fair that we discuss how to correctly maintain an OpenLDAP deployment.

19.1. Directory Backups

Backup strategies largely depend on the amount of change in the database and how much of that change an administrator might be willing to lose in a catastrophic failure. There are two basic methods that can be used:

1. Backup the LMDB database itself

The LMDB database can be copied live using the mdb_copy command. If the database is a sparse file via the use of the "writemap" environment flag, the resulting copy will be the actual size of the database rather than a sparse copy.

2. Periodically run slapcat and back up the LDIF file:

Slapcat can be run while slapd is active. However, one runs the risk of an inconsistent database- not from the point of slapd, but from the point of the applications using LDAP. For example, if a provisioning application performed tasks that consisted of several LDAP operations, and the slapcat took place concurrently with those operations, then there might be inconsistencies in the LDAP database from the point of view of that provisioning application and applications that depended on it. One must, therefore, be convinced something like that won't happen. One way to do that would be to put the database in read-only mode while performing the slapcat. The other disadvantage of this approach is that the generated LDIF files can be rather large and the accumulation of the day's backups could add up to a substantial amount of space.

You can use *slapcat*(8) to generate an LDIF file for each of your *slapd*(8) back-mdb databases.

```
        slapcat -f slapd.conf -b "dc=example,dc=com"
```

For back-mdb this command may be ran while slapd(8) is running.

19.2. Checkpointing

Setting a checkpoint is only necessary when back-mdb has the dbnosync flag set. Otherwise it has no effect. With back-mdb the kbyte option is not implemented, meaning it will only run a checkpoint based on the elapsed amount of minutes flag.

19.3. Migration

If upgrading, please consult Upgrading from 2.5.x first to see if you need to make changes to your configuration as part of the upgrade.

After that, the simplest steps needed to migrate between versions or upgrade, depending on your deployment type are:

1. **Stop the current server when convenient**
2. **slapcat the current data out**
3. **Clear out the current data directory (/usr/local/var/openldap-data/)**
4. **Perform the software upgrades**
5. **Perform any configuration upgrades required**
6. **slapadd the exported data back into the directory**
7. **Start the server**

Obviously this doesn't cater for any complicated deployments with N-Way Multi-Provider, but following the above sections and using either commercial support or community support should help. Also check the Troubleshooting section.

20. Monitoring

slapd(8) supports an optional LDAP monitoring interface you can use to obtain information regarding the current state of your *slapd* instance. For instance, the interface allows you to determine how many clients are connected to the server currently. The monitoring information is provided by a specialized backend, the *monitor* backend. A manual page, *slapd-monitor*(5) is available.

When the monitoring interface is enabled, LDAP clients may be used to access information provided by the *monitor* backend, subject to access and other controls.

When enabled, the *monitor* backend dynamically generates and returns objects in response to search requests in the *cn=Monitor* subtree. Each object contains information about a particular aspect of the server. The information is held in a combination of user applications and operational attributes. This information can be accessed with *ldapsearch(1)*, with any general-purpose LDAP browser, or with specialized monitoring tools. The Accessing Monitoring Information section provides a brief tutorial on how to use *ldapsearch*(1) to access monitoring information, while the Monitor information section details monitoring information base and its organization.

While support for the monitor backend is included in default builds of slapd(8), this support requires some configuration to become active. This may be done using either `cn=config` or *slapd.conf*(5). The former is discussed in the Monitor configuration via cn=config section of this of this chapter. The latter is discussed in the Monitor configuration via slapd.conf(5) section of this chapter. These sections assume monitor backend is built into *slapd* (e.g., `--enable-monitor=yes`, the default). If the monitor backend was built as a module (e.g., `--enable-monitor=mod`, this module must loaded. Loading of modules is discussed in the Configuring slapd and The slapd Configuration File chapters.

20.1. Monitor configuration via cn=config(5)

The *monitor backend* is statically built into slapd and can be instantiated via ldapadd.

```
        dn: olcDatabase=monitor,cn=config
        objectClass: olcDatabaseConfig
        olcDatabase: monitor
```

20.2. Monitor configuration via slapd.conf(5)

Configuration of the slapd.conf(5) to support LDAP monitoring is quite simple.

First, ensure *core.schema* schema configuration file is included by your *slapd.conf*(5) file. The *monitor* backend requires it.

Second, instantiate the *monitor backend* by adding a *database monitor* directive below your existing database sections. For instance:

```
                database monitor
```

Lastly, add additional global or database directives as needed.

Like most other database backends, the monitor backend does honor slapd(8) access and other administrative controls. As some monitor information may be sensitive, it is generally recommend access to cn=monitor be restricted to directory administrators and their monitoring agents. Adding an *access* directive immediately below the *database monitor* directive is a clear and effective approach for controlling access. For instance, the addition of the following *access* directive immediately below the *database monitor* directive restricts access to monitoring information to the specified directory manager.

```
access to *
        by dn.exact="cn=Manager,dc=example,dc=com
        by * none
```

More information on *slapd*(8) access controls, see *The access Control Directive* section of the The slapd Configuration File chapter and *slapd.access*(5).

After restarting *slapd*(8), you are ready to start exploring the monitoring information provided in `cn=config` as discussed in the Accessing Monitoring Information section of this chapter.

One can verify slapd(8) is properly configured to provide monitoring information by attempting to read the `cn=monitor` object. For instance, if the following *ldapsearch*(1) command returns the cn=monitor object (with, as requested, no attributes), it's working.

```
ldapsearch -x -D 'cn=Manager,dc=example,dc=com' -W \
        -b 'cn=Monitor' -s base 1.1
```

Note that unlike general purpose database backends, the database suffix is hardcoded. It's always `cn=Monitor`. So no *suffix* directive should be provided. Also note that general purpose database backends, the monitor backend cannot be instantiated multiple times. That is, there can only be one (or zero) occurrences of `database monitor` in the server's configuration.

20.3. Accessing Monitoring Information

As previously discussed, when enabled, the *monitor* backend dynamically generates and returns objects in response to search requests in the *cn=Monitor* subtree. Each object contains information about a particular aspect of the server. The information is held in a combination of user applications and operational attributes. This information can be accessed with *ldapsearch(1)*, with any general-purpose LDAP browser, or with specialized monitoring tools.

This section provides a provides a brief tutorial on how to use *ldapsearch*(1) to access monitoring information.

To inspect any particular monitor object, one performs search operation on the object with a baseObject scope and a `(objectClass=*)` filter. As the monitoring information is contained in a combination of user applications and operational attributes, the return all user applications attributes (e.g., `'*'`) and all operational attributes (e.g., `'+'`) should be requested. For instance, to read the `cn=Monitor` object itself, the *ldapsearch*(1) command (modified to fit your configuration) can be used:

```
ldapsearch -x -D 'cn=Manager,dc=example,dc=com' -W \
        -b 'cn=Monitor' -s base '(objectClass=*)' '*' '+'
```

When run against your server, this should produce output similar to:

```
dn: cn=Monitor
objectClass: monitorServer
structuralObjectClass: monitorServer
```

```
cn: Monitor
creatorsName:
modifiersName:
createTimestamp: 20061208223558Z
modifyTimestamp: 20061208223558Z
description: This subtree contains monitoring/managing objects.
description: This object contains information about this server.
description: Most of the information is held in operational attributes, which
 must be explicitly requested.
monitoredInfo: OpenLDAP: slapd 2.5 (Dec  7 2006 17:30:29)
entryDN: cn=Monitor
subschemaSubentry: cn=Subschema
hasSubordinates: TRUE
```

To reduce the number of uninteresting attributes returned, one can be more selective when requesting which attributes are to be returned. For instance, one could request the return of all attributes allowed by the *monitorServer* object class (e.g., `@objectClass`) instead of all user and all operational attributes:

```
ldapsearch -x -D 'cn=Manager,dc=example,dc=com' -W \
        -b 'cn=Monitor' -s base '(objectClass=*)' '@monitorServer'
```

This limits the output as follows:

```
dn: cn=Monitor
objectClass: monitorServer
cn: Monitor
description: This subtree contains monitoring/managing objects.
description: This object contains information about this server.
description: Most of the information is held in operational attributes, which
 must be explicitly requested.
monitoredInfo: OpenLDAP: slapd 2.X (Dec  7 2006 17:30:29)
```

To return the names of all the monitoring objects, one performs a search of `cn=Monitor` with subtree scope and `(objectClass=*)` filter and requesting no attributes (e.g., `1.1`) be returned.

```
ldapsearch -x -D 'cn=Manager,dc=example,dc=com' -W -b 'cn=Monitor' -s sub 1.1
```

If you run this command you will discover that there are many objects in the *cn=Monitor* subtree. The following section describes some of the commonly available monitoring objects.

20.4. Monitor Information

The *monitor* backend provides a wealth of information useful for monitoring the slapd(8) contained in set of monitor objects. Each object contains information about a particular aspect of the server, such as a backends, a connection, or a thread. Some objects serve as containers for other objects and used to construct a hierarchy of objects.

In this hierarchy, the most superior object is {cn=Monitor}. While this object primarily serves as a container for other objects, most of which are containers, this object provides information about this server. In particular, it provides the slapd(8) version string. Example:

```
dn: cn=Monitor
monitoredInfo: OpenLDAP: slapd 2.X (Dec  7 2006 17:30:29)
```

Note: Examples in this section (and its subsections) have been trimmed to show only key information.

20.4.1. Backends

The `cn=Backends,cn=Monitor` object provides a list of available backends. The list of available backends includes all builtin backends, as well as those backends loaded by modules. For example:

```
dn: cn=Backends,cn=Monitor
monitoredInfo: config
monitoredInfo: ldif
monitoredInfo: monitor
monitoredInfo: mdb
```

This indicates the *config*, *ldif*, *monitor*, and *mdb* backends are available.

The `cn=Backends,cn=Monitor` object is also a container for available backend objects. Each available backend object contains information about a particular backend. For example:

```
dn: cn=Backend 0,cn=Backends,cn=Monitor
monitoredInfo: config
monitorRuntimeConfig: TRUE
supportedControl: 2.16.840.1.113730.3.4.2
seeAlso: cn=Database 0,cn=Databases,cn=Monitor

dn: cn=Backend 1,cn=Backends,cn=Monitor
monitoredInfo: ldif
monitorRuntimeConfig: TRUE
supportedControl: 2.16.840.1.113730.3.4.2

dn: cn=Backend 2,cn=Backends,cn=Monitor
monitoredInfo: monitor
monitorRuntimeConfig: TRUE
supportedControl: 2.16.840.1.113730.3.4.2
seeAlso: cn=Database 2,cn=Databases,cn=Monitor

dn: cn=Backend 3,cn=Backends,cn=Monitor
monitoredInfo: mdb
monitorRuntimeConfig: TRUE
supportedControl: 1.3.6.1.1.12
supportedControl: 2.16.840.1.113730.3.4.2
supportedControl: 1.3.6.1.4.1.4203.666.5.2
supportedControl: 1.2.840.113556.1.4.319
supportedControl: 1.3.6.1.1.13.1
supportedControl: 1.3.6.1.1.13.2
supportedControl: 1.3.6.1.4.1.4203.1.10.1
supportedControl: 1.2.840.113556.1.4.1413
supportedControl: 1.3.6.1.4.1.4203.666.11.7.2
```

For each of these objects, monitorInfo indicates which backend the information in the object is about. For instance, the `cn=Backend 5,cn=Backends,cn=Monitor` object contains (in the example) information about the *mdb* backend.

Attribute	Description
monitoredInfo	Name of backend
supportedControl	supported LDAP control extensions

seeAlso	Database objects of instances of this backend

20.4.2. Connections

The main entry is empty; it should contain some statistics on the number of connections.

Dynamic child entries are created for each open connection, with stats on the activity on that connection (the format will be detailed later). There are two special child entries that show the number of total and current connections respectively.

For example:

Total Connections:

```
dn: cn=Total,cn=Connections,cn=Monitor
structuralObjectClass: monitorCounterObject
monitorCounter: 4
entryDN: cn=Total,cn=Connections,cn=Monitor
subschemaSubentry: cn=Subschema
hasSubordinates: FALSE
```

Current Connections:

```
dn: cn=Current,cn=Connections,cn=Monitor
structuralObjectClass: monitorCounterObject
monitorCounter: 2
entryDN: cn=Current,cn=Connections,cn=Monitor
subschemaSubentry: cn=Subschema
hasSubordinates: FALSE
```

20.4.3. Databases

The main entry contains the naming context of each configured database; the child entries contain, for each database, the type and the naming context.

For example:

```
dn: cn=Database 2,cn=Databases,cn=Monitor
structuralObjectClass: monitoredObject
monitoredInfo: monitor
monitorIsShadow: FALSE
monitorContext: cn=Monitor
readOnly: FALSE
entryDN: cn=Database 2,cn=Databases,cn=Monitor
subschemaSubentry: cn=Subschema
hasSubordinates: FALSE
```

20.4.4. Listener

It contains the description of the devices the server is currently listening on:

```
dn: cn=Listener 0,cn=Listeners,cn=Monitor
structuralObjectClass: monitoredObject
monitorConnectionLocalAddress: IP=0.0.0.0:389
entryDN: cn=Listener 0,cn=Listeners,cn=Monitor
```

```
subschemaSubentry: cn=Subschema
hasSubordinates: FALSE
```

20.4.5. Log

It contains the currently active log items. The *Log* subsystem allows user modify operations on the *description* attribute, whose values *MUST* be in the list of admittable log switches:

```
Trace
Packets
Args
Conns
BER
Filter
Config
ACL
Stats
Stats2
Shell
Parse
Sync
```

These values can be added, replaced or deleted; they affect what messages are sent to the syslog device. Custom values could be added by custom modules.

20.4.6. Operations

It shows some statistics on the operations performed by the server:

```
Initiated
Completed
```

and for each operation type, i.e.:

```
Bind
Unbind
Add
Delete
Modrdn
Modify
Compare
Search
Abandon
Extended
```

There are too many types to list example here, so please try for yourself using Monitor search example

20.4.7. Overlays

The main entry contains the type of overlays available at run-time; the child entries, for each overlay, contain the type of the overlay.

It should also contain the modules that have been loaded if dynamic overlays are enabled:

```
# Overlays, Monitor
```

```
dn: cn=Overlays,cn=Monitor
structuralObjectClass: monitorContainer
monitoredInfo: syncprov
monitoredInfo: accesslog
monitoredInfo: glue
entryDN: cn=Overlays,cn=Monitor
subschemaSubentry: cn=Subschema
hasSubordinates: TRUE
```

20.4.8. SASL

Currently empty.

20.4.9. Statistics

It shows some statistics on the data sent by the server:

```
Bytes
PDU
Entries
Referrals
```

e.g.

```
# Entries, Statistics, Monitor
dn: cn=Entries,cn=Statistics,cn=Monitor
structuralObjectClass: monitorCounterObject
monitorCounter: 612248
entryDN: cn=Entries,cn=Statistics,cn=Monitor
subschemaSubentry: cn=Subschema
hasSubordinates: FALSE
```

20.4.10. Threads

It contains the maximum number of threads enabled at startup and the current backload.

e.g.

```
# Max, Threads, Monitor
dn: cn=Max,cn=Threads,cn=Monitor
structuralObjectClass: monitoredObject
monitoredInfo: 16
entryDN: cn=Max,cn=Threads,cn=Monitor
subschemaSubentry: cn=Subschema
hasSubordinates: FALSE
```

20.4.11. Time

It contains two child entries with the start time and the current time of the server.

e.g.

Start time:

```
dn: cn=Start,cn=Time,cn=Monitor
```

```
structuralObjectClass: monitoredObject
monitorTimestamp: 20061205124040Z
entryDN: cn=Start,cn=Time,cn=Monitor
subschemaSubentry: cn=Subschema
hasSubordinates: FALSE
```

Current time:

```
dn: cn=Current,cn=Time,cn=Monitor
structuralObjectClass: monitoredObject
monitorTimestamp: 20061207120624Z
entryDN: cn=Current,cn=Time,cn=Monitor
subschemaSubentry: cn=Subschema
hasSubordinates: FALSE
```

20.4.12. TLS

Currently empty.

20.4.13. Waiters

It contains the number of current read waiters.

e.g.

Read waiters:

```
dn: cn=Read,cn=Waiters,cn=Monitor
structuralObjectClass: monitorCounterObject
monitorCounter: 7
entryDN: cn=Read,cn=Waiters,cn=Monitor
subschemaSubentry: cn=Subschema
hasSubordinates: FALSE
```

Write waiters:

```
dn: cn=Write,cn=Waiters,cn=Monitor
structuralObjectClass: monitorCounterObject
monitorCounter: 0
entryDN: cn=Write,cn=Waiters,cn=Monitor
subschemaSubentry: cn=Subschema
hasSubordinates: FALSE
```

Add new monitored things here and discuss, referencing man pages and present examples

21. Load Balancing with lloadd

As covered in the Replication chapter, replication is a fundamental requirement for delivering a resilient enterprise deployment. As such there's a need for an LDAPv3 capable load balancer to spread the load between the various directory instances.

lloadd(8) provides the capability to distribute LDAP v3 requests between a set of running *slapd* instances. It can run as a standalone daemon *lloadd*, or as an embedded module running inside of *slapd*.

21.1. Overview

lloadd(8) was designed to handle LDAP loads. It is protocol-aware and can balance LDAP loads on a per-operation basis rather than on a per-connection basis.

lloadd(8) distributes the load across a set of slapd instances. The client connects to the load balancer instance which forwards the request to one of the servers and returns the response back to the client.

21.2. When to use the OpenLDAP load balancer

In general, the OpenLDAP load balancer spreads the load across configured backend servers. It does not perform so-called intelligent routing. It does not understand semantics behind the operations being performed by the clients.

More considerations:

- Servers are indistinguishable with respect to data contents. The exact same copy of data resides on every server.
- The sequence of operations isn't important. For example, read after update isn't required by the client.
- If your client can handle both connection pooling and load distribution then it's preferable to lloadd.
- Clients with different requirements (e.g. a coherent session vs. simple but high traffic clients) are directed to separate lloadd configurations.

21.3. Directing operations to backends

21.3.1. Default behaviour

In the simplest configuration several backends would be configured within a single roundrobin tier:

```
feature proxyauthz

bindconf bindmethod=simple
         binddn="cn=Manager,dc=example,dc=com"
         credentials=secret

tier roundrobin
backend-server uri=ldap://server1.example.com
               numconns=5 bindconns=5
               max-pending-ops=10 conn-max-pending=3
```

```
                  retry=5000
backend-server uri=ldap://server2.example.com
                  numconns=5 bindconns=5
                  max-pending-ops=10 conn-max-pending=3
                  retry=5000
```

After startup *lloadd* will open 10 connections to each **ldap://server1.example.com** and **ldap://server2.example.com**, 5 for regular requests, where it will bind as **cn=Manager,dc=example,dc=com**, and 5 dedicated to serving client Bind requests. If connection set up fails, it will wait 5000ms (5 seconds) before making another attempt to that server.

When a new Bind request comes from a client, it will be allocated to one of the available *bind connections*, each of which can only carry one request at a time. For other requests that need to be passed on to the backends, backends are considered in order:

- if the number of pending/in-flight for that backend is at or above 10, it is skipped
- the first appropriate upstream connection is chosen:
    - an idle *bind connection* for Bind requests
    - a *regular connection* with less than 3 pending operations for other types of requests
- if no such connection is available, the next backend in order is checked
- if we go through the whole list without choosing an upstream connection, we return a failure to the client, either an **LDAP_UNAVAILABLE** if no connections of the appropriate type have been established at all or **LDAP_BUSY** otherwise

When a connection is chosen, the operation is forwarded and response(s) returned to the client. Should that connection go away before the final response is received, the client is notified with a **LDAP_OTHER** failure code.

So long as *feature proxyauthz* is configured, every operation forwarded over a *regular connection* has the **PROXYAUTHZ** control (RFC4370) prepended indicating the client's bound identity, unless that identity matches the *binddn* configured in *bindconf*.

If another tier is configured:

```
tier roundrobin
backend-server uri=ldap://fallback.example.com
                  numconns=5 bindconns=5
                  max-pending-ops=10 conn-max-pending=3
                  retry=5000
```

Backends in this tier will only be considered when *lloadd* would have returned **LDAP_UNAVAILABLE** in the above case.

21.3.2. Alternate selection strategies

For various reasons, the *roundrobin* tier is appropriate in the majority of use cases as it is both very scalable in terms of its implementation and how its self-limiting interacts with backends when multiple *lloadd* instances are being used at the same time.

Two alternative selection strategies have been implemented:

- ♦ *tier weighted* applies predefined weights to how often a backend is considered first

- *tier bestof* measures the time to first response from each backend, when a new operation needs to be forwarded, two backends are selected at random and the backend with better response time is considered first. If connections on neither backend can be used, selection falls back to the regular strategy used by the roundrobin backend

The *weighted* tier might be appropriate when servers have differing load capacity. Due to its reinforced self-limiting feedback, the *bestof* tier might be appropriate in large scale environments where each backend's capacity/latency fluctuates widely and rapidly.

21.3.3. Coherence

21.3.3.1. Write coherence

In default configurations, every operation submitted by the client is either processed internally (e.g. StartTLS, Abandon, Unbind, ...) or is forwarded to a connection of lloadd's choosing, independent of any other other operation submitted by the same client.

There are certain traffic patterns where such such freedom is undesirable and some kind of coherency is required. This applies to write traffic, controls like Paged Results or many extended operations.

Client's operations can be pinned to the same backend as the last write operation:

```
write_coherence 5
```

In this case, client's requests will be passed over to the same backend (not necessarily over the same upstream connection) from the moment a write request is passed on till at least 5 seconds have elapsed since last write operation has finished.

```
write_coherence -1
```

Here, there is no timeout and the moment a write request is passed on to a backend, the client's operations will forever be passed on to this backend.

In both cases above, this limitation is lifted the moment a Bind request is received from the client connection.

21.3.3.2. Extended operations/controls

Many controls and Extended operations establish shared state on the session. While *lloadd* implements some of these (StartTLS being one example), it supports the administrator in defining how to deal with those it does not implement special handling for.

```
restrict_exop 1.1 reject
# TXN Exop
restrict_exop 1.3.6.1.1.21.1 connection
# Password Modify Exop
restrict_exop 1.3.6.1.4.1.4203.1.11.1 write

# Paged Results Control
restrict_control 1.2.840.113556.1.4.319 connection
# Syncrepl
restrict_control 1.3.6.1.4.1.4203.1.9.1 reject
```

The above configuration uses the special invalid OID of *1.1* to instruct *lloadd* to reject any Extended operation it does not recognize, except for Password Modify operation which is treated according to *write_coherence* above and the LDAP transactions, where it forwards all subsequent requests over to the same upstream connection. Similarly, once a Paged results control is seen on an operation, subsequent request will stick to the same upstream connection while LDAP Syncrepl requests will be rejected outright.

With both *restrict_exop* and *restrict_control*, any such limitation is lifted when a new Bind request comes in as any client state is assumed to be reset.

When configuring these to anything else than *reject*, keep in mind that many extensions have not been designed or implemented with a multiplexing proxy like *lloadd* in mind and might open considerable operational and/or security concerns when allowed.

21.4. Runtime configurations

It deploys in one of two ways:

1. Standalone daemon: *lloadd*
2. Loaded into the slapd daemon as a module: *lloadd.la*

It is recommended to run with the balancer module embedded in slapd because dynamic configuration (cn=config) and the monitor backend are then available.

Sample load balancer scenario:

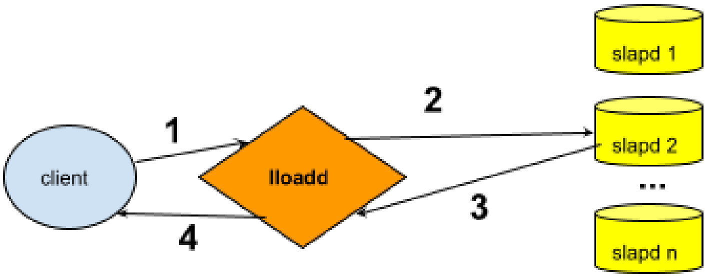


Figure: Load balancer sample scenario

1. The LDAP client submits an LDAP operation to the load balancer daemon.
2. The load balancer forwards the request to one of the backend instances in its pool of servers.
3. The backend slapd server processes the request and returns the response to the load balancer instance.
4. The load balancer returns the response to the client. The client's unaware that it's connecting to a load balancer instead of slapd.

21.5. Build Notes

To build the load balancer from source, follow the instructions in the A Quick-Start Guide substituting the following commands:

1. To configure as standalone daemon:
   ```
   ./configure --enable-balancer=yes
   ```

2. To configure as embedded module to slapd:
   `./configure --enable-modules --enable-balancer=mod`

21.6. Sample Runtime

1. To run embedded as *lloadd* module:
   `slapd [-h URLs] [-f lloadd-config-file] [-u user] [-g group]`
    - the startup is the same as starting the *slapd* daemon.
    - URLs is for slapd management. The load balancer's listener URLs set in the configuration file or node. (more later)
2. To run as standalone daemon:
   `lloadd [-h URLs] [-f lloadd-config-file] [-u user] [-g group]`
    - Other than a different daemon name, running standalone has the same options as starting *slapd* .
    - -h URLs specify the lloadd's interface directly, there is no management interface.

For a complete list of options, checkout the man page *lloadd.8*

21.7. Configuring load balancer

21.7.1. Common configuration options

Many of the same configuration options as slapd. For complete list, check the *lloadd*(5) man page.

Edit the slapd.conf or cn=config configuration file.

To configure your working *lloadd*(8) you need to make the following changes to your configuration file:

1. include *core.schema* (embedded only)
2. *TLSShareSlapdCTX { on | off }*
3. Other common TLS slapd options
4. Setup argsfile/pidfile
5. Setup moduleload path (embedded mode only)
6. *moduleload lloadd.la*
7. loglevel, threads, ACL's
8. *backend lload* begin lloadd specific backend configurations
9. *listen ldap://:PORT* Specify listen port for load balancer
10. *feature proxyauthz* Use the proxy authZ control to forward client's identity
11. *io-threads INT* specify the number of threads to use for the connection manager. The default is 1 and this is typically adequate for up to 16 CPU cores

21.7.2. Sample backend config

Sample setup config for load balancer running in front of four slapd instances.

```
backend lload

# The Load Balancer manages its own sockets, so they have to be separate
# from the ones slapd manages (as specified with the -h "URLS" option at
# startup).
listen ldap://:1389
```

```
# Enable authorization tracking
feature proxyauthz

# Specify the number of threads to use for the connection manager.  The default is 1 and this i
# The value should be set to a power of 2:
io-threads  2

# If TLS is configured above, use the same context for the Load Balancer
# If using cn=config, this can be set to false and different settings
# can be used for the Load Balancer
TLSShareSlapdCTX true

# Authentication and other options (timeouts) shared between backends.
bindconf bindmethod=simple
         binddn=dc=example,dc=com credentials=secret
         network-timeout=5
         tls_cacert="/usr/local/etc/openldap/ca.crt"
         tls_cert="/usr/local/etc/openldap/host.crt"
         tls_key="/usr/local/etc/openldap/host.pem"


# List the backends we should relay operations to, they all have to be
# practically indistinguishable. Only TLS settings can be specified on
# a per-backend basis.

tier roundrobin
backend-server uri=ldap://ldaphost01 starttls=critical retry=5000
               max-pending-ops=50 conn-max-pending=10
               numconns=10 bindconns=5
backend-server uri=ldap://ldaphost02 starttls=critical retry=5000
               max-pending-ops=50 conn-max-pending=10
               numconns=10 bindconns=5
backend-server uri=ldap://ldaphost03 starttls=critical retry=5000
               max-pending-ops=50 conn-max-pending=10
               numconns=10 bindconns=5
backend-server uri=ldap://ldaphost04 starttls=critical retry=5000
               max-pending-ops=50 conn-max-pending=10
               numconns=10 bindconns=5

#######################################################################
# Monitor database
#######################################################################
database        monitor
```

22. Tuning

This is perhaps one of the most important chapters in the guide, because if you have not tuned *slapd*(8) correctly or grasped how to design your directory and environment, you can expect very poor performance.

Reading, understanding and experimenting using the instructions and information in the following sections, will enable you to fully understand how to tailor your directory server to your specific requirements.

It should be noted that the following information has been collected over time from our community based FAQ. So obviously the benefit of this real world experience and advice should be of great value to the reader.

22.1. Performance Factors

Various factors can play a part in how your directory performs on your chosen hardware and environment. We will attempt to discuss these here.

22.1.1. Memory

Scale your cache to use available memory and increase system memory if you can.

22.1.2. Disks

Use fast filesystems, and conduct your own testing to see which filesystem types perform best with your workload. (On our own Linux testing, EXT2 and JFS tend to provide better write performance than everything else, including newer filesystems like EXT4, BTRFS, etc.)

Use fast subsystems. Put each database on separate disks.

22.1.3. Network Topology

http://www.openldap.org/faq/data/cache/363.html

Drawing here.

22.1.4. Directory Layout Design

Reference to other sections and good/bad drawing here.

22.1.5. Expected Usage

Discussion.

22.2. Indexes

22.2.1. Understanding how a search works

If you're searching on a filter that has been indexed, then the search reads the index and pulls exactly the entries that are referenced by the index. If the filter term has not been indexed, then the search must read every single entry in the target scope and test to see if each entry matches the filter. Obviously indexing can save a lot of work when it's used correctly.

In back-mdb, indexes can only track a certain number of entries per key (by default that number is 2^16 = 65536). If more entries' values hash to this key, some/all of them will have to be represented by a range of candidates, making the index less useful over time as deletions cannot usually be tracked accurately.

22.2.2. What to index

As a general rule, to make any use of indexes, you must set up an equality index on objectClass:

```
        index objectClass eq
```

Then you should create indices to match the actual filter terms used in search queries.

```
        index cn,sn,givenname,mail eq
```

Each attribute index can be tuned further by selecting the set of index types to generate. For example, substring and approximate search for organizations (o) may make little sense (and isn't like done very often). And searching for *userPassword* likely makes no sense what so ever.

General rule: don't go overboard with indexes. Unused indexes must be maintained and hence can only slow things down.

See *slapd.conf*(5) and *slapdindex*(8) for more information

22.2.3. Presence indexing

If your client application uses presence filters and if the target attribute exists on the majority of entries in your target scope, then all of those entries are going to be read anyway, because they are valid members of the result set. In a subtree where 100% of the entries are going to contain the same attributes, the presence index does absolutely NOTHING to benefit the search, because 100% of the entries match that presence filter. As an example, setting a presence index on objectClass provides no benefit since it is present on every entry.

So the resource cost of generating the index is a complete waste of CPU time, disk, and memory. Don't do it unless you know that it will be used, and that the attribute in question occurs very infrequently in the target data.

Almost no applications use presence filters in their search queries. Presence indexing is pointless when the target attribute exists on the majority of entries in the database. In most LDAP deployments, presence indexing should not be done, it's just wasted overhead.

See the *Logging* section below on what to watch out for if you have a frequently searched for attribute that is unindexed.

22.2.4. Equality indexing

Similarly to presence indexes, equality indexes are most useful if the values searched for are uncommon. Most OpenLDAP indexes work by hashing the normalised value and using the hash as the key. Hashing behaviour depends on the matching rule syntax, some matching rules also implement indexers that help speed up inequality (lower than, ...) queries.

Check the documentation and other parts of this guide if some indexes are mandatory - e.g. to enable replication, it is expected you index certain operational attributes, likewise if you rely on filters in ACL processing.

Approximate indexes are usually identical to equality indexes unless a matching rule explicitly implements it. As of OpenLDAP 2.5, only directoryStringApproxMatch and IA5StringApproxMatch matchers and indexers are implemented, currently using soundex or metaphone, with metaphone being the default.

22.2.5. Substring indexing

Substring indexes work on splitting the value into short chunks and then indexing those in a similar way to how equality index does. The storage space needed to store all of this data is analogous to the amount of data being indexed, which makes the indexes extremely heavy-handed in most scenarios.

22.3. Logging

22.3.1. What log level to use

The default of *loglevel stats* (256) is really the best bet. There's a corollary to this when problems *do* arise, don't try to trace them using syslog. Use the debug flag instead, and capture slapd's stderr output. syslog is too slow for debug tracing, and it's inherently lossy - it will throw away messages when it can't keep up. See *slapd.conf*(5) or *slapd-config*(5) for more information on how to configure the loglevel.

Contrary to popular belief, *loglevel 0* is not ideal for production as you won't be able to track when problems first arise.

22.3.2. What to watch out for

The most common message you'll see that you should pay attention to is:

```
"<= mdb_equality_candidates: (foo) index_param failed (18)"
```

That means that some application tried to use an equality filter (*foo=<somevalue>*) and attribute *foo* does not have an equality index. If you see a lot of these messages, you should add the index. If you see one every month or so, it may be acceptable to ignore it.

The default syslog level is stats (256) which logs the basic parameters of each request; it usually produces 1-3 lines of output. On Solaris and systems that only provide synchronous syslog, you may want to turn it off completely, but usually you want to leave it enabled so that you'll be able to see index messages whenever they arise. On Linux you can configure syslogd to run asynchronously, in which case the performance hit for moderate syslog traffic pretty much disappears.

22.3.3. Improving throughput

You can improve logging performance on some systems by configuring syslog not to sync the file system with every write (*man syslogd/syslog.conf*). In Linux, you can prepend the log file name with a "-" in *syslog.conf*. For example, if you are using the default LOCAL4 logging you could try:

```
# LDAP logs
LOCAL4.*         -/var/log/ldap
```

For syslog-ng, add or modify the following line in *syslog-ng.conf*:

```
options { sync(n); };
```

where n is the number of lines which will be buffered before a write.

22.4. *slapd*(8) Threads

slapd(8) can process requests via a configurable number of threads, which in turn affects the in/out rate of connections.

This value should generally be a function of the number of "real" cores on the system, for example on a server with 2 CPUs with one core each, set this to 8, or 4 threads per real core. This is a "read" maximized value. The more threads that are configured per core, the slower *slapd*(8) responds for "read" operations. On the flip side, it appears to handle write operations faster in a heavy write/low read scenario.

The upper bound for good read performance appears to be 16 threads (which also happens to be the default setting).

23. Troubleshooting

If you're having trouble using OpenLDAP, get onto the OpenLDAP-Software mailing list, or:

- Browse the list archives at http://www.openldap.org/lists/#archives
- Search the FAQ at http://www.openldap.org/faq/
- Search the Issue Tracking System at http://www.openldap.org/its/

Chances are the problem has been solved and explained in detail many times before.

23.1. User or Software errors?

More often than not, an error is caused by a configuration problem or a misunderstanding of what you are trying to implement and/or achieve.

We will now attempt to discuss common user errors.

23.2. Checklist

The following checklist can help track down your problem. Please try to use if **before** posting to the list, or in the rare circumstances of reporting a bug.

1. **Use the *slaptest* tool to verify configurations before starting *slapd***

2. **Verify that *slapd* is listening to the specified port(s) (389 and 636, generally) before trying the *ldapsearch***

3. **Can you issue an *ldapsearch*?**

4. **If not, have you enabled complex ACLs without fully understanding them?**

5. **Do you have a system wide LDAP setting pointing to the wrong LDAP Directory?**

6. **Are you using TLS?**

7. **Have your certificates expired?**

23.3. OpenLDAP Bugs

Sometimes you may encounter an actual OpenLDAP bug, in which case please visit our Issue Tracking system http://www.openldap.org/its/ and report it. However, make sure it's not already a known bug or a common user problem.

- bugs in historic versions of OpenLDAP will not be considered;
- bugs in released versions that are no longer present in the Git master branch, either because they have been fixed or because they no longer apply, will not be considered as well;

- bugs in distributions of OpenLDAP software that are not related to the software as provided by OpenLDAP will not be considered; in those cases please refer to the distributor.

Note: Our Issue Tracking system is **NOT** for OpenLDAP **Support**, please join our mailing Lists: http://www.openldap.org/lists/ for that.

The information you should provide in your bug report is discussed in our FAQ-O-MATIC at http://www.openldap.org/faq/data/cache/59.html

23.4. 3rd party software error

The OpenLDAP Project only supports OpenLDAP software.

You may however seek commercial support (http://www.openldap.org/support/) or join the general LDAP forum for non-commercial discussions and information relating to LDAP at: http://www.umich.edu/~dirsvcs/ldap/mailinglist.html

23.5. How to contact the OpenLDAP Project

- Mailing Lists: http://www.openldap.org/lists/
- Project: http://www.openldap.org/project/
- Issue Tracking: http://www.openldap.org/its/

23.6. How to present your problem

23.7. Debugging *slapd*(8)

After reading through the above sections and before e-mailing the OpenLDAP lists, you might want to try out some of the following to track down the cause of your problems:

- A loglevel of stats (256) is generally a good first loglevel to use for getting information useful to list members on issues. This is the default loglevel if none is configured.
- Running *slapd -d -1* can often track down fairly simple issues, such as missing schemas and incorrect file permissions for the *slapd* user to things like certs
- Check your logs for errors, as discussed at http://www.openldap.org/faq/data/cache/358.html

23.8. Commercial Support

The firms listed at http://www.openldap.org/support/ offer technical support services catering to OpenLDAP community.

The listing of any given firm should not be viewed as an endorsement or recommendation of any kind, nor as otherwise indicating there exists a business relationship or an affiliation between any listed firm and the OpenLDAP Foundation or the OpenLDAP Project or its contributors.

A. Changes Since Previous Release

The following sections attempt to summarize the new features and changes in OpenLDAP software since the 2.5.x release and the OpenLDAP Admin Guide.

A.1. New Features and Enhancements in 2.6

A.1.1. New features in slapd

slapd now supports logging directly to a file, bypassing syslog.

A.1.2. New features in lloadd

lloadd now supports additional balancing mechansims

A.2. Obsolete Features Removed From 2.6

These features were strongly deprecated in 2.5 and removed in 2.6.

A.2.1. back-ndb

The experimental and incomplete back-ndb backend was removed.

B. Upgrading from 2.5.x

The following sections attempt to document the steps you will need to take in order to upgrade from the latest 2.5.x OpenLDAP version.

The normal upgrade procedure, as discussed in the Maintenance section, should of course still be followed prior to doing any of this.

B.1. ppolicy overlay

The pwdCheckModule option has been moved to the overlay configuration. Existing settings in password policy entries will be ignored. It will be necessary to use pwdUseCheckModule instead and add this configuration directive to the overlay when upgrading if it is currently in use.

B.2. lloadd backends

Backends for lloadd are now grouped in tiers specifying the balancing strategy. OpenLDAP 2.5 configurations must be updated to account for this change.

B.3. monitor backend

In 2.5 and prior, the managedInfo attribute in the cn=Log entry could be used to change the loglevel of the slapd process. In 2.6, monitorLogLevel can be used to change the slapd log level and monitorDebugLevel can be used to change the slapd debug level.

B.4. contrib modules

If still using the lastbind overlay with olcLastBindPrecision (when olcLastBindForwardUpdates is needed), you will need to configure precision on its backend entry instead and the overlay will honour it. The old attribute is no longer accepted or supported.

C. Common errors encountered when using OpenLDAP Software

The following sections attempt to summarize the most common causes of LDAP errors when using OpenLDAP

C.1. Common causes of LDAP errors

C.1.1. ldap_*: Can't contact LDAP server

The **Can't contact LDAP server** error is usually returned when the LDAP server cannot be contacted. This may occur for many reasons:

- the LDAP server is not running; this can be checked by running, for example,

```
telnet <host> <port>
```

replacing <*host*> and <*port*> with the hostname and the port the server is supposed to listen on.

- the client has not been instructed to contact a running server; with OpenLDAP command-line tools this is accomplished by providing the -H switch, whose argument is a valid LDAP url corresponding to the interface the server is supposed to be listening on.

C.1.2. ldap_*: No such object

The **no such object** error is generally returned when the target DN of the operation cannot be located. This section details reasons common to all operations. You should also look for answers specific to the operation (as indicated in the error message).

The most common reason for this error is non-existence of the named object. First, check for typos.

Also note that, by default, a new directory server holds no objects (except for a few system entries). So, if you are setting up a new directory server and get this message, it may simply be that you have yet to add the object you are trying to locate.

The error commonly occurs because a DN was not specified and a default was not properly configured.

If you have a suffix specified in slapd.conf eg.

```
suffix "dc=example,dc=com"
```

You should use

```
ldapsearch -b 'dc=example,dc=com' '(cn=jane*)'
```

to tell it where to start the search.

The `-b` should be specified for all LDAP commands unless you have an *ldap.conf*(5) default configured.

See *ldapsearch*(1), *ldapmodify*(1)

Also, *slapadd*(8) and its ancillary programs are very strict about the syntax of the LDIF file.

Some liberties in the LDIF file may result in an apparently successful creation of the database, but accessing some parts of it may be difficult.

One known common error in database creation is putting a blank line before the first entry in the LDIF file. **There must be no leading blank lines in the LDIF file.**

It is generally recommended that *ldapadd*(1) be used instead of *slapadd*(8) when adding new entries your directory. *slapadd*(8) should be used to bulk load entries known to be valid.

Another cause of this message is a referral ({SECT:Constructing a Distributed Directory Service}}) entry to an unpopulated directory.

Either remove the referral, or add a single record with the referral base DN to the empty directory.

This error may also occur when slapd is unable to access the contents of its database because of file permission problems. For instance, on a Red Hat Linux system, slapd runs as user 'ldap'. When slapadd is run as root to create a database from scratch, the contents of `/var/lib/ldap` are created with user and group root and with permission 600, making the contents inaccessible to the slapd server.

C.1.3. ldap_*: Can't chase referral

This is caused by the line

```
        referral        ldap://root.openldap.org
```

In `slapd.conf`, it was provided as an example for how to use referrals in the original file. However if your machine is not permanently connected to the Internet, it will fail to find the server, and hence produce an error message.

To resolve, just place a # in front of line and restart slapd or point it to an available ldap server.

See also: *ldapadd*(1), *ldapmodify*(1) and *slapd.conf*(5)

C.1.4. ldap_*: server is unwilling to perform

slapd will return an unwilling to perform error if the backend holding the target entry does not support the given operation.

The password backend is only willing to perform searches. It will return an unwilling to perform error for all other operations.

C.1.5. ldap_*: Insufficient access

This error occurs when server denies the operation due to insufficient access. This is usually caused by binding to a DN with insufficient privileges (or binding anonymously) to perform the operation.

You can bind as the rootdn/rootpw specified in *slapd.conf*(5) to gain full access. Otherwise, you must bind to an entry which has been granted the appropriate rights through access controls.

C.1.6. ldap_*: Invalid DN syntax

The target (or other) DN of the operation is invalid. This implies that either the string representation of the DN is not in the required form, one of the types in the attribute value assertions is not defined, or one of the values in the attribute value assertions does not conform to the appropriate syntax.

C.1.7. ldap_*: Referral hop limit exceeded

This error generally occurs when the client chases a referral which refers itself back to a server it already contacted. The server responds as it did before and the client loops. This loop is detected when the hop limit is exceeded.

This is most often caused through misconfiguration of the server's default referral. The default referral should not be itself:

That is, on ldap://myldap/ the default referral should not be ldap://myldap/ (or any hostname/ip which is equivalent to myldap).

C.1.8. ldap_*: operations error

In some versions of *slapd*(8), *operationsError* was returned instead of other.

C.1.9. ldap_*: other error

The other result code indicates an internal error has occurred. While the additional information provided with the result code might provide some hint as to the problem, often one will need to consult the server's log files.

C.1.10. ldap_add/modify: Invalid syntax

This error is reported when a value of an attribute does not conform to syntax restrictions. Additional information is commonly provided stating which value of which attribute was found to be invalid. Double check this value and other values (the server will only report the first error it finds).

Common causes include:

- extraneous whitespace (especially trailing whitespace)
- improperly encoded characters (LDAPv3 uses UTF-8 encoded Unicode)
- empty values (few syntaxes allow empty values)

For certain syntax, like OBJECT IDENTIFIER (OID), this error can indicate that the OID descriptor (a "short name") provided is unrecognized. For instance, this error is returned if the *objectClass* value provided is unrecognized.

C.1.11. ldap_add/modify: Object class violation

This error is returned with the entry to be added or the entry as modified violates the object class schema rules. Normally additional information is returned the error detailing the violation. Some of these are detailed below.

Violations related to the entry's attributes:

```
            Attribute not allowed
```

A provided attribute is not allowed by the entry's object class(es).

```
            Missing required attribute
```

An attribute required by the entry's object class(es) was not provided.

Violations related to the entry's class(es):

```
            Entry has no objectClass attribute
```

The entry did not state which object classes it belonged to.

```
            Unrecognized objectClass
```

One (or more) of the listed objectClass values is not recognized.

```
            No structural object class provided
```

None of the listed objectClass values is structural.

```
            Invalid structural object class chain
```

Two or more structural objectClass values are not in same structural object class chain.

```
            Structural object class modification
```

Modify operation attempts to change the structural class of the entry.

```
            Instantiation of abstract objectClass.
```

An abstract class is not subordinate to any listed structural or auxiliary class.

```
            Invalid structural object class
```

Other structural object class problem.

```
            No structuralObjectClass operational attribute
```

This is commonly returned when a shadow server is provided an entry which does not contain the structuralObjectClass operational attribute.

Note that the above error messages as well as the above answer assumes basic knowledge of LDAP/X.500 schema.

C.1.12. ldap_add: No such object

The "ldap_add: No such object" error is commonly returned if parent of the entry being added does not exist. Add the parent entry first...

For example, if you are adding "cn=bob,dc=domain,dc=com" and you get:

```
            ldap_add: No such object
```

The entry "dc=domain,dc=com" likely doesn't exist. You can use ldapsearch to see if does exist:

```
            ldapsearch -b 'dc=domain,dc=com' -s base '(objectclass=*)'
```

If it doesn't, add it. See A Quick-Start Guide for assistance.

Note: if the entry being added is the same as database suffix, it's parent isn't required. i.e.: if your suffix is "dc=domain,dc=com", "dc=com" doesn't need to exist to add "dc=domain,dc=com".

This error will also occur if you try to add any entry that the server is not configured to hold.

For example, if your database suffix is "dc=domain,dc=com" and you attempt to add "dc=domain2,dc=com", "dc=com", "dc=domain,dc=org", "o=domain,c=us", or an other DN in the "dc=domain,dc=com" subtree, the server will return a "No such object" (or referral) error.

slapd(8) will generally return "no global superior knowledge" as additional information indicating its return noSuchObject instead of a referral as the server is not configured with knowledge of a global superior server.

C.1.13. ldap add: invalid structural object class chain

This particular error refers to the rule about STRUCTURAL objectclasses, which states that an object is of one STRUCTURAL class, the structural class of the object. The object is said to belong to this class, zero or more auxiliaries classes, and their super classes.

While all of these classes are commonly listed in the objectClass attribute of the entry, one of these classes is the structural object class of the entry. Thus, it is OK for an objectClass attribute to contain inetOrgPerson, organizationalPerson, and person because they inherit one from another to form a single super class chain. That is, inetOrgPerson SUPs organizationPerson SUPs person. On the other hand, it is invalid for both inetOrgPerson and account to be listed in objectClass as inetOrgPerson and account are not part of the same super class chain (unless some other class is also listed with is a subclass of both).

To resolve this problem, one must determine which class will better serve structural object class for the entry, adding this class to the objectClass attribute (if not already present), and remove any other structural class from the entry's objectClass attribute which is not a super class of the structural object class.

Which object class is better depends on the particulars of the situation. One generally should consult the documentation for the applications one is using for help in making the determination.

C.1.14. ldap_add: no structuralObjectClass operational attribute

ldapadd(1) may error:

```
adding new entry "uid=XXX,ou=People,o=campus,c=ru"
  ldap_add: Internal (implementation specific) error (80)
     additional info: no structuralObjectClass operational attribute
```

when slapd(8) cannot determine, based upon the contents of the objectClass attribute, what the structural class of the object should be.

C.1.15. ldap_add/modify/rename: Naming violation

OpenLDAP's slapd checks for naming attributes and distinguished values consistency, according to RFC 4512.

Naming attributes are those attributeTypes that appear in an entry's RDN; distinguished values are the values of the naming attributes that appear in an entry's RDN, e.g, in

```
cn=Someone+mail=someone@example.com,dc=example,dc=com
```

the naming attributes are cn and mail, and the distinguished values are Someone and someone@example.com.

OpenLDAP's slapd checks for consistency when:

- adding an entry
- modifying an entry, if the values of the naming attributes are changed
- renaming an entry, if the RDN of the entry changes

Possible causes of error are:

- the naming attributes are not present in the entry; for example:

  ```
  dn: dc=example,dc=com
  objectClass: organization
  o: Example
  # note: "dc: example" is missing
  ```

- the naming attributes are present in the entry, but in the attributeType definition they are marked as:
  - collective
  - operational
  - obsolete
- the naming attributes are present in the entry, but the distinguished values are not; for example:

  ```
  dn: dc=example,dc=com
  objectClass: domain
  dc: foobar
  # note: "dc" is present, but the value is not "example"
  ```

- the naming attributes are present in the entry, with the distinguished values, but the naming attributes:
  - do not have an equality field, so equality cannot be asserted
  - the matching rule is not supported (yet)

    - the matching rule is not appropriate
- the given distinguished values do not comply with their syntax
- other errors occurred during the validation/normalization/match process; this is a catchall: look at previous logs for details in case none of the above apply to your case.

In any case, make sure that the attributeType definition for the naming attributes contains an appropriate EQUALITY field; or that of the superior, if they are defined based on a superior attributeType (look at the SUP field). See RFC 4512 for details.

C.1.16. ldap_add/delete/modify/rename: no global superior knowledge

If the target entry name places is not within any of the databases the server is configured to hold and the server has no knowledge of a global superior, the server will indicate it is unwilling to perform the operation and provide the text "no global superior knowledge" as additional text.

Likely the entry name is incorrect, or the server is not properly configured to hold the named entry, or, in distributed directory environments, a default referral was not configured.

C.1.17. ldap_bind: Insufficient access

Current versions of slapd(8) requires that clients have authentication permission to attribute types used for authentication purposes before accessing them to perform the bind operation. As all bind operations are done anonymously (regardless of previous bind success), the auth access must be granted to anonymous.

In the example ACL below grants the following access:

- to anonymous users:
    - permission to authenticate using values of userPassword
- to authenticated users:
    - permission to update (but not read) their userPassword
    - permission to read any object excepting values of userPassword

All other access is denied.

```
access to attr=userPassword
  by self =w
  by anonymous auth
access *
  by self write
  by users read
```

C.1.18. ldap_bind: Invalid credentials

The error usually occurs when the credentials (password) provided does not match the userPassword held in entry you are binding to.

The error can also occur when the bind DN specified is not known to the server.

Check both! In addition to the cases mentioned above you should check if the server denied access to userPassword on selected parts of the directory. In fact, slapd always returns "Invalid credentials" in case of failed bind, regardless of the failure reason, since other return codes could reveal the validity of the user's name.

To debug access rules defined in slapd.conf, add "ACL" to log level.

C.1.19. ldap_bind: Protocol error

There error is generally occurs when the LDAP version requested by the client is not supported by the server.

The OpenLDAP Software 2.x server, by default, only accepts version 3 LDAP Bind requests but can be configured to accept a version 2 LDAP Bind request.

Note: The 2.x server expects LDAPv3 [RFC4510] to be used when the client requests version 3 and expects a limited LDAPv3 variant (basically, LDAPv3 syntax and semantics in an LDAPv2 PDUs) to be used when version 2 is expected.

This variant is also sometimes referred to as LDAPv2+, but differs from the U-Mich LDAP variant in a number of ways.

C.1.20. ldap_modify: cannot modify object class

This message is commonly returned when attempting to modify the objectClass attribute in a manner inconsistent with the LDAP/X.500 information model. In particular, it commonly occurs when one tries to change the structure of the object from one class to another, for instance, trying to change an 'apple' into a 'pear' or a 'fruit' into a 'pear'.

Such changes are disallowed by the slapd(8) in accordance with LDAP and X.500 restrictions.

C.1.21. ldap_sasl_interactive_bind_s: ...

If you intended to bind using a DN and password and get an error from ldap_sasl_interactive_bind_s, you likely forgot to provide a '-x' option to the command. By default, SASL authentication is used. '-x' is necessary to select "simple" authentication.

C.1.22. ldap_sasl_interactive_bind_s: No such Object

This indicates that LDAP SASL authentication function could not read the Root DSE. The error will occur when the server doesn't provide a root DSE. This may be due to access controls.

C.1.23. ldap_sasl_interactive_bind_s: No such attribute

This indicates that LDAP SASL authentication function could read the Root DSE but it contained no supportedSASLMechanism attribute.

The supportedSASLmechanism attribute lists mechanisms currently available. The list may be empty because none of the supported mechanisms are currently available. For example, EXTERNAL is listed only if the client has established its identity by authenticating at a lower level (e.g. TLS).

Note: the attribute may not be visible due to access controls

---

Note: SASL bind is the default for all OpenLDAP tools, e.g. ldapsearch(1), ldapmodify(1). To force use of "simple" bind, use the "-x" option. Use of "simple" bind is not recommended unless one has adequate confidentiality protection in place (e.g. TLS/SSL, IPSEC).

C.1.24. ldap_sasl_interactive_bind_s: Unknown authentication method

This indicates that none of the SASL authentication supported by the server are supported by the client, or that they are too weak or otherwise inappropriate for use by the client. Note that the default security options disallows the use of certain mechanisms such as ANONYMOUS and PLAIN (without TLS).

Note: SASL bind is the default for all OpenLDAP tools. To force use of "simple" bind, use the "-x" option. Use of "simple" bind is not recommended unless one has adequate confidentiality protection in place (e.g. TLS/SSL, IPSEC).

C.1.25. ldap_sasl_interactive_bind_s: Local error (82)

Apparently not having forward and reverse DNS entries for the LDAP server can result in this error.

C.1.26. ldap_search: Partial results and referral received

This error is returned with the server responses to an LDAPv2 search query with both results (zero or more matched entries) and references (referrals to other servers). See also: ldapsearch(1).

If the updatedn on the replica does not exist, a referral will be returned. It may do this as well if the ACL needs tweaking.

C.1.27. ldap_start_tls: Operations error

ldapsearch(1) and other tools will return

```
        ldap_start_tls: Operations error (1)
              additional info: TLS already started
```

When the user (though command line options and/or ldap.conf(5)) has requested TLS (SSL) be started twice. For instance, when specifying both "-H ldaps://server.do.main" and "-ZZ".

C.2. Other Errors

C.2.1. ber_get_next on fd X failed errno=34 (Numerical result out of range)

This slapd error generally indicates that the client sent a message that exceeded an administrative limit. See sockbuf_max_incoming and sockbuf_max_incoming_auth configuration directives in slapd.conf(5).

C.2.2. ber_get_next on fd X failed errno=11 (Resource temporarily unavailable)

This message is not indicative of abnormal behavior or error. It simply means that expected data is not yet available from the resource, in this context, a network socket. slapd(8) will process the data once it does becomes available.

C.2.3. daemon: socket() failed errno=97 (Address family not supported)

This message indicates that the operating system does not support one of the (protocol) address families which slapd(8) was configured to support. Most commonly, this occurs when slapd(8) was configured to support IPv6 yet the operating system kernel wasn't. In such cases, the message can be ignored.

C.2.4. GSSAPI: gss_acquire_cred: Miscellaneous failure; Permission denied;

This message means that slapd is not running as root and, thus, it cannot get its Kerberos 5 key from the keytab, usually file /etc/krb5.keytab.

A keytab file is used to store keys that are to be used by services or daemons that are started at boot time. It is very important that these secrets are kept beyond reach of intruders.

That's why the default keytab file is owned by root and protected from being read by others. Do not mess with these permissions, build a different keytab file for slapd instead, and make sure it is owned by the user that slapd runs as.

To do this, start kadmin, and enter the following commands:

```
addprinc -randkey ldap/ldap.example.com@EXAMPLE.COM
ktadd -k /etc/openldap/ldap.keytab ldap/ldap.example.com@EXAMPLE.COM
```

Then, on the shell, do:

```
chown ldap:ldap /etc/openldap/ldap.keytab
chmod 600 /etc/openldap/ldap.keytab
```

Now you have to tell slapd (well, actually tell the gssapi library in Kerberos 5 that is invoked by Cyrus SASL) where to find the new keytab. You do this by setting the environment variable KRB5_KTNAME like this:

```
export KRB5_KTNAME="FILE:/etc/openldap/ldap.keytab"
```

Set that environment variable on the slapd start script (Red Hat users might find /etc/sysconfig/ldap a perfect place).

This only works if you are using MIT kerberos. It doesn't work with Heimdal, for instance.

In Heimdal there is a function gsskrb5_register_acceptor_identity() that sets the path of the keytab file you want to use. In Cyrus SASL 2 you can add

```
keytab: /path/to/file
```

to your application's SASL config file to use this feature. This only works with Heimdal.

C.2.5. access from unknown denied

This related to TCP wrappers. See hosts_access(5) for more information. in the log file: "access from unknown denied" This related to TCP wrappers. See hosts_access(5) for more information. for example: add the line "slapd: .hosts.you.want.to.allow" in /etc/hosts.allow to get rid of the error.

C.2.6. ldap_read: want=# error=Resource temporarily unavailable

This message occurs normally. It means that pending data is not yet available from the resource, a network socket. slapd(8) will process the data once it becomes available.

C.2.7. `make test' fails

Some times, `make test' fails at the very first test with an obscure message like

```
make test
make[1]: Entering directory `/ldap_files/openldap-2.5.0/tests'
make[2]: Entering directory `/ldap_files/openldap-2.5.0/tests'
Initiating LDAP tests for MDB...
Cleaning up test run directory leftover from previous run.
 Running ./scripts/all...
>>>>> Executing all LDAP tests for mdb
>>>>> Starting test000-rootdse ...
running defines.sh
Starting slapd on TCP/IP port 9011...
Using ldapsearch to retrieve the root DSE...
Waiting 5 seconds for slapd to start...
./scripts/test000-rootdse: line 40: 10607 Segmentation fault $SLAPD -f $CONF1 -h $UR
Waiting 5 seconds for slapd to start...
Waiting 5 seconds for slapd to start...
Waiting 5 seconds for slapd to start...
Waiting 5 seconds for slapd to start...
Waiting 5 seconds for slapd to start...
./scripts/test000-rootdse: kill: (10607) - No such pid
ldap_sasl_bind_s: Can't contact LDAP server (-1)
>>>>> Test failed
>>>>> ./scripts/test000-rootdse failed (exit 1)
make[2]: *** [mdb-yes] Error 1
make[2]: Leaving directory `/ldap_files/openldap-2.5.0/tests'
make[1]: *** [test] Error 2
make[1]: Leaving directory `/ldap_files/openldap-2.5.0/tests'
make: *** [test] Error 2
```

or so. Usually, the five lines

Waiting 5 seconds for slapd to start...

indicate that slapd didn't start at all.

In tests/testrun/slapd.1.log there is a full log of what slapd wrote while trying to start. The log level can be increased by setting the environment variable SLAPD_DEBUG to the corresponding value; see loglevel in slapd.conf(5) for the meaning of log levels.

A typical reason for this behavior is a runtime link problem, i.e. slapd cannot find some dynamic libraries it was linked against. Try running ldd(1) on slapd (for those architectures that support runtime linking).

There might well be other reasons; the contents of the log file should help clarifying them.

Tests that fire up multiple instances of slapd typically log to tests/testrun/slapd.<n>.log, with a distinct <n> for each instance of slapd; list tests/testrun/ for possible values of <n>.

C.2.8. ldap_*: Internal (implementation specific) error (80) - additional info: entry index delete failed

This seems to be related with wrong ownership of the MDB's dir (/var/lib/ldap) and files. The files must be owned by the user that slapd runs as.

```
chown -R ldap:ldap /var/lib/ldap
```

fixes it in Debian

C.2.9. ldap_sasl_interactive_bind_s: Can't contact LDAP server (-1)

Using SASL, when a client contacts LDAP server, the slapd service dies immediately and client gets an error :

```
SASL/GSSAPI authentication started ldap_sasl_interactive_bind_s: Can't contact LDAP server
```

Then check the slapd service, it stopped.

D. Recommended OpenLDAP Software Dependency Versions

This appendix details the recommended versions of the software that OpenLDAP depends on.

Please read the Prerequisite software section for more information on the following software dependencies.

D.1. Dependency Versions

Table 8.5: OpenLDAP Software Dependency Versions

Feature	**Software**	**Version**
Transport Layer Security:		
	`OpenSSL`	`1.1.1+`
	`GnuTLS`	`3.6.0+`
Simple Authentication and Security Layer	`Cyrus SASL`	`2.1.27+`
LDAP Load Balancer	`libevent`	`2.1+`
Threads:	`POSIX` *`pthreads`*	`Version`

E. Real World OpenLDAP Deployments and Examples

Examples and discussions

F. OpenLDAP Software Contributions

The following sections attempt to summarize the various contributions in OpenLDAP software, as found in `openldap_src/contrib`

F.1. Client APIs

Intro and discuss

F.1.1. ldapc++

Intro and discuss

F.1.2. ldaptcl

Intro and discuss

F.2. Overlays

F.2.1. acl

Plugins that implement access rules. Currently only posixGroup, which implements access control based on posixGroup membership.

F.2.2. addpartial

Treat Add requests as Modify requests if the entry exists.

F.2.3. allop

Return operational attributes for root DSE even when not requested, since some clients expect this.

F.2.4. autogroup

Automated updates of group memberships.

F.2.5. comp_match

Component Matching rules (RFC 3687).

F.2.6. denyop

Deny selected operations, returning *unwillingToPerform*.

F.2.7. dsaschema

Permit loading DSA-specific schema, including operational attrs.

F.2.8. lastmod

Track the time of the last write operation to a database.

F.2.9. nops

Remove null operations, e.g. changing a value to same as before.

F.2.10. nssov

Handle NSS lookup requests through a local Unix Domain socket.

F.2.11. passwd

Support additional password mechanisms.

F.2.12. proxyOld

Proxy Authorization compatibility with obsolete internet-draft.

F.2.13. smbk5pwd

Make the PasswordModify Extended Operation update Kerberos keys and Samba password hashes as well as *userPassword*.

F.2.14. trace

Trace overlay invocation.

F.2.15. usn

Maintain *usnCreated* and *usnChanged* attrs similar to Microsoft AD.

F.3. Tools

Intro and discuss

F.3.1. Statistic Logging

statslog

F.4. SLAPI Plugins

Intro and discuss

F.4.1. addrdnvalues

More

G. Configuration File Examples

G.1. slapd.conf

G.2. ldap.conf

G.3. a-n-other.conf

H. LDAP Result Codes

For the purposes of this guide, we have incorporated the standard LDAP result codes from *Appendix A. LDAP Result Codes* of RFC4511, a copy of which can be found in `doc/rfc` of the OpenLDAP source code.

We have expanded the description of each error in relation to the OpenLDAP toolsets. LDAP extensions may introduce extension-specific result codes, which are not part of RFC4511. OpenLDAP returns the result codes related to extensions it implements. Their meaning is documented in the extension they are related to.

H.1. Non-Error Result Codes

These result codes (called "non-error" result codes) do not indicate an error condition:

```
success (0),
compareFalse (5),
compareTrue (6),
referral (10), and
saslBindInProgress (14).
```

The *success*, *compareTrue*, and *compareFalse* result codes indicate successful completion (and, hence, are referred to as "successful" result codes).

The *referral* and *saslBindInProgress* result codes indicate the client needs to take additional action to complete the operation.

H.2. Result Codes

Existing LDAP result codes are described as follows:

H.3. success (0)

Indicates the successful completion of an operation.

Note: this code is not used with the Compare operation. See compareFalse (5) and compareTrue (6).

H.4. operationsError (1)

Indicates that the operation is not properly sequenced with relation to other operations (of same or different type).

For example, this code is returned if the client attempts to StartTLS (RFC4511 Section 4.14) while there are other uncompleted operations or if a TLS layer was already installed.

H.5. protocolError (2)

Indicates the server received data that is not well-formed.

For Bind operation only, this code is also used to indicate that the server does not support the requested protocol version.

For Extended operations only, this code is also used to indicate that the server does not support (by design or configuration) the Extended operation associated with the *requestName*.

For request operations specifying multiple controls, this may be used to indicate that the server cannot ignore the order of the controls as specified, or that the combination of the specified controls is invalid or unspecified.

H.6. timeLimitExceeded (3)

Indicates that the time limit specified by the client was exceeded before the operation could be completed.

H.7. sizeLimitExceeded (4)

Indicates that the size limit specified by the client was exceeded before the operation could be completed.

H.8. compareFalse (5)

Indicates that the Compare operation has successfully completed and the assertion has evaluated to FALSE or Undefined.

H.9. compareTrue (6)

Indicates that the Compare operation has successfully completed and the assertion has evaluated to TRUE.

H.10. authMethodNotSupported (7)

Indicates that the authentication method or mechanism is not supported.

H.11. strongerAuthRequired (8)

Indicates the server requires strong(er) authentication in order to complete the operation.

When used with the Notice of Disconnection operation, this code indicates that the server has detected that an established security association between the client and server has unexpectedly failed or been compromised.

H.12. referral (10)

Indicates that a referral needs to be chased to complete the operation (see RFC4511 Section 4.1.10).

H.13. adminLimitExceeded (11)

Indicates that an administrative limit has been exceeded.

H.14. unavailableCriticalExtension (12)

Indicates a critical control is unrecognized (see RFC4511 Section 4.1.11).

H.15. confidentialityRequired (13)

Indicates that data confidentiality protections are required.

H.16. saslBindInProgress (14)

Indicates the server requires the client to send a new bind request, with the same SASL mechanism, to continue the authentication process (see RFC4511 Section 4.2).

H.17. noSuchAttribute (16)

Indicates that the named entry does not contain the specified attribute or attribute value.

H.18. undefinedAttributeType (17)

Indicates that a request field contains an unrecognized attribute description.

H.19. inappropriateMatching (18)

Indicates that an attempt was made (e.g., in an assertion) to use a matching rule not defined for the attribute type concerned.

H.20. constraintViolation (19)

Indicates that the client supplied an attribute value that does not conform to the constraints placed upon it by the data model.

For example, this code is returned when multiple values are supplied to an attribute that has a SINGLE-VALUE constraint.

H.21. attributeOrValueExists (20)

Indicates that the client supplied an attribute or value to be added to an entry, but the attribute or value already exists.

H.22. invalidAttributeSyntax (21)

Indicates that a purported attribute value does not conform to the syntax of the attribute.

H.23. noSuchObject (32)

Indicates that the object does not exist in the DIT.

H.24. aliasProblem (33)

Indicates that an alias problem has occurred. For example, the code may used to indicate an alias has been dereferenced that names no object.

H.25. invalidDNSyntax (34)

Indicates that an LDAPDN or RelativeLDAPDN field (e.g., search base, target entry, ModifyDN newrdn, etc.) of a request does not conform to the required syntax or contains attribute values that do not conform to the syntax of the attribute's type.

H.26. aliasDereferencingProblem (36)

Indicates that a problem occurred while dereferencing an alias. Typically, an alias was encountered in a situation where it was not allowed or where access was denied.

H.27. inappropriateAuthentication (48)

Indicates the server requires the client that had attempted to bind anonymously or without supplying credentials to provide some form of credentials.

H.28. invalidCredentials (49)

Indicates that the provided credentials (e.g., the user's name and password) are invalid.

H.29. insufficientAccessRights (50)

Indicates that the client does not have sufficient access rights to perform the operation.

H.30. busy (51)

Indicates that the server is too busy to service the operation.

H.31. unavailable (52)

Indicates that the server is shutting down or a subsystem necessary to complete the operation is offline.

H.32. unwillingToPerform (53)

Indicates that the server is unwilling to perform the operation.

H.33. loopDetect (54)

Indicates that the server has detected an internal loop (e.g., while dereferencing aliases or chaining an operation).

H.34. namingViolation (64)

Indicates that the entry's name violates naming restrictions.

H.35. objectClassViolation (65)

Indicates that the entry violates object class restrictions.

H.36. notAllowedOnNonLeaf (66)

Indicates that the operation is inappropriately acting upon a non-leaf entry.

H.37. notAllowedOnRDN (67)

Indicates that the operation is inappropriately attempting to remove a value that forms the entry's relative distinguished name.

H.38. entryAlreadyExists (68)

Indicates that the request cannot be fulfilled (added, moved, or renamed) as the target entry already exists.

H.39. objectClassModsProhibited (69)

Indicates that an attempt to modify the object class(es) of an entry's 'objectClass' attribute is prohibited.

For example, this code is returned when a client attempts to modify the structural object class of an entry.

H.40. affectsMultipleDSAs (71)

Indicates that the operation cannot be performed as it would affect multiple servers (DSAs).

H.41. other (80)

Indicates the server has encountered an internal error.

I. Glossary

I.1. Terms

Term	Definition
3DES	Triple DES
ABNF	Augmented Backus-Naur Form
ACDF	Access Control Decision Function
ACE	ASCII Compatible Encoding
ASCII	American Standard Code for Information Interchange
ACID	Atomicity, Consistency, Isolation, and Durability
ACI	Access Control Information
ACL	Access Control List
AES	Advance Encryption Standard
ABI	Application Binary Interface
API	Application Program Interface
ASN.1	Abstract Syntax Notation - One
AVA	Attribute Value Assertion
AuthcDN	Authentication DN
AuthcId	Authentication Identity
AuthzDN	Authorization DN
AuthzId	Authorization Identity
BCP	Best Current Practice
BER	Basic Encoding Rules
BNF	Backus-Naur Form
C	The C Programming Language
CA	Certificate Authority
CER	Canonical Encoding Rules
CLDAP	Connection-less LDAP
CN	Common Name
CRAM-MD5	SASL MD5 Challenge/Response Authentication Mechanism
CRL	Certificate Revocation List
DAP	Directory Access Protocol
DC	Domain Component
DER	Distinguished Encoding Rules
DES	Data Encryption Standard
DIB	Directory Information Base
DIGEST-MD5	SASL Digest MD5 Authentication Mechanism
DISP	Directory Information Shadowing Protocol
DIT	Directory Information Tree
DNS	Domain Name System

DN	Distinguished Name
DOP	Directory Operational Binding Management Protocol
DSAIT	DSA Information Tree
DSA	Directory System Agent
DSE	DSA-specific Entry
DSP	Directory System Protocol
DS	Draft Standard
DUA	Directory User Agent
EXTERNAL	SASL External Authentication Mechanism
FAQ	Frequently Asked Questions
FTP	File Transfer Protocol
FYI	For Your Information
GSER	Generic String Encoding Rules
GSS-API	Generic Security Service Application Program Interface
GSSAPI	SASL Kerberos V GSS-API Authentication Mechanism
I-D	Internet-Draft
IA5	International Alphabet 5
IDNA	Internationalized Domain Names in Applications
IDN	Internationalized Domain Name
ID	Identifier
IDL	Index Data Lookups
IP	Internet Protocol
IPC	Inter-process communication
IPsec	Internet Protocol Security
IPv4	Internet Protocol, version 4
IPv6	Internet Protocol, version 6
ITS	Issue Tracking System
JPEG	Joint Photographic Experts Group
Kerberos	Kerberos Authentication Service
LBER	Lightweight BER
LDAP	Lightweight Directory Access Protocol
LDAP Sync	LDAP Content Synchronization
LDAPv3	LDAP, version 3
LDIF	LDAP Data Interchange Format
LMDB	Lightning Memory-Mapped Database
MD5	Message Digest 5
MDB	Memory-Mapped Database (Backend)
MIB	Management Information Base
MODDN	Modify DN
MODRDN	Modify RDN
NSSR	Non-specific Subordinate Reference
OID	Object Identifier

OSI	Open Systems Interconnect
OTP	One Time Password
PDU	Protocol Data Unit
PEM	Privacy Enhanced eMail
PEN	Private Enterprise Number
PKCS	Public Key Cryptosystem
PKI	Public Key Infrastructure
PKIX	Public Key Infrastructure (X.509)
PLAIN	SASL Plaintext Password Authentication Mechanism
POSIX	Portable Operating System Interface
PS	Proposed Standard
RDN	Relative Distinguished Name
RFC	Request for Comments
RPC	Remote Procedure Call
RXER	Robust XML Encoding Rules
SASL	Simple Authentication and Security Layer
SDF	Simple Document Format
SDSE	Shadowed DSE
SHA1	Secure Hash Algorithm 1
SLAPD	Standalone LDAP Daemon
SLURPD	Standalone LDAP Update Replication Daemon
SMTP	Simple Mail Transfer Protocol
SNMP	Simple Network Management Protocol
SQL	Structured Query Language
SRP	Secure Remote Password
SSF	Security Strength Factor
SSL	Secure Socket Layer
STD	Internet Standard
TCP	Transmission Control Protocol
TLS	Transport Layer Security
UCS	Universal Multiple-Octet Coded Character Set
UDP	User Datagram Protocol
UID	User Identifier
Unicode	The Unicode Standard
UNIX	Unix
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
URN	Uniform Resource Name
UTF-8	8-bit UCS/Unicode Transformation Format
UTR	Unicode Technical Report
UUID	Universally Unique Identifier
WWW	World Wide Web

X.500	X.500 Directory Services
X.509	X.509 Public Key and Attribute Certificate Frameworks
XED	XML Enabled Directory
XER	XML Encoding Rules
XML	Extensible Markup Language
syncrepl	LDAP Sync-based Replication
lloadd	LDAP Load Balancer

I.2. Related Organizations

Name	Long	Jump
ANSI	American National Standards Institute	https://www.ansi.org/
BSI	British Standards Institute	https://www.bsigroup.com/en-GB/
COSINE	Co-operation and Open Systems Interconnection in Europe	
CPAN	Comprehensive Perl Archive Network	https://www.cpan.org/
Cyrus	Project Cyrus	https://www.cyrusimap.org/
FSF	Free Software Foundation	https://www.fsf.org/
GNU	GNU Not Unix Project	https://www.gnu.org/
IAB	Internet Architecture Board	https://www.iab.org/
IANA	Internet Assigned Numbers Authority	https://www.iana.org/
IEEE	Institute of Electrical and Electronics Engineers	https://www.ieee.org
IESG	Internet Engineering Steering Group	https://www.ietf.org/about/groups/iesg/
IETF	Internet Engineering Task Force	https://www.ietf.org/
IRTF	Internet Research Task Force	https://irtf.org/
ISO	International Standards Organisation	https://www.iso.org/
ISOC	Internet Society	https://www.internetsociety.org/
ITU	International Telecommunication	https://www.itu.int/

	Union	
OLF	OpenLDAP Foundation	https://www.openldap.org/foundation/
OLP	OpenLDAP Project	https://www.openldap.org/project/
OpenSSL	OpenSSL Project	https://www.openssl.org/
RFC Editor	RFC Editor	https://www.rfc-editor.org/
Oracle	Oracle Corporation	https://www.oracle.com/
UM	University of Michigan	https://www.umich.edu/
UMLDAP	University of Michigan LDAP Team	https://web.archive.org/web/20160302011357/http://www.umich.edu/~dirsvcs/ldap/l

I.3. Related Products

Name	Jump
SDF	https://metacpan.org/release/sdf
Cyrus	https://www.cyrusimap.org/
Cyrus SASL	https://www.cyrusimap.org/sasl/
Git	https://git-scm.com/
GNU	https://www.gnu.org/software/
GnuTLS	https://gnutls.org/
Heimdal	https://github.com/heimdal/
JLDAP	https://www.openldap.org/jldap/
libevent	https://libevent.org/
MIT Kerberos	https://web.mit.edu/kerberos/
OpenLDAP	https://www.openldap.org/
OpenLDAP FAQ	https://www.openldap.org/faq/
OpenLDAP ITS	https://bugs.openldap.org/
OpenLDAP Software	https://www.openldap.org/software/
OpenSSL	https://www.openssl.org/
Perl	https://www.perl.org/
UMLDAP	https://web.archive.org/web/20160302011357/http://www.umich.edu/~dirsvcs/ldap/ldap.html

I.4. References

Reference	Document	Status	Jump
UM-GUIDE	The SLAPD and SLURPD Administrators Guide	O	https://web.archive.org/web/20170809071245/http://www.umich.edu/~dirsvc
RFC2079	Definition of an X.500 Attribute	PS	https://www.rfc-editor.org/rfc/rfc2079.txt

	Type and an Object Class to Hold Uniform Resource Identifiers		
RFC2296	Use of Language Codes in LDAP	PS	https://www.rfc-editor.org/rfc/rfc2296.txt
RFC2307	An Approach for Using LDAP as a Network Information Service	X	https://www.rfc-editor.org/rfc/rfc2307.txt
RFC2589	Lightweight Directory Access Protocol (v3): Extensions for Dynamic Directory Services	PS	https://www.rfc-editor.org/rfc/rfc2589.txt
RFC2798	Definition of the inetOrgPerson LDAP Object Class	I	https://www.rfc-editor.org/rfc/rfc2798.txt
RFC2831	Using Digest Authentication as a SASL Mechanism	PS	https://www.rfc-editor.org/rfc/rfc2831.txt
RFC2849	The LDAP Data Interchange Format	PS	https://www.rfc-editor.org/rfc/rfc2849.txt
RFC3088	OpenLDAP Root Service	X	https://www.rfc-editor.org/rfc/rfc3088.txt
RFC3296	Named Subordinate References in LDAP	PS	https://www.rfc-editor.org/rfc/rfc3296.txt
RFC3384	Lightweight Directory Access Protocol (version 3) Replication Requirements	I	https://www.rfc-editor.org/rfc/rfc3384.txt
RFC3494	Lightweight Directory Access Protocol version 2 (LDAPv2) to Historic Status	I	https://www.rfc-editor.org/rfc/rfc3494.txt
RFC4013	SASLprep: Stringprep	PS	https://www.rfc-editor.org/rfc/rfc4013.txt

	Profile for User Names and Passwords		
RFC4346	The Transport Layer Security (TLS) Protocol, Version 1.1	PS	https://www.rfc-editor.org/rfc/rfc4346.txt
RFC4370	Lightweight Directory Access Protocol (LDAP) Proxied Authorization Control	PS	https://www.rfc-editor.org/rfc/rfc4370.txt
RFC4422	Simple Authentication and Security Layer (SASL)	PS	https://www.rfc-editor.org/rfc/rfc4422.txt
RFC4510	Lightweight Directory Access Protocol (LDAP): Technical Specification Roadmap	PS	https://www.rfc-editor.org/rfc/rfc4510.txt
RFC4511	Lightweight Directory Access Protocol (LDAP): The Protocol	PS	https://www.rfc-editor.org/rfc/rfc4511.txt
RFC4512	Lightweight Directory Access Protocol (LDAP): Directory Information Models	PS	https://www.rfc-editor.org/rfc/rfc4512.txt
RFC4513	Lightweight Directory Access Protocol (LDAP): Authentication Methods and Security Mechanisms	PS	https://www.rfc-editor.org/rfc/rfc4513.txt
RFC4514	Lightweight Directory Access Protocol (LDAP): String Representation of	PS	https://www.rfc-editor.org/rfc/rfc4514.txt

	Distinguished Names		
RFC4515	Lightweight Directory Access Protocol (LDAP): String Representation of Search Filters	PS	https://www.rfc-editor.org/rfc/rfc4515.txt
RFC4516	Lightweight Directory Access Protocol (LDAP): Uniform Resource Locator	PS	https://www.rfc-editor.org/rfc/rfc4516.txt
RFC4517	Lightweight Directory Access Protocol (LDAP): Syntaxes and Matching Rules	PS	https://www.rfc-editor.org/rfc/rfc4517.txt
RFC4518	Lightweight Directory Access Protocol (LDAP): Internationalized String Preparation	PS	https://www.rfc-editor.org/rfc/rfc4518.txt
RFC4519	Lightweight Directory Access Protocol (LDAP): Schema for User Applications	PS	https://www.rfc-editor.org/rfc/rfc4519.txt
RFC4520	IANA Considerations for LDAP	BCP	https://www.rfc-editor.org/rfc/rfc4520.txt
RFC4533	The Lightweight Directory Access Protocol (LDAP) Content Synchronization Operation	X	https://www.rfc-editor.org/rfc/rfc4533.txt
Chu-LDAPI	Using LDAP Over IPC Mechanisms	ID	https://tools.ietf.org/html/draft-chu-ldap-ldapi-00

J. Generic configure Instructions

```
Basic Installation
==================

   These are generic installation instructions.

   The `configure' shell script attempts to guess correct values for
various system-dependent variables used during compilation.  It uses
those values to create a `Makefile' in each directory of the package.
It may also create one or more `.h' files containing system-dependent
definitions.  Finally, it creates a shell script `config.status' that
you can run in the future to recreate the current configuration, a file
`config.cache' that saves the results of its tests to speed up
reconfiguring, and a file `config.log' containing compiler output
(useful mainly for debugging `configure').

   If you need to do unusual things to compile the package, please try
to figure out how `configure' could check whether to do them, and mail
diffs or instructions to the address given in the `README' so they can
be considered for the next release.  If at some point `config.cache'
contains results you don't want to keep, you may remove or edit it.

   The file `configure.in' is used to create `configure' by a program
called `autoconf'.  You only need `configure.in' if you want to change
it or regenerate `configure' using a newer version of `autoconf'.

The simplest way to compile this package is:

  1. `cd' to the directory containing the package's source code and type
     `./configure' to configure the package for your system.  If you're
     using `csh' on an old version of System V, you might need to type
     `sh ./configure' instead to prevent `csh' from trying to execute
     `configure' itself.

     Running `configure' takes awhile.  While running, it prints some
     messages telling which features it is checking for.

  2. Type `make' to compile the package.

  3. Optionally, type `make check' to run any self-tests that come with
     the package.

  4. Type `make install' to install the programs and any data files and
     documentation.

  5. You can remove the program binaries and object files from the
     source code directory by typing `make clean'.  To also remove the
     files that `configure' created (so you can compile the package for
     a different kind of computer), type `make distclean'.  There is
     also a `make maintainer-clean' target, but that is intended mainly
     for the package's developers.  If you use it, you may have to get
     all sorts of other programs in order to regenerate files that came
     with the distribution.

Compilers and Options
=====================

   Some systems require unusual options for compilation or linking that
the `configure' script does not know about.  You can give `configure'
```

```
initial values for variables by setting them in the environment.  Using
a Bourne-compatible shell, you can do that on the command line like
this:
     CC=c89 CFLAGS=-O2 LIBS=-lposix ./configure

Or on systems that have the `env' program, you can do it like this:
     env CPPFLAGS=-I/usr/local/include LDFLAGS=-s ./configure

Compiling For Multiple Architectures
====================================

   You can compile the package for more than one kind of computer at the
same time, by placing the object files for each architecture in their
own directory.  To do this, you must use a version of `make' that
supports the `VPATH' variable, such as GNU `make'.  `cd' to the
directory where you want the object files and executables to go and run
the `configure' script.  `configure' automatically checks for the
source code in the directory that `configure' is in and in `..'.

   If you have to use a `make' that does not supports the `VPATH'
variable, you have to compile the package for one architecture at a time
in the source code directory.  After you have installed the package for
one architecture, use `make distclean' before reconfiguring for another
architecture.

Installation Names
==================

   By default, `make install' will install the package's files in
`/usr/local/bin', `/usr/local/man', etc.  You can specify an
installation prefix other than `/usr/local' by giving `configure' the
option `--prefix=PATH'.

   You can specify separate installation prefixes for
architecture-specific files and architecture-independent files.  If you
give `configure' the option `--exec-prefix=PATH', the package will use
PATH as the prefix for installing programs and libraries.
Documentation and other data files will still use the regular prefix.

   In addition, if you use an unusual directory layout you can give
options like `--bindir=PATH' to specify different values for particular
kinds of files.  Run `configure --help' for a list of the directories
you can set and what kinds of files go in them.

   If the package supports it, you can cause programs to be installed
with an extra prefix or suffix on their names by giving `configure' the
option `--program-prefix=PREFIX' or `--program-suffix=SUFFIX'.

Optional Features
=================

   Some packages pay attention to `--enable-FEATURE' options to
`configure', where FEATURE indicates an optional part of the package.
They may also pay attention to `--with-PACKAGE' options, where PACKAGE
is something like `gnu-as' or `x' (for the X Window System).  The
`README' should mention any `--enable-' and `--with-' options that the
package recognizes.

   For packages that use the X Window System, `configure' can usually
find the X include and library files automatically, but if it doesn't,
you can use the `configure' options `--x-includes=DIR' and
```

```
`--x-libraries=DIR' to specify their locations.

Specifying the System Type
==========================

   There may be some features `configure' can not figure out
automatically, but needs to determine by the type of host the package
will run on.  Usually `configure' can figure that out, but if it prints
a message saying it can not guess the host type, give it the
`--host=TYPE' option.  TYPE can either be a short name for the system
type, such as `sun4', or a canonical name with three fields:
     CPU-COMPANY-SYSTEM

See the file `config.sub' for the possible values of each field.  If
`config.sub' isn't included in this package, then this package doesn't
need to know the host type.

   If you are building compiler tools for cross-compiling, you can also
use the `--target=TYPE' option to select the type of system they will
produce code for and the `--build=TYPE' option to select the type of
system on which you are compiling the package.

Sharing Defaults
================

   If you want to set default values for `configure' scripts to share,
you can create a site shell script called `config.site' that gives
default values for variables like `CC', `cache_file', and `prefix'.
`configure' looks for `PREFIX/share/config.site' if it exists, then
`PREFIX/etc/config.site' if it exists.  Or, you can set the
`CONFIG_SITE' environment variable to the location of the site script.
A warning: not all `configure' scripts look for a site script.

Operation Controls
==================

   `configure' recognizes the following options to control how it
operates.

`--cache-file=FILE'
     Use and save the results of the tests in FILE instead of
     `./config.cache'.  Set FILE to `/dev/null' to disable caching, for
     debugging `configure'.

`--help'
     Print a summary of the options to `configure', and exit.

`--quiet'
`--silent'
`-q'
     Do not print messages saying which checks are being made.  To
     suppress all normal output, redirect it to `/dev/null' (any error
     messages will still be shown).

`--srcdir=DIR'
     Look for the package's source code in directory DIR.  Usually
     `configure' can determine that directory automatically.

`--version'
     Print the version of Autoconf used to generate the `configure'
     script, and exit.
```

```
`configure' also accepts some other, not widely useful, options.
```

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