Security in MySQL

Abstract

This is the MySQL Security Guide extract from the MySQL 5.7 Reference Manual.

For help with using MySQL, please visit either the MySQL Forums or MySQL Mailing Lists, where you can discuss your issues with other MySQL users.

For additional documentation on MySQL products, including translations of the documentation into other languages, and downloadable versions in variety of formats, including HTML and PDF formats, see the MySQL Documentation Library.

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Preface and Legal Notices

This is the MySQL Security Guide extract from the MySQL 5.7 Reference Manual.

Legal Notices

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Chapter 1 Security

When thinking about security within a MySQL installation, you should consider a wide range of possible topics and how they affect the security of your MySQL server and related applications:

- General factors that affect security. These include choosing good passwords, not granting unnecessary privileges to users, ensuring application security by preventing SQL injections and data corruption, and others. See Chapter 2, *General Security Issues*.
- Security of the installation itself. The data files, log files, and the all the application files of your installation should be protected to ensure that they are not readable or writable by unauthorized parties. For more information, see Chapter 3, *Postinstallation Setup and Testing*.
- Access control and security within the database system itself, including the users and databases granted with access to the databases, views and stored programs in use within the database. For more information, see Chapter 4, *The MySQL Access Privilege System*, and Chapter 5, *MySQL User Account Management*.
- The features offered by security-related plugins. See Chapter 7, *Security Plugins*.
- Network security of MySQL and your system. The security is related to the grants for individual users, but you may also wish to restrict MySQL so that it is available only locally on the MySQL server host, or to a limited set of other hosts.
- Ensure that you have adequate and appropriate backups of your database files, configuration and log files. Also be sure that you have a recovery solution in place and test that you are able to successfully recover the information from your backups. See Backup and Recovery.

Chapter 2 General Security Issues

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This section describes general security issues to be aware of and what you can do to make your MySQL installation more secure against attack or misuse. For information specifically about the access control system that MySQL uses for setting up user accounts and checking database access, see Chapter 3, *Postinstallation Setup and Testing*.

For answers to some questions that are often asked about MySQL Server security issues, see Appendix A, *MySQL 5.7 FAQ: Security*.

2.1 Security Guidelines

Anyone using MySQL on a computer connected to the Internet should read this section to avoid the most common security mistakes.

In discussing security, it is necessary to consider fully protecting the entire server host (not just the MySQL server) against all types of applicable attacks: eavesdropping, altering, playback, and denial of service. We do not cover all aspects of availability and fault tolerance here.

MySQL uses security based on Access Control Lists (ACLs) for all connections, queries, and other operations that users can attempt to perform. There is also support for SSL-encrypted connections between MySQL clients and servers. Many of the concepts discussed here are not specific to MySQL at all; the same general ideas apply to almost all applications.

When running MySQL, follow these guidelines:

- **Do not ever give anyone (except MySQL `root` accounts) access to the `user` table in the `mysql` database!** This is critical.
- Learn how the MySQL access privilege system works (see Chapter 4, *The MySQL Access Privilege System*). Use the `GRANT` and `REVOKE` statements to control access to MySQL. Do not grant more privileges than necessary. Never grant privileges to all hosts.

  Checklist:

  - Try `mysql -u root`. If you are able to connect successfully to the server without being asked for a password, anyone can connect to your MySQL server as the MySQL `root` user with full privileges! Review the MySQL installation instructions, paying particular attention to the information about setting a `root` password. See Section 3.4, “Securing the Initial MySQL Accounts”.
  - Use the `SHOW GRANTS` statement to check which accounts have access to what. Then use the `REVOKE` statement to remove those privileges that are not necessary.

- Do not store cleartext passwords in your database. If your computer becomes compromised, the intruder can take the full list of passwords and use them. Instead, use `SHA2()`, `SHA1()`, `MD5()`, or some other one-way hashing function and store the hash value.

  To prevent password recovery using rainbow tables, do not use these functions on a plain password; instead, choose some string to be used as a salt, and use hash(hash(password)+salt) values.

- Do not choose passwords from dictionaries. Special programs exist to break passwords. Even passwords like “xfish98” are very bad. Much better is “duag98” which contains the same word “fish” but typed one key to the left on a standard QWERTY keyboard. Another method is to use a password that is taken from the first characters of each word in a sentence (for example, “Four score and seven years ago” results in a password of “Fsasya”). The password is easy to remember and type, but difficult to guess for someone who does not know the sentence. In this case, you can additionally substitute digits for the number words to obtain the phrase “4 score and 7 years ago”, yielding the password “4sa7ya” which is even more difficult to guess.

- Invest in a firewall. This protects you from at least 50% of all types of exploits in any software. Put MySQL behind the firewall or in a demilitarized zone (DMZ).

  Checklist:

  - Try to scan your ports from the Internet using a tool such as `nmap`. MySQL uses port 3306 by default. This port should not be accessible from untrusted hosts. As a simple way to check whether your MySQL port is open, try the following command from some remote machine, where *`server_host`* is the host name or IP address of the host on which your MySQL server runs:

    ```
    shell> telnet server_host 3306
    ```

    If `telnet` hangs or the connection is refused, the port is blocked, which is how you want it to be. If you get a connection and some garbage characters, the port is open, and should be closed on your firewall or router, unless you really have a good reason to keep it open.

- Applications that access MySQL should not trust any data entered by users, and should be written using proper defensive programming techniques. See Section 2.7, “Client Programming Security Guidelines”.

- Do not transmit plain (unencrypted) data over the Internet. This information is accessible to everyone who has the time and ability to intercept it and use it for their own purposes. Instead, use an encrypted protocol such as SSL or SSH. MySQL supports internal SSL connections. Another technique is to use SSH port-forwarding to create an encrypted (and compressed) tunnel for the communication.

- Learn to use the `tcpdump` and `strings` utilities. In most cases, you can check whether MySQL data streams are unencrypted by issuing a command like the following:

  ```
  shell> tcpdump -l -i eth0 -w - src or dst port 3306 | strings
  ```

  This works under Linux and should work with small modifications under other systems.

  > **Warning**
  >
  > If you do not see cleartext data, this does not always mean that the information actually is encrypted. If you need high security, consult with a security expert.

2.2 Keeping Passwords Secure

Passwords occur in several contexts within MySQL. The following sections provide guidelines that enable end users and administrators to keep these passwords secure and avoid exposing them. There

is also a discussion of how MySQL uses password hashing internally and of a plugin that you can use to enforce stricter passwords.

2.2.1 End-User Guidelines for Password Security

MySQL users should use the following guidelines to keep passwords secure.

When you run a client program to connect to the MySQL server, it is inadvisable to specify your password in a way that exposes it to discovery by other users. The methods you can use to specify your password when you run client programs are listed here, along with an assessment of the risks of each method. In short, the safest methods are to have the client program prompt for the password or to specify the password in a properly protected option file.

- Use the `mysql_config_editor` utility, which enables you to store authentication credentials in an encrypted login path file named `.mylogin.cnf`. The file can be read later by MySQL client programs to obtain authentication credentials for connecting to MySQL Server. See `mysql_config_editor` — MySQL Configuration Utility.

- Use a `-p`*`your_pass`* or `--password=`*`your_pass`* option on the command line. For example:

```
shell> mysql -u francis -pfrank db_name
```

  This is convenient *but insecure*. On some systems, your password becomes visible to system status programs such as `ps` that may be invoked by other users to display command lines. MySQL clients typically overwrite the command-line password argument with zeros during their initialization sequence. However, there is still a brief interval during which the value is visible. Also, on some systems this overwriting strategy is ineffective and the password remains visible to `ps`. (SystemV Unix systems and perhaps others are subject to this problem.)

  If your operating environment is set up to display your current command in the title bar of your terminal window, the password remains visible as long as the command is running, even if the command has scrolled out of view in the window content area.

- Use the `-p` or `--password` option on the command line with no password value specified. In this case, the client program solicits the password interactively:

```
shell> mysql -u francis -p db_name
Enter password: ********
```

  The `*` characters indicate where you enter your password. The password is not displayed as you enter it.

  It is more secure to enter your password this way than to specify it on the command line because it is not visible to other users. However, this method of entering a password is suitable only for programs that you run interactively. If you want to invoke a client from a script that runs noninteractively, there is no opportunity to enter the password from the keyboard. On some systems, you may even find that the first line of your script is read and interpreted (incorrectly) as your password.

- Store your password in an option file. For example, on Unix, you can list your password in the `[client]` section of the `.my.cnf` file in your home directory:

```
[client]
password=your_pass
```

  To keep the password safe, the file should not be accessible to anyone but yourself. To ensure this, set the file access mode to `400` or `600`. For example:

```
shell> chmod 600 .my.cnf
```

To name from the command line a specific option file containing the password, use the `--defaults-file=file_name` option, where `file_name` is the full path name to the file. For example:

```
shell> mysql --defaults-file=/home/francis/mysql-opts
```

Using Option Files, discusses option files in more detail.

- Store your password in the `MYSQL_PWD` environment variable. See MySQL Program Environment Variables.

  This method of specifying your MySQL password must be considered *extremely insecure* and should not be used. Some versions of `ps` include an option to display the environment of running processes. On some systems, if you set `MYSQL_PWD`, your password is exposed to any other user who runs `ps`. Even on systems without such a version of `ps`, it is unwise to assume that there are no other methods by which users can examine process environments.

On Unix, the `mysql` client writes a record of executed statements to a history file (see mysql Logging). By default, this file is named `.mysql_history` and is created in your home directory. Passwords can be written as plain text in SQL statements such as `CREATE USER` and `ALTER USER`, so if you use these statements, they are logged in the history file. To keep this file safe, use a restrictive access mode, the same way as described earlier for the `.my.cnf` file.

If your command interpreter is configured to maintain a history, any file in which the commands are saved will contain MySQL passwords entered on the command line. For example, `bash` uses `~/.bash_history`. Any such file should have a restrictive access mode.

2.2.2 Administrator Guidelines for Password Security

Database administrators should use the following guidelines to keep passwords secure.

MySQL stores passwords for user accounts in the `mysql.user` table. Access to this table should never be granted to any nonadministrative accounts.

Account passwords can be expired so that users must reset them. See Section 5.6, “Password Expiration Policy”, and Section 5.7, “Password Expiration and Sandbox Mode”.

The `validate_password` plugin can be used to enforce a policy on acceptable password. See Section 7.2, “The Password Validation Plugin”.

A user who has access to modify the plugin directory (the value of the `plugin_dir` system variable) or the `my.cnf` file that specifies the plugin directory location can replace plugins and modify the capabilities provided by plugins, including authentication plugins.

Files such as log files to which passwords might be written should be protected. See Section 2.2.3, “Passwords and Logging”.

2.2.3 Passwords and Logging

Passwords can be written as plain text in SQL statements such as `CREATE USER`, `GRANT`, `SET PASSWORD`, and statements that invoke the `PASSWORD()` function. If such statements are logged by the MySQL server as written, passwords in them become visible to anyone with access to the logs.

In MySQL 5.7, statement logging avoids writing passwords in cleartext for the following statements:

```
CREATE USER ... IDENTIFIED BY ...
```

```
ALTER USER ... IDENTIFIED BY ...
GRANT ... IDENTIFIED BY ...
SET PASSWORD ...
SLAVE START ... PASSWORD = ...
CREATE SERVER ... OPTIONS(... PASSWORD ...)
ALTER SERVER ... OPTIONS(... PASSWORD ...)
```

Passwords in those statements are rewritten to not appear literally in statement text written to the general query log, slow query log, and binary log. Rewriting does not apply to other statements. In particular, `INSERT` or `UPDATE` statements for the `mysql.user` table that refer to literal passwords are logged as is, so you should avoid such statements. (Direct manipulation of grant tables is discouraged, anyway.)

For the general query log, password rewriting can be suppressed by starting the server with the `--log-raw` option. For security reasons, this option is not recommended for production use. For diagnostic purposes, it may be useful to see the exact text of statements as received by the server.

Contents of the audit log file produced by the audit log plugin are not encrypted. For security reasons, this file should be written to a directory accessible only to the MySQL server and users with a legitimate reason to view the log. See Section 7.4.3, “MySQL Enterprise Audit Security Considerations”.

Statements received by the server may be rewritten if a query rewrite plugin is installed (see Query Rewrite Plugins). In this case, the `--log-raw` option affects statement logging as follows:

- Without `--log-raw`, the server logs the statement returned by the query rewrite plugin. This may differ from the statement as received.
- With `--log-raw`, the server logs the original statement as received.

An implication of password rewriting is that statements that cannot be parsed (due, for example, to syntax errors) are not written to the general query log because they cannot be known to be password free. Use cases that require logging of all statements including those with errors should use the `--log-raw` option, bearing in mind that this also bypasses password rewriting.

Password rewriting occurs only when plain text passwords are expected. For statements with syntax that expect a password hash value, no rewriting occurs. If a plain text password is supplied erroneously for such syntax, the password is logged as given, without rewriting. For example, the following statement is logged as shown because a password hash value is expected:

```
CREATE USER 'user1'@'localhost' IDENTIFIED BY PASSWORD 'not-so-secret';
```

To guard log files against unwarranted exposure, locate them in a directory that restricts access to the server and the database administrator. If the server logs to tables in the `mysql` database, grant access to those tables only to the database administrator.

Replication slaves store the password for the replication master in the master info repository, which can be either a file or a table (see Replication Relay and Status Logs). Ensure that the repository can be accessed only by the database administrator. An alternative to storing the password in a file is to use the `START SLAVE` statement to specify credentials for connecting to the master.

Use a restricted access mode to protect database backups that include log tables or log files containing passwords.

2.2.4 Password Hashing in MySQL

> **Note**
>
> The information in this section applies fully only before MySQL 5.7.5, and only for accounts that use the `mysql_native_password` or `mysql_old_password` authentication plugins. Support for pre-4.1

> password hashes is removed in MySQL 5.7.5. This includes removal of the `mysql_old_password` authentication plugin and the `OLD_PASSWORD()` function. Also, `secure_auth` cannot be disabled, and `old_passwords` cannot be set to 1.
>
> As of MySQL 5.7.5, only the information about 4.1 password hashes and the `mysql_native_password` authentication plugin remains relevant.

MySQL lists user accounts in the `user` table of the `mysql` database. Each MySQL account can be assigned a password, although the `user` table does not store the cleartext version of the password, but a hash value computed from it.

MySQL uses passwords in two phases of client/server communication:

- When a client attempts to connect to the server, there is an initial authentication step in which the client must present a password that has a hash value matching the hash value stored in the `user` table for the account the client wants to use.
- After the client connects, it can (if it has sufficient privileges) set or change the password hash for accounts listed in the `user` table. The client can do this by using the `PASSWORD()` function to generate a password hash, or by using a password-generating statement (`CREATE USER`, `GRANT`, or `SET PASSWORD`).

In other words, the server *checks* hash values during authentication when a client first attempts to connect. The server *generates* hash values if a connected client invokes the `PASSWORD()` function or uses a password-generating statement to set or change a password.

Password hashing methods in MySQL have the history described following. These changes are illustrated by changes in the result from the `PASSWORD()` function that computes password hash values and in the structure of the `user` table where passwords are stored.

The Original (Pre-4.1) Hashing Method

The original hashing method produced a 16-byte string. Such hashes look like this:

```
mysql> SELECT PASSWORD('mypass');
+--------------------+
| PASSWORD('mypass') |
+--------------------+
| 6f8c114b58f2ce9e   |
+--------------------+
```

To store account passwords, the `Password` column of the `user` table was at this point 16 bytes long.

The 4.1 Hashing Method

MySQL 4.1 introduced password hashing that provided better security and reduced the risk of passwords being intercepted. There were several aspects to this change:

- Different format of password values produced by the `PASSWORD()` function
- Widening of the `Password` column
- Control over the default hashing method
- Control over the permitted hashing methods for clients attempting to connect to the server

The changes in MySQL 4.1 took place in two stages:

- MySQL 4.1.0 used a preliminary version of the 4.1 hashing method. This method was short lived and the following discussion says nothing more about it.

- In MySQL 4.1.1, the hashing method was modified to produce a longer 41-byte hash value:

```
mysql> SELECT PASSWORD('mypass');
+-------------------------------------------+
| PASSWORD('mypass')                        |
+-------------------------------------------+
| *6C8989366EAF75BB670AD8EA7A7FC1176A95CEF4 |
+-------------------------------------------+
```

  The longer password hash format has better cryptographic properties, and client authentication based on long hashes is more secure than that based on the older short hashes.

  To accommodate longer password hashes, the `Password` column in the `user` table was changed at this point to be 41 bytes, its current length.

  A widened `Password` column can store password hashes in both the pre-4.1 and 4.1 formats. The format of any given hash value can be determined two ways:

  - The length: 4.1 and pre-4.1 hashes are 41 and 16 bytes, respectively.
  - Password hashes in the 4.1 format always begin with a `*` character, whereas passwords in the pre-4.1 format never do.

  To permit explicit generation of pre-4.1 password hashes, two additional changes were made:

  - The `OLD_PASSWORD()` function was added, which returns hash values in the 16-byte format.
  - For compatibility purposes, the `old_passwords` system variable was added, to enable DBAs and applications control over the hashing method. The default `old_passwords` value of 0 causes hashing to use the 4.1 method (41-byte hash values), but setting `old_passwords=1` causes hashing to use the pre-4.1 method. In this case, `PASSWORD()` produces 16-byte values and is equivalent to `OLD_PASSWORD()`

  To permit DBAs control over how clients are permitted to connect, the `secure_auth` system variable was added. Starting the server with this variable disabled or enabled permits or prohibits clients to connect using the older pre-4.1 password hashing method. Before MySQL 5.6.5, `secure_auth` is disabled by default. As of 5.6.5, `secure_auth` is enabled by default to promote a more secure default configuration DBAs can disable it at their discretion, but this is not recommended, and pre-4.1 password hashes are deprecated and should be avoided. (For account upgrade instructions, see Section 7.1.3, “Migrating Away from Pre-4.1 Password Hashing and the mysql_old_password Plugin”.)

  In addition, the `mysql` client supports a `--secure-auth` option that is analogous to `secure_auth`, but from the client side. It can be used to prevent connections to less secure accounts that use pre-4.1 password hashing. This option is disabled by default before MySQL 5.6.7, enabled thereafter.

Compatibility Issues Related to Hashing Methods

The widening of the `Password` column in MySQL 4.1 from 16 bytes to 41 bytes affects installation or upgrade operations as follows:

- If you perform a new installation of MySQL, the `Password` column is made 41 bytes long automatically.
- Upgrades from MySQL 4.1 or later to current versions of MySQL should not give rise to any issues in regard to the `Password` column because both versions use the same column length and password hashing method.
- For upgrades from a pre-4.1 release to 4.1 or later, you must upgrade the system tables after upgrading. (See `mysql_upgrade` — Check and Upgrade MySQL Tables.)

The 4.1 hashing method is understood only by MySQL 4.1 (and higher) servers and clients, which can result in some compatibility problems. A 4.1 or higher client can connect to a pre-4.1 server, because the client understands both the pre-4.1 and 4.1 password hashing methods. However, a pre-4.1 client that attempts to connect to a 4.1 or higher server may run into difficulties. For example, a 4.0 `mysql` client may fail with the following error message:

```
shell> mysql -h localhost -u root
Client does not support authentication protocol requested
by server; consider upgrading MySQL client
```

This phenomenon also occurs for attempts to use the older PHP `mysql` extension after upgrading to MySQL 4.1 or higher. (See Common Problems with MySQL and PHP.)

The following discussion describes the differences between the pre-4.1 and 4.1 hashing methods, and what you should do if you upgrade your server but need to maintain backward compatibility with pre-4.1 clients. (However, permitting connections by old clients is not recommended and should be avoided if possible.) Additional information can be found in Client does not support authentication protocol. This information is of particular importance to PHP programmers migrating MySQL databases from versions older than 4.1 to 4.1 or higher.

The differences between short and long password hashes are relevant both for how the server uses passwords during authentication and for how it generates password hashes for connected clients that perform password-changing operations.

The way in which the server uses password hashes during authentication is affected by the width of the `Password` column:

- If the column is short, only short-hash authentication is used.
- If the column is long, it can hold either short or long hashes, and the server can use either format:
  - Pre-4.1 clients can connect, but because they know only about the pre-4.1 hashing method, they can authenticate only using accounts that have short hashes.
  - 4.1 and later clients can authenticate using accounts that have short or long hashes.

Even for short-hash accounts, the authentication process is actually a bit more secure for 4.1 and later clients than for older clients. In terms of security, the gradient from least to most secure is:

- Pre-4.1 client authenticating with short password hash
- 4.1 or later client authenticating with short password hash
- 4.1 or later client authenticating with long password hash

The way in which the server generates password hashes for connected clients is affected by the width of the `Password` column and by the `old_passwords` system variable. A 4.1 or later server generates long hashes only if certain conditions are met: The `Password` column must be wide enough to hold long values and `old_passwords` must not be set to 1.

Those conditions apply as follows:

- The `Password` column must be wide enough to hold long hashes (41 bytes). If the column has not been updated and still has the pre-4.1 width of 16 bytes, the server notices that long hashes cannot fit into it and generates only short hashes when a client performs password-changing operations using the `PASSWORD()` function or a password-generating statement. This is the behavior that occurs if you have upgraded from a version of MySQL older than 4.1 to 4.1 or later but have not yet run the `mysql_upgrade` program to widen the `Password` column.
- If the `Password` column is wide, it can store either short or long password hashes. In this case, the `PASSWORD()` function and password-generating statements generate long hashes unless the server

was started with the `old_passwords` system variable set to 1 to force the server to generate short password hashes instead.

The purpose of the `old_passwords` system variable is to permit backward compatibility with pre-4.1 clients under circumstances where the server would otherwise generate long password hashes. The option does not affect authentication (4.1 and later clients can still use accounts that have long password hashes), but it does prevent creation of a long password hash in the `user` table as the result of a password-changing operation. Were that permitted to occur, the account could no longer be used by pre-4.1 clients. With `old_passwords` disabled, the following undesirable scenario is possible:

- An old pre-4.1 client connects to an account that has a short password hash.
- The client changes its own password. With `old_passwords` disabled, this results in the account having a long password hash.
- The next time the old client attempts to connect to the account, it cannot, because the account has a long password hash that requires the 4.1 hashing method during authentication. (Once an account has a long password hash in the user table, only 4.1 and later clients can authenticate for it because pre-4.1 clients do not understand long hashes.)

This scenario illustrates that, if you must support older pre-4.1 clients, it is problematic to run a 4.1 or higher server without `old_passwords` set to 1. By running the server with `old_passwords=1`, password-changing operations do not generate long password hashes and thus do not cause accounts to become inaccessible to older clients. (Those clients cannot inadvertently lock themselves out by changing their password and ending up with a long password hash.)

The downside of `old_passwords=1` is that any passwords created or changed use short hashes, even for 4.1 or later clients. Thus, you lose the additional security provided by long password hashes. To create an account that has a long hash (for example, for use by 4.1 clients) or to change an existing account to use a long password hash, an administrator can set the session value of `old_passwords` set to 0 while leaving the global value set to 1:

```
mysql> SET @@session.old_passwords = 0;
Query OK, 0 rows affected (0.00 sec)
mysql> SELECT @@session.old_passwords, @@global.old_passwords;
+-------------------------+------------------------+
| @@session.old_passwords | @@global.old_passwords |
+-------------------------+------------------------+
|                       0 |                      1 |
+-------------------------+------------------------+
1 row in set (0.00 sec)
mysql> CREATE USER 'newuser'@'localhost' IDENTIFIED BY 'newpass';
Query OK, 0 rows affected (0.03 sec)
mysql> SET PASSWORD FOR 'existinguser'@'localhost' = PASSWORD('existingpass');
Query OK, 0 rows affected (0.00 sec)
```

The following scenarios are possible in MySQL 4.1 or later. The factors are whether the `Password` column is short or long, and, if long, whether the server is started with `old_passwords` enabled or disabled.

Scenario 1: Short `Password` column in user table:

- Only short hashes can be stored in the `Password` column.
- The server uses only short hashes during client authentication.
- For connected clients, password hash-generating operations involving the `PASSWORD()` function or password-generating statements use short hashes exclusively. Any change to an account's password results in that account having a short password hash.
- The value of `old_passwords` is irrelevant because with a short `Password` column, the server generates only short password hashes anyway.

This scenario occurs when a pre-4.1 MySQL installation has been upgraded to 4.1 or later but `mysql_upgrade` has not been run to upgrade the system tables in the `mysql` database. (This is not a recommended configuration because it does not permit use of more secure 4.1 password hashing.)

Scenario 2: Long `Password` column; server started with `old_passwords=1`:

- Short or long hashes can be stored in the `Password` column.
- 4.1 and later clients can authenticate for accounts that have short or long hashes.
- Pre-4.1 clients can authenticate only for accounts that have short hashes.
- For connected clients, password hash-generating operations involving the `PASSWORD()` function or password-generating statements use short hashes exclusively. Any change to an account's password results in that account having a short password hash.

In this scenario, newly created accounts have short password hashes because `old_passwords=1` prevents generation of long hashes. Also, if you create an account with a long hash before setting `old_passwords` to 1, changing the account's password while `old_passwords=1` results in the account being given a short password, causing it to lose the security benefits of a longer hash.

To create a new account that has a long password hash, or to change the password of any existing account to use a long hash, first set the session value of `old_passwords` set to 0 while leaving the global value set to 1, as described previously.

In this scenario, the server has an up to date `Password` column, but is running with the default password hashing method set to generate pre-4.1 hash values. This is not a recommended configuration but may be useful during a transitional period in which pre-4.1 clients and passwords are upgraded to 4.1 or later. When that has been done, it is preferable to run the server with `old_passwords=0` and `secure_auth=1`.

Scenario 3: Long `Password` column; server started with `old_passwords=0`:

- Short or long hashes can be stored in the `Password` column.
- 4.1 and later clients can authenticate using accounts that have short or long hashes.
- Pre-4.1 clients can authenticate only using accounts that have short hashes.
- For connected clients, password hash-generating operations involving the `PASSWORD()` function or password-generating statements use long hashes exclusively. A change to an account's password results in that account having a long password hash.

As indicated earlier, a danger in this scenario is that it is possible for accounts that have a short password hash to become inaccessible to pre-4.1 clients. A change to such an account's password made using the `PASSWORD()` function or a password-generating statement results in the account being given a long password hash. From that point on, no pre-4.1 client can connect to the server using that account. The client must upgrade to 4.1 or later.

If this is a problem, you can change a password in a special way. For example, normally you use `SET PASSWORD` as follows to change an account password:

```
SET PASSWORD FOR 'some_user'@'some_host' = PASSWORD('mypass');
```

To change the password but create a short hash, use the `OLD_PASSWORD()` function instead:

```
SET PASSWORD FOR 'some_user'@'some_host' = OLD_PASSWORD('mypass');
```

`OLD_PASSWORD()` is useful for situations in which you explicitly want to generate a short hash.

The disadvantages for each of the preceding scenarios may be summarized as follows:

In scenario 1, you cannot take advantage of longer hashes that provide more secure authentication.

In scenario 2, `old_passwords=1` prevents accounts with short hashes from becoming inaccessible, but password-changing operations cause accounts with long hashes to revert to short hashes unless you take care to change the session value of `old_passwords` to 0 first.

In scenario 3, accounts with short hashes become inaccessible to pre-4.1 clients if you change their passwords without explicitly using `OLD_PASSWORD()`.

The best way to avoid compatibility problems related to short password hashes is to not use them:

- Upgrade all client programs to MySQL 4.1 or later.
- Run the server with `old_passwords=0`.
- Reset the password for any account with a short password hash to use a long password hash.
- For additional security, run the server with `secure_auth=1`.

2.3 Making MySQL Secure Against Attackers

When you connect to a MySQL server, you should use a password. The password is not transmitted in clear text over the connection. Password handling during the client connection sequence was upgraded in MySQL 4.1.1 to be very secure. If you are still using pre-4.1.1-style passwords, the encryption algorithm is not as strong as the newer algorithm. With some effort, a clever attacker who can sniff the traffic between the client and the server can crack the password. (See Section 2.2.4, “Password Hashing in MySQL”, for a discussion of the different password handling methods.)

All other information is transferred as text, and can be read by anyone who is able to watch the connection. If the connection between the client and the server goes through an untrusted network, and you are concerned about this, you can use the compressed protocol to make traffic much more difficult to decipher. You can also use MySQL's internal SSL support to make the connection even more secure. See Chapter 6, *Using Secure Connections*. Alternatively, use SSH to get an encrypted TCP/IP connection between a MySQL server and a MySQL client. You can find an Open Source SSH client at http://www.openssh.org/, and a comparison of both Open Source and Commercial SSH clients at http://en.wikipedia.org/wiki/Comparison_of_SSH_clients.

To make a MySQL system secure, you should strongly consider the following suggestions:

- Require all MySQL accounts to have a password. A client program does not necessarily know the identity of the person running it. It is common for client/server applications that the user can specify any user name to the client program. For example, anyone can use the `mysql` program to connect as any other person simply by invoking it as `mysql -u other_user db_name` if `other_user` has no password. If all accounts have a password, connecting using another user's account becomes much more difficult.

  For a discussion of methods for setting passwords, see Section 5.5, “Assigning Account Passwords”.

- Make sure that the only Unix user account with read or write privileges in the database directories is the account that is used for running `mysqld`.

- Never run the MySQL server as the Unix `root` user. This is extremely dangerous, because any user with the `FILE` privilege is able to cause the server to create files as `root` (for example, `~root/.bashrc`). To prevent this, `mysqld` refuses to run as `root` unless that is specified explicitly using the `--user=root` option.

  `mysqld` can (and should) be run as an ordinary, unprivileged user instead. You can create a separate Unix account named `mysql` to make everything even more secure. Use this account only for administering MySQL. To start `mysqld` as a different Unix user, add a `user` option that specifies

the user name in the `[mysqld]` group of the `my.cnf` option file where you specify server options. For example:

```
[mysqld]
user=mysql
```

This causes the server to start as the designated user whether you start it manually or by using `mysqld_safe` or `mysql.server`. For more details, see Section 2.5, “How to Run MySQL as a Normal User”.

Running `mysqld` as a Unix user other than `root` does not mean that you need to change the `root` user name in the `user` table. *User names for MySQL accounts have nothing to do with user names for Unix accounts*.

- Do not grant the `FILE` privilege to nonadministrative users. Any user that has this privilege can write a file anywhere in the file system with the privileges of the `mysqld` daemon. This includes the server's data directory containing the files that implement the privilege tables. To make `FILE`-privilege operations a bit safer, files generated with `SELECT ... INTO OUTFILE` do not overwrite existing files and are writable by everyone.

  The `FILE` privilege may also be used to read any file that is world-readable or accessible to the Unix user that the server runs as. With this privilege, you can read any file into a database table. This could be abused, for example, by using `LOAD DATA` to load `/etc/passwd` into a table, which then can be displayed with `SELECT`.

  To limit the location in which files can be read and written, set the `secure_file_priv` system to a specific directory. See Server System Variables.

- Do not grant the `PROCESS` or `SUPER` privilege to nonadministrative users. The output of `mysqladmin processlist` and `SHOW PROCESSLIST` shows the text of any statements currently being executed, so any user who is permitted to see the server process list might be able to see statements issued by other users such as `UPDATE user SET password=PASSWORD('not_secure')`.

  `mysqld` reserves an extra connection for users who have the `SUPER` privilege, so that a MySQL `root` user can log in and check server activity even if all normal connections are in use.

  The `SUPER` privilege can be used to terminate client connections, change server operation by changing the value of system variables, and control replication servers.

- Do not permit the use of symlinks to tables. (This capability can be disabled with the `--skip-symbolic-links` option.) This is especially important if you run `mysqld` as `root`, because anyone that has write access to the server's data directory then could delete any file in the system! See Using Symbolic Links for MyISAM Tables on Unix.

- Stored programs and views should be written using the security guidelines discussed in Access Control for Stored Programs and Views.

- If you do not trust your DNS, you should use IP addresses rather than host names in the grant tables. In any case, you should be very careful about creating grant table entries using host name values that contain wildcards.

- If you want to restrict the number of connections permitted to a single account, you can do so by setting the `max_user_connections` variable in `mysqld`. The `GRANT` statement also supports resource control options for limiting the extent of server use permitted to an account. See GRANT Syntax.

- If the plugin directory is writable by the server, it may be possible for a user to write executable code to a file in the directory using `SELECT ... INTO DUMPFILE`. This can be prevented by making `plugin_dir` read only to the server or by setting `--secure-file-priv` to a directory where `SELECT` writes can be made safely.

2.4 Security-Related mysqld Options and Variables

The following table shows `mysqld` options and system variables that affect security. For descriptions of each of these, see Server Command Options, and Server System Variables.

Table 2.1 Security Option/Variable Summary

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
allow-suspicious-udfs	Yes	Yes				
automatic_sp_privileges			Yes		Global	Yes
chroot	Yes	Yes				
des-key-file	Yes	Yes				
local_infile			Yes		Global	Yes
old_passwords			Yes		Both	Yes
safe-user-create	Yes	Yes				
secure-auth	Yes	Yes			Global	Yes
- *Variable*: secure_auth			Yes		Global	Yes
secure-file-priv	Yes	Yes			Global	No
- *Variable*: secure_file_priv			Yes		Global	No
skip-grant-tables	Yes	Yes				
skip-name-resolve	Yes	Yes			Global	No
- *Variable*: skip_name_resolve			Yes		Global	No
skip-networking	Yes	Yes			Global	No
- *Variable*: skip_networking			Yes		Global	No
skip-show-database	Yes	Yes			Global	No
- *Variable*: skip_show_database			Yes		Global	No

2.5 How to Run MySQL as a Normal User

On Windows, you can run the server as a Windows service using a normal user account.

On Linux, for installations performed using a MySQL repository, RPM packages, or Debian packages, the MySQL server `mysqld` should be started by the local `mysql` operating system user. Starting by another operating system user is not supported by the init scripts that are included as part of the installation.

On Unix (or Linux for installations performed using `tar` or `tar.gz` packages) , the MySQL server `mysqld` can be started and run by any user. However, you should avoid running the server as the Unix `root` user for security reasons. To change `mysqld` to run as a normal unprivileged Unix user *`user_name`*, you must do the following:

1. Stop the server if it is running (use `mysqladmin shutdown`).
2. Change the database directories and files so that *`user_name`* has privileges to read and write files in them (you might need to do this as the Unix `root` user):

```
shell> chown -R user_name /path/to/mysql/datadir
```

If you do not do this, the server will not be able to access databases or tables when it runs as *user_name*.

If directories or files within the MySQL data directory are symbolic links, `chown -R` might not follow symbolic links for you. If it does not, you will also need to follow those links and change the directories and files they point to.

3. Start the server as user *user_name*. Another alternative is to start `mysqld` as the Unix `root` user and use the `--user=user_name` option. `mysqld` starts up, then switches to run as the Unix user *user_name* before accepting any connections.

4. To start the server as the given user automatically at system startup time, specify the user name by adding a `user` option to the `[mysqld]` group of the `/etc/my.cnf` option file or the `my.cnf` option file in the server's data directory. For example:

```
[mysqld]
user=user_name
```

If your Unix machine itself is not secured, you should assign passwords to the MySQL `root` account in the grant tables. Otherwise, any user with a login account on that machine can run the `mysql` client with a `--user=root` option and perform any operation. (It is a good idea to assign passwords to MySQL accounts in any case, but especially so when other login accounts exist on the server host.) See Section 3.4, “Securing the Initial MySQL Accounts”.

2.6 Security Issues with LOAD DATA LOCAL

The `LOAD DATA` statement can load a file that is located on the server host, or it can load a file that is located on the client host when the `LOCAL` keyword is specified.

There are two potential security issues with supporting the `LOCAL` version of `LOAD DATA` statements:

- The transfer of the file from the client host to the server host is initiated by the MySQL server. In theory, a patched server could be built that would tell the client program to transfer a file of the server's choosing rather than the file named by the client in the `LOAD DATA` statement. Such a server could access any file on the client host to which the client user has read access.
- In a Web environment where the clients are connecting from a Web server, a user could use `LOAD DATA LOCAL` to read any files that the Web server process has read access to (assuming that a user could run any command against the SQL server). In this environment, the client with respect to the MySQL server actually is the Web server, not the remote program being run by the user who connects to the Web server.

To deal with these problems, `LOAD DATA LOCAL` works like this:

- By default, all MySQL clients and libraries in binary distributions are compiled with the `-DENABLED_LOCAL_INFILE=1` option.
- If you build MySQL from source but do not invoke `CMake` with the `-DENABLED_LOCAL_INFILE=1` option, `LOAD DATA LOCAL` cannot be used by any client unless it is written explicitly to invoke `mysql_options(... MYSQL_OPT_LOCAL_INFILE, 0)`. See mysql_options().
- You can disable all `LOAD DATA LOCAL` statements from the server side by starting `mysqld` with the `--local-infile=0` option.
- For the `mysql` command-line client, enable `LOAD DATA LOCAL` by specifying the `--local-infile[=1]` option, or disable it with the `--local-infile=0` option. For `mysqlimport`, local

data file loading is off by default; enable it with the `--local` or `-L` option. In any case, successful use of a local load operation requires that the server permits it.

- If you use `LOAD DATA LOCAL` in Perl scripts or other programs that read the `[client]` group from option files, you can add the `local-infile=1` option to that group. However, to keep this from causing problems for programs that do not understand `local-infile`, specify it using the `loose-` prefix:

```
[client]
loose-local-infile=1
```

- If `LOAD DATA LOCAL` is disabled, either in the server or the client, a client that attempts to issue such a statement receives the following error message:

```
ERROR 1148: The used command is not allowed with this MySQL version
```

2.7 Client Programming Security Guidelines

Applications that access MySQL should not trust any data entered by users, who can try to trick your code by entering special or escaped character sequences in Web forms, URLs, or whatever application you have built. Be sure that your application remains secure if a user enters something like `; DROP DATABASE mysql;`. This is an extreme example, but large security leaks and data loss might occur as a result of hackers using similar techniques, if you do not prepare for them.

A common mistake is to protect only string data values. Remember to check numeric data as well. If an application generates a query such as `SELECT * FROM table WHERE ID=234` when a user enters the value `234`, the user can enter the value `234 OR 1=1` to cause the application to generate the query `SELECT * FROM table WHERE ID=234 OR 1=1`. As a result, the server retrieves every row in the table. This exposes every row and causes excessive server load. The simplest way to protect from this type of attack is to use single quotation marks around the numeric constants: `SELECT * FROM table WHERE ID='234'`. If the user enters extra information, it all becomes part of the string. In a numeric context, MySQL automatically converts this string to a number and strips any trailing nonnumeric characters from it.

Sometimes people think that if a database contains only publicly available data, it need not be protected. This is incorrect. Even if it is permissible to display any row in the database, you should still protect against denial of service attacks (for example, those that are based on the technique in the preceding paragraph that causes the server to waste resources). Otherwise, your server becomes unresponsive to legitimate users.

Checklist:

- Enable strict SQL mode to tell the server to be more restrictive of what data values it accepts. See Server SQL Modes.
- Try to enter single and double quotation marks (`'` and `"`) in all of your Web forms. If you get any kind of MySQL error, investigate the problem right away.
- Try to modify dynamic URLs by adding `%22` (`"`), `%23` (#), and `%27` (`'`) to them.
- Try to modify data types in dynamic URLs from numeric to character types using the characters shown in the previous examples. Your application should be safe against these and similar attacks.
- Try to enter characters, spaces, and special symbols rather than numbers in numeric fields. Your application should remove them before passing them to MySQL or else generate an error. Passing unchecked values to MySQL is very dangerous!
- Check the size of data before passing it to MySQL.
- Have your application connect to the database using a user name different from the one you use for administrative purposes. Do not give your applications any access privileges they do not need.

Many application programming interfaces provide a means of escaping special characters in data values. Properly used, this prevents application users from entering values that cause the application to generate statements that have a different effect than you intend:

- MySQL C API: Use the `mysql_real_escape_string_quote()` API call.
- MySQL++: Use the `escape` and `quote` modifiers for query streams.
- PHP: Use either the `mysqli` or `pdo_mysql` extensions, and not the older `ext/mysql` extension. The preferred API's support the improved MySQL authentication protocol and passwords, as well as prepared statements with placeholders. See also Choosing an API.

  If the older `ext/mysql` extension must be used, then for escaping use the `mysql_real_escape_string_quote()` function and not `mysql_escape_string()` or `addslashes()` because only `mysql_real_escape_string_quote()` is character set-aware; the other functions can be “bypassed” when using (invalid) multibyte character sets.
- Perl DBI: Use placeholders or the `quote()` method.
- Ruby DBI: Use placeholders or the `quote()` method.
- Java JDBC: Use a `PreparedStatement` object and placeholders.

Other programming interfaces might have similar capabilities.

Chapter 3 Postinstallation Setup and Testing

Table of Contents

This section discusses tasks that you should perform after installing MySQL:

- If necessary, initialize the data directory and create the MySQL grant tables. For some MySQL installation methods, data directory initialization may be done for you automatically:

  - Windows distributions prior to MySQL 5.7.7 include a data directory with pre-built tables in the `mysql` database. As of 5.7.7, Windows installation operations performed by MySQL Installer initialize the data directory automatically.

  - Installation on Linux using a server RPM or Debian distribution from Oracle.

  - Installation using the native packaging system on many platforms, including Debian Linux, Ubuntu Linux, Gentoo Linux, and others.

  - Installation on OS X using a DMG distribution.

  For other platforms and installation types, including installation from generic binary and source distributions, you must initialize the data directory yourself. For instructions, see Section 3.1, “Initializing the Data Directory”.

- Start the server and make sure that it can be accessed. For instructions, see Section 3.2, “Starting the Server”, and Section 3.3, “Testing the Server”.

- Assign passwords to the initial `root` account in the grant tables, if that was not already done during data directory initialization. Passwords prevent unauthorized access to the MySQL server. For instructions, see Section 3.4, “Securing the Initial MySQL Accounts”.

- Optionally, arrange for the server to start and stop automatically when your system starts and stops. For instructions, see Section 3.5, “Starting and Stopping MySQL Automatically”.

- Optionally, populate time zone tables to enable recognition of named time zones. For instructions, see MySQL Server Time Zone Support.

When you are ready to create additional user accounts, you can find information on the MySQL access control system and account management in Chapter 4, *The MySQL Access Privilege System*, and Chapter 5, *MySQL User Account Management*.

3.1 Initializing the Data Directory

After installing MySQL, you must initialize the data directory, including the tables in the `mysql` system database. For some MySQL installation methods, data directory initialization may be done automatically, as described in Chapter 3, *Postinstallation Setup and Testing*. For other installation

methods, including installation from generic binary and source distributions, you must initialize the data directory yourself.

This section describes how to initialize the data directory on Unix and Unix-like systems. (For Windows, see Windows Postinstallation Procedures.) For some suggested commands that you can use to test whether the server is accessible and working properly, see Section 3.3, “Testing the Server”.

In the examples shown here, the server runs under the user ID of the `mysql` login account. This assumes that such an account exists. Either create the account if it does not exist, or substitute the name of a different existing login account that you plan to use for running the server. For information about creating the account, see Creating a `mysql` System User and Group, in Installing MySQL on Unix/Linux Using Generic Binaries.

1. Change location into the top-level directory of your MySQL installation, represented here by *`BASEDIR`*:

   ```
   shell> cd BASEDIR
   ```

   `BASEDIR` is likely to be something like `/usr/local/mysql` or `/usr/local`. The following steps assume that you have changed location to this directory.

   You will find several files and subdirectories in the *`BASEDIR`* directory. The most important for installation purposes are the `bin` and `scripts` subdirectories, which contain the server as well as client and utility programs.

2. Create a directory that provides a location to use as the value of the `secure_file_priv` system variable that limits import/export operations to a specific directory. See Server System Variables.

   ```
   shell> mkdir mysql-files
   shell> chmod 750 mysql-files
   ```

3. If necessary, ensure that the distribution contents are accessible to `mysql`. If you installed the distribution as `mysql`, no further action is required. If you installed the distribution as `root`, its contents will be owned by `root`. Change its ownership to `mysql` by executing the following commands as `root` in the installation directory. The first command changes the owner attribute of the files to the `mysql` user. The second changes the group attribute to the `mysql` group.

   ```
   shell> chown -R mysql .
   shell> chgrp -R mysql .
   ```

4. If necessary, initialize the data directory, including the `mysql` database containing the initial MySQL grant tables that determine how users are permitted to connect to the server.

   Typically, data directory initialization need be done only the first time you install MySQL. If you are upgrading an existing installation, you should run `mysql_upgrade` instead (see `mysql_upgrade` — Check and Upgrade MySQL Tables). However, the command that initializes the data directory does not overwrite any existing privilege tables, so it should be safe to run in any circumstances.

   As of MySQL 5.7.6, use the server to initialize the data directory:

   ```
   shell> bin/mysqld --initialize --user=mysql
   ```

   Before MySQL 5.7.6, use `mysql_install_db`:

   ```
   shell> bin/mysql_install_db --user=mysql
   ```

   For more information, see Section 3.1.1, “Initializing the Data Directory Manually Using mysqld”, or Section 3.1.2, “Initializing the Data Directory Manually Using mysql_install_db”, depending on which command you use.

5. If you want the server to be able to deploy with automatic support for secure connections, use the `mysql_ssl_rsa_setup` utility to create default SSL and RSA files:

   ```
   shell> mysql_ssl_rsa_setup
   ```

   For more information, see `mysql_ssl_rsa_setup` — Create SSL/RSA Files.

6. After initializing the data directory, you can establish the final installation ownership settings. To leave the installation owned by `mysql`, no action is required here. Otherwise, most of the MySQL installation can be owned by `root` if you like. The exception is that the data directory and the `mysql-files` directory must be owned by `mysql`. To accomplish this, run the following commands as `root` in the installation directory. For some distribution types, the data directory might be named `var` rather than `data`; adjust the second command accordingly.

   ```
   shell> chown -R root .
   shell> chown -R mysql data mysql-files
   ```

   If the plugin directory (the directory named by the `plugin_dir` system variable) is writable by the server, it may be possible for a user to write executable code to a file in the directory using `SELECT ... INTO DUMPFILE`. This can be prevented by making the plugin directory read only to the server or by setting the `secure_file_priv` system variable at server startup to a directory where `SELECT` writes can be performed safely. (For example, set it to the `mysql-files` directory created earlier.)

7. To specify options that the MySQL server should use at startup, put them in a `/etc/my.cnf` or `/etc/mysql/my.cnf` file. You can use such a file, for example, to set the `secure_file_priv` system variable. See Server Configuration Defaults. If you do not do this, the server starts with its default settings.

8. If you want MySQL to start automatically when you boot your machine, see Section 3.5, “Starting and Stopping MySQL Automatically”.

Data directory initialization creates time zone tables in the `mysql` database but does not populate them. To do so, use the instructions in MySQL Server Time Zone Support.

3.1.1 Initializing the Data Directory Manually Using mysqld

This section describes how to initialize the data directory using `mysqld`, the MySQL server.

> **Note**
>
> The procedure described here is available for all platforms as of MySQL 5.7.6. Prior to 5.7.6, use `mysql_install_db` on Unix and Unix-like systems (see Section 3.1.2, “Initializing the Data Directory Manually Using mysql_install_db”). Prior to MySQL 5.7.7, Windows distributions include a data directory with prebuilt tables in the `mysql` database.

The following instructions assume that your current location is the MySQL installation directory, represented here by *`BASEDIR`*:

```
shell> cd BASEDIR
```

To initialize the data directory, invoke `mysqld` with the `--initialize` or `--initialize-insecure` option, depending on whether you want the server to generate a random initial password for the `'root'@'localhost'` account.

On Windows, use one of these commands:

```
C:\> bin\mysqld --initialize
```

```
C:\> bin\mysqld --initialize-insecure
```

On Unix and Unix-like systems, it is important to make sure that the database directories and files are owned by the `mysql` login account so that the server has read and write access to them when you run it later. To ensure this, run `mysqld` as `root` and include the `--user` option as shown here:

```
shell> bin/mysqld --initialize --user=mysql
shell> bin/mysqld --initialize-insecure --user=mysql
```

Otherwise, execute the program while logged in as `mysql`, in which case you can omit the `--user` option from the command.

Regardless of platform, use `--initialize` for “secure by default” installation (that is, including generation of a random initial `root` password). In this case, the password is marked as expired and you will need to choose a new one. With the `--initialize-insecure` option, no `root` password is generated; it is assumed that you will assign a password to the account in timely fashion before putting the server into production use.

It might be necessary to specify other options such as `--basedir` or `--datadir` if `mysqld` does not identify the correct locations for the installation directory or data directory. For example (enter the command on one line):

```
shell> bin/mysqld --initialize --user=mysql
         --basedir=/opt/mysql/mysql
         --datadir=/opt/mysql/mysql/data
```

Alternatively, put the relevant option settings in an option file and pass the name of that file to `mysqld`. For Unix and Unix-like systems, suppose that the option file name is `/opt/mysql/mysql/etc/my.cnf`. Put these lines in the file:

```
[mysqld]
basedir=/opt/mysql/mysql
datadir=/opt/mysql/mysql/data
```

Then invoke `mysqld` as follows (enter the command on a single line with the `--defaults-file` option first):

```
shell> bin/mysqld --defaults-file=/opt/mysql/mysql/etc/my.cnf
         --initialize --user=mysql
```

On Windows, suppose that `C:\my.ini` contains these lines:

```
[mysqld]
basedir=C:\\Program Files\\MySQL\\MySQL Server 5.7
datadir=D:\\MySQLdata
```

Then invoke `mysqld` as follows (the `--defaults-file` option must be first):

```
C:\> bin/mysqld --defaults-file=C:\my.ini --initialize
```

When invoked with the `--initialize` or `--initialize-insecure` option, `mysqld` performs the following initialization sequence.

> **Note**
>
> The server writes any messages to its standard error output. This may be redirected to the error log, so look there if you do not see the messages on your screen. For information about the error log, including where it is located, see The Error Log.

On Windows, use the `--console` option to direct messages to the console.

1. The server checks for the existence of the data directory as follows:

   - If no data directory exists, the server creates it.
   - If a data directory exists and is not empty (that is, it contains files or subdirectories), the server exits after producing an error message:

     ```
     [ERROR] --initialize specified but the data directory exists. Aborting.
     ```

     In this case, remove or rename the data directory and try again.

     As of MySQL 5.7.11, an existing data directory is permitted to be nonempty if every entry either has a name that begins with a period (`.`) or is named using an `--ignore-db-dir` option.

2. Within the data directory, the server creates the `mysql` system database and its tables, including the grant tables, server-side help tables, and time zone tables. For a complete listing and description of the grant tables, see Chapter 4, *The MySQL Access Privilege System*.

3. The server initializes the system tablespace and related data structures needed to manage `InnoDB` tables.

   Note

   After `mysqld` sets up the `InnoDB` system tablespace, changes to some tablespace characteristics require setting up a whole new instance. This includes the file name of the first file in the system tablespace and the number of undo logs. If you do not want to use the default values, make sure that the settings for the `innodb_data_file_path` and `innodb_log_file_size` configuration parameters are in place in the MySQL configuration file before running `mysqld`. Also make sure to specify as necessary other parameters that affect the creation and location of `InnoDB` files, such as `innodb_data_home_dir` and `innodb_log_group_home_dir`.

   If those options are in your configuration file but that file is not in a location that MySQL reads by default, specify the file location using the `--defaults-extra-file` option when you run `mysqld`.

4. The server creates a `'root'@'localhost'` superuser account. The server's action with respect to a password for this account depends on how you invoke it:

   - With `--initialize` but not `--initialize-insecure`, the server generates a random password, marks it as expired, and writes a message displaying the password:

     ```
     [Warning] A temporary password is generated for root@localhost:
     iTag*AfrH5ej
     ```

   - With `--initialize-insecure`, (either with or without `--initialize` because `--initialize-insecure` implies `--initialize`), the server does not generate a password or mark it expired, and writes a warning message:

     ```
     Warning] root@localhost is created with an empty password ! Please
     consider switching off the --initialize-insecure option.
     ```

5. The server populates the server-side help tables if content is available (in the `fill_help_tables.sql` file). The server does not populate the time zone tables; to do so, see MySQL Server Time Zone Support.

6. If the `--init-file` option was given to name a file of SQL statements, the server executes the statements in the file. This option enables you to perform custom bootstrapping sequences.

   When the server operates in bootstrap mode, some functionality is unavailable that limits the statements permitted in the file. These include statements that relate to account management (such as `CREATE USER` or `GRANT`), replication, and global transaction identifiers.

7. The server exits.

After you initialize the data directory by starting the server with `--initialize` or `--initialize-insecure`, start the server normally (that is, without either of those options) and assign the `'root'@'localhost'` account a new password:

1. Start the server. For instructions, see Section 3.2, “Starting the Server”.

2. Connect to the server:

   - If you used `--initialize` but not `--initialize-insecure` to initialize the data directory, connect to the server as `root` using the random password that the server generated during the initialization sequence:

     ```
     shell> mysql -u root -p
     Enter password: (enter the random root password here)
     ```

     Look in the server error log if you do not know this password.

   - If you used `--initialize-insecure` to initialize the data directory, connect to the server as `root` without a password:

     ```
     shell> mysql -u root --skip-password
     ```

3. After connecting, assign a new `root` password:

   ```
   mysql> ALTER USER 'root'@'localhost' IDENTIFIED BY 'new_password';
   ```

> **Note**
>
> The data directory initialization sequence performed by the server does not substitute for the actions performed by `mysql_secure_installation` or `mysql_ssl_rsa_setup`. See `mysql_secure_installation` — Improve MySQL Installation Security, and `mysql_ssl_rsa_setup` — Create SSL/RSA Files.

3.1.2 Initializing the Data Directory Manually Using mysql_install_db

This section describes how to initialize the data directory using `mysql_install_db`.

> **Note**
>
> The procedure described here is used on Unix and Unix-like systems prior to MySQL 5.7.6. (For Windows, MySQL distributions include a data directory with prebuilt tables in the `mysql` database.) As of MySQL 5.7.6, `mysql_install_db` is deprecated. To initialize the data directory, use the procedure described at Section 3.1.1, “Initializing the Data Directory Manually Using mysqld”.

The following instructions assume that your current location is the MySQL installation directory, represented here by *`BASEDIR`*:

```
shell> cd BASEDIR
```

To initialize the data directory, invoke `mysql_install_db`. This program might be located under the base directory in either `bin` or `scripts`, depending on your version of MySQL. If it is in `scripts`, adjust the following commands appropriately.

```
shell> bin/mysql_install_db --user=mysql
```

It is important to make sure that the database directories and files are owned by the `mysql` login account so that the server has read and write access to them when you run it later. To ensure this, run `mysql_install_db` as `root` and include the `--user` option as shown. Otherwise, execute the program while logged in as `mysql`, in which case you can omit the `--user` option from the command.

The `mysql_install_db` command creates the server's data directory. Under the data directory, it creates directories for the `mysql` database that holds the grant tables and (prior to MySQL 5.7.4) a `test` database that you can use to test MySQL. The program also creates privilege table entries for the initial account or accounts. For a complete listing and description of the grant tables, see Chapter 4, *The MySQL Access Privilege System*.

It might be necessary to specify other options such as `--basedir` or `--datadir` if `mysql_install_db` does not identify the correct locations for the installation directory or data directory. For example:

```
shell> bin/mysql_install_db --user=mysql \
         --basedir=/opt/mysql/mysql \
         --datadir=/opt/mysql/mysql/data
```

If `mysql_install_db` generates a random password for the `root` account, start the server and assign a new password:

1. Start the server (use the first command if your installation includes `mysqld_safe`, the second it if includes systemd support):

   ```
   shell> bin/mysqld_safe --user=mysql &
   shell> systemctl start mysqld
   ```

   Substitute the appropriate service name if it differs from `mysqld`; for example, `mysql` on SLES systems.

2. Look in the `$HOME/.mysql_secret` file to find the random password that `mysql_install_db` wrote there. Then connect to the server as `root` using that password:

   ```
   shell> mysql -u root -h 127.0.0.1 -p
   Enter password: (enter the random password here)
   ```

3. After connecting, assign a new `root` password:

   ```
   mysql> SET PASSWORD FOR 'root'@'localhost' = PASSWORD('new_password');
   ```

   After resetting the password, remove the `.mysql_secret` file; otherwise, if you run `mysql_secure_installation`, that command may see the file and expire the `root` password again as part of ensuring secure deployment.

If `mysql_install_db` did not generate a random password, you should still assign one. For instructions, see Section 3.4, “Securing the Initial MySQL Accounts”. That section also describes how to remove the `test` database, if `mysql_install_db` created one and you do not want it.

If you have trouble with `mysql_install_db` at this point, see Section 3.1.3, “Problems Running mysql_install_db”.

3.1.3 Problems Running mysql_install_db

The purpose of the `mysql_install_db` program is to initialize the data directory, including the tables in the `mysql` system database. It does not overwrite existing MySQL privilege tables, and it does not affect any other data.

To re-create your privilege tables, first stop the `mysqld` server if it is running. Then rename the `mysql` directory under the data directory to save it, and run `mysql_install_db`. Suppose that your current directory is the MySQL installation directory and that `mysql_install_db` is located in the `bin` directory and the data directory is named `data`. To rename the `mysql` database and re-run `mysql_install_db`, use these commands.

```
shell> mv data/mysql data/mysql.old
shell> bin/mysql_install_db --user=mysql
```

When you run `mysql_install_db`, you might encounter the following problems:

- **`mysql_install_db` fails to install the grant tables**

  You may find that `mysql_install_db` fails to install the grant tables and terminates after displaying the following messages:

  ```
  Starting mysqld daemon with databases from XXXXXX
  mysqld ended
  ```

  In this case, you should examine the error log file very carefully. The log should be located in the directory `XXXXXX` named by the error message and should indicate why `mysqld` did not start. If you do not understand what happened, include the log when you post a bug report. See How to Report Bugs or Problems.

- **There is a `mysqld` process running**

  This indicates that the server is running, in which case the grant tables have probably been created already. If so, there is no need to run `mysql_install_db` at all because it needs to be run only once, when you first install MySQL.

- **Installing a second `mysqld` server does not work when one server is running**

  This can happen when you have an existing MySQL installation, but want to put a new installation in a different location. For example, you might have a production installation, but you want to create a second installation for testing purposes. Generally the problem that occurs when you try to run a second server is that it tries to use a network interface that is in use by the first server. In this case, you should see one of the following error messages:

  ```
  Can't start server: Bind on TCP/IP port:
  Address already in use
  Can't start server: Bind on unix socket...
  ```

  For instructions on setting up multiple servers, see Running Multiple MySQL Instances on One Machine.

- **You do not have write access to the `/tmp` directory**

  If you do not have write access to create temporary files or a Unix socket file in the default location (the `/tmp` directory) or the `TMPDIR` environment variable, if it has been set, an error occurs when you run `mysql_install_db` or the `mysqld` server.

  You can specify different locations for the temporary directory and Unix socket file by executing these commands prior to starting `mysql_install_db` or `mysqld`, where *`some_tmp_dir`* is the full path name to some directory for which you have write permission:

```
shell> TMPDIR=/some_tmp_dir/
shell> MYSQL_UNIX_PORT=/some_tmp_dir/mysql.sock
shell> export TMPDIR MYSQL_UNIX_PORT
```

Then you should be able to run `mysql_install_db` and start the server with these commands:

```
shell> bin/mysql_install_db --user=mysql
shell> bin/mysqld_safe --user=mysql &
```

See How to Protect or Change the MySQL Unix Socket File, and MySQL Program Environment Variables.

There are some alternatives to running the `mysql_install_db` program provided in the MySQL distribution:

- If you want the initial privileges to be different from the standard defaults, use account-management statements such as `CREATE USER`, `GRANT`, and `REVOKE` to change the privileges *after* the grant tables have been set up. In other words, run `mysql_install_db`, and then use `mysql -u root mysql` to connect to the server as the MySQL `root` user so that you can issue the necessary statements. (See Account Management Statements.)

  To install MySQL on several machines with the same privileges, put the `CREATE USER`, `GRANT`, and `REVOKE` statements in a file and execute the file as a script using `mysql` after running `mysql_install_db`. For example:

  ```
  shell> bin/mysql_install_db --user=mysql
  shell> bin/mysql -u root < your_script_file
  ```

  This enables you to avoid issuing the statements manually on each machine.

- It is possible to re-create the grant tables completely after they have previously been created. You might want to do this if you are just learning how to use `CREATE USER`, `GRANT`, and `REVOKE` and have made so many modifications after running `mysql_install_db` that you want to wipe out the tables and start over.

  To re-create the grant tables, stop the server if it is running and remove the `mysql` database directory. Then run `mysql_install_db` again.

3.2 Starting the Server

This section describes how start the server on Unix and Unix-like systems. (For Windows, see Starting the Server for the First Time.) For some suggested commands that you can use to test whether the server is accessible and working properly, see Section 3.3, “Testing the Server”.

Start the MySQL server like this if your installation includes `mysqld_safe`:

```
shell> bin/mysqld_safe --user=mysql &
```

> **Note**
>
> For Linux systems on which MySQL is installed using RPM packages, server startup and shutdown is managed using systemd rather than `mysqld_safe`, and `mysqld_safe` is no longer installed.

Start the server like this if your installation includes systemd support:

```
shell> systemctl start mysqld
```

Substitute the appropriate service name if it differs from `mysqld`; for example, `mysql` on SLES systems.

It is important that the MySQL server be run using an unprivileged (non-`root`) login account. To ensure this, run `mysqld_safe` as `root` and include the `--user` option as shown. Otherwise, you should execute the program while logged in as `mysql`, in which case you can omit the `--user` option from the command.

For further instructions for running MySQL as an unprivileged user, see Section 2.5, “How to Run MySQL as a Normal User”.

If the command fails immediately and prints `mysqld ended`, look for information in the error log (which by default is the *`host_name`*`.err` file in the data directory).

If the server is unable to access the data directory it starts or read the grant tables in the `mysql` database, it writes a message to its error log. Such problems can occur if you neglected to create the grant tables by initializing the data directory before proceeding to this step, or if you ran the command that initializes the data directory without the `--user` option. Remove the `data` directory and run the command with the `--user` option.

If you have other problems starting the server, see Section 3.2.1, “Troubleshooting Problems Starting the MySQL Server”. For more information about `mysqld_safe`, see `mysqld_safe` — MySQL Server Startup Script. For more information about systemd support, see Managing MySQL Server with systemd.

3.2.1 Troubleshooting Problems Starting the MySQL Server

This section provides troubleshooting suggestions for problems starting the server. For additional suggestions for Windows systems, see Troubleshooting a Microsoft Windows MySQL Server Installation.

If you have problems starting the server, here are some things to try:

- Check the error log to see why the server does not start. Log files are located in the data directory (typically `C:\Program Files\MySQL\MySQL Server 5.7\data` on Windows, `/usr/local/mysql/data` for a Unix/Linux binary distribution, and `/usr/local/var` for a Unix/Linux source distribution). Look in the data directory for files with names of the form *`host_name`*`.err` and *`host_name`*`.log`, where *`host_name`* is the name of your server host. Then examine the last few lines of these files. Use `tail` to display them:

  ```
  shell> tail host_name.err
  shell> tail host_name.log
  ```

- Specify any special options needed by the storage engines you are using. You can create a `my.cnf` file and specify startup options for the engines that you plan to use. If you are going to use storage engines that support transactional tables (`InnoDB`, `NDB`), be sure that you have them configured the way you want before starting the server. If you are using `InnoDB` tables, see InnoDB Configuration for guidelines and InnoDB Startup Options and System Variables for option syntax.

  Although storage engines use default values for options that you omit, Oracle recommends that you review the available options and specify explicit values for any options whose defaults are not appropriate for your installation.

- Make sure that the server knows where to find the data directory. The `mysqld` server uses this directory as its current directory. This is where it expects to find databases and where it expects to write log files. The server also writes the pid (process ID) file in the data directory.

  The default data directory location is hardcoded when the server is compiled. To determine what the default path settings are, invoke `mysqld` with the `--verbose` and `--help` options. If the data directory is located somewhere else on your system, specify that location with the `--datadir` option

to `mysqld` or `mysqld_safe`, on the command line or in an option file. Otherwise, the server will not work properly. As an alternative to the `--datadir` option, you can specify `mysqld` the location of the base directory under which MySQL is installed with the `--basedir`, and `mysqld` looks for the `data` directory there.

To check the effect of specifying path options, invoke `mysqld` with those options followed by the `--verbose` and `--help` options. For example, if you change location into the directory where `mysqld` is installed and then run the following command, it shows the effect of starting the server with a base directory of `/usr/local`:

```
shell> ./mysqld --basedir=/usr/local --verbose --help
```

You can specify other options such as `--datadir` as well, but `--verbose` and `--help` must be the last options.

Once you determine the path settings you want, start the server without `--verbose` and `--help`.

If `mysqld` is currently running, you can find out what path settings it is using by executing this command:

```
shell> mysqladmin variables
```

Or:

```
shell> mysqladmin -h host_name variables
```

`host_name` is the name of the MySQL server host.

- Make sure that the server can access the data directory. The ownership and permissions of the data directory and its contents must allow the server to read and modify them.

  If you get `Errcode 13` (which means `Permission denied`) when starting `mysqld`, this means that the privileges of the data directory or its contents do not permit server access. In this case, you change the permissions for the involved files and directories so that the server has the right to use them. You can also start the server as `root`, but this raises security issues and should be avoided.

  Change location into the data directory and check the ownership of the data directory and its contents to make sure the server has access. For example, if the data directory is `/usr/local/mysql/var`, use this command:

  ```
  shell> ls -la /usr/local/mysql/var
  ```

  If the data directory or its files or subdirectories are not owned by the login account that you use for running the server, change their ownership to that account. If the account is named `mysql`, use these commands:

  ```
  shell> chown -R mysql /usr/local/mysql/var
  shell> chgrp -R mysql /usr/local/mysql/var
  ```

  Even with correct ownership, MySQL might fail to start up if there is other security software running on your system that manages application access to various parts of the file system. In this case, reconfigure that software to enable `mysqld` to access the directories it uses during normal operation.

- Verify that the network interfaces the server wants to use are available.

  If either of the following errors occur, it means that some other program (perhaps another `mysqld` server) is using the TCP/IP port or Unix socket file that `mysqld` is trying to use:

  ```
  ```

```
Can't start server: Bind on TCP/IP port: Address already in use
Can't start server: Bind on unix socket...
```

Use `ps` to determine whether you have another `mysqld` server running. If so, shut down the server before starting `mysqld` again. (If another server is running, and you really want to run multiple servers, you can find information about how to do so in Running Multiple MySQL Instances on One Machine.)

If no other server is running, execute the command `telnet *your_host_name tcp_ip_port_number*`. (The default MySQL port number is 3306.) Then press Enter a couple of times. If you do not get an error message like `telnet: Unable to connect to remote host: Connection refused`, some other program is using the TCP/IP port that `mysqld` is trying to use. Track down what program this is and disable it, or tell `mysqld` to listen to a different port with the `--port` option. In this case, specify the same non-default port number for client programs when connecting to the server using TCP/IP.

Another reason the port might be inaccessible is that you have a firewall running that blocks connections to it. If so, modify the firewall settings to permit access to the port.

If the server starts but you cannot connect to it, make sure that you have an entry in `/etc/hosts` that looks like this:

```
127.0.0.1       localhost
```

- If you cannot get `mysqld` to start, try to make a trace file to find the problem by using the `--debug` option. See The DBUG Package.

3.3 Testing the Server

After the data directory is initialized and you have started the server, perform some simple tests to make sure that it works satisfactorily. This section assumes that your current location is the MySQL installation directory and that it has a `bin` subdirectory containing the MySQL programs used here. If that is not true, adjust the command path names accordingly.

Alternatively, add the `bin` directory to your `PATH` environment variable setting. That enables your shell (command interpreter) to find MySQL programs properly, so that you can run a program by typing only its name, not its path name. See Setting Environment Variables.

Use `mysqladmin` to verify that the server is running. The following commands provide simple tests to check whether the server is up and responding to connections:

```
shell> bin/mysqladmin version
shell> bin/mysqladmin variables
```

If you cannot connect to the server, specify a `-u root` option to connect as `root`. If you have assigned a password for the `root` account already, you'll also need to specify `-p` on the command line and enter the password when prompted. For example:

```
shell> bin/mysqladmin -u root -p version
Enter password: (enter root password here)
```

The output from `mysqladmin version` varies slightly depending on your platform and version of MySQL, but should be similar to that shown here:

```
shell> bin/mysqladmin version
mysqladmin  Ver 14.12 Distrib 5.7.18, for pc-linux-gnu on i686
...
Server version          5.7.18
Protocol version        10
```

```
Connection              Localhost via UNIX socket
UNIX socket             /var/lib/mysql/mysql.sock
Uptime:                 14 days 5 hours 5 min 21 sec
Threads: 1  Questions: 366  Slow queries: 0
Opens: 0  Flush tables: 1  Open tables: 19
Queries per second avg: 0.000
```

To see what else you can do with `mysqladmin`, invoke it with the `--help` option.

Verify that you can shut down the server (include a `-p` option if the `root` account has a password already):

```
shell> bin/mysqladmin -u root shutdown
```

Verify that you can start the server again. Do this by using `mysqld_safe` or by invoking `mysqld` directly. For example:

```
shell> bin/mysqld_safe --user=mysql &
```

If `mysqld_safe` fails, see Section 3.2.1, “Troubleshooting Problems Starting the MySQL Server”.

Run some simple tests to verify that you can retrieve information from the server. The output should be similar to that shown here.

Use `mysqlshow` to see what databases exist:

```
shell> bin/mysqlshow
+--------------------+
|     Databases      |
+--------------------+
| information_schema |
| mysql              |
| performance_schema |
| sys                |
+--------------------+
```

The list of installed databases may vary, but will always include the minimum of `mysql` and `information_schema`.

If you specify a database name, `mysqlshow` displays a list of the tables within the database:

```
shell> bin/mysqlshow mysql
Database: mysql
+---------------------------+
|          Tables           |
+---------------------------+
| columns_priv              |
| db                        |
| engine_cost               |
| event                     |
| func                      |
| general_log               |
| gtid_executed             |
| help_category             |
| help_keyword              |
| help_relation             |
| help_topic                |
| innodb_index_stats        |
| innodb_table_stats        |
| ndb_binlog_index          |
| plugin                    |
| proc                      |
| procs_priv                |
| proxies_priv              |
| server_cost               |
```

```
| servers                   |
| slave_master_info         |
| slave_relay_log_info      |
| slave_worker_info         |
| slow_log                  |
| tables_priv               |
| time_zone                 |
| time_zone_leap_second     |
| time_zone_name            |
| time_zone_transition      |
| time_zone_transition_type |
| user                      |
+---------------------------+
```

Use the `mysql` program to select information from a table in the `mysql` database:

```
shell> bin/mysql -e "SELECT User, Host, plugin FROM mysql.user" mysql
+------+-----------+-----------------------+
| User | Host      | plugin                |
+------+-----------+-----------------------+
| root | localhost | mysql_native_password |
+------+-----------+-----------------------+
```

At this point, your server is running and you can access it. To tighten security if you have not yet assigned a password to the initial account, follow the instructions in Section 3.4, “Securing the Initial MySQL Accounts”.

For more information about `mysql`, `mysqladmin`, and `mysqlshow`, see `mysql` — The MySQL Command-Line Tool, `mysqladmin` — Client for Administering a MySQL Server, and `mysqlshow` — Display Database, Table, and Column Information.

3.4 Securing the Initial MySQL Accounts

The MySQL installation process involves initializing the data directory, including the `mysql` database containing the grant tables that define MySQL accounts. For details, see Chapter 3, *Postinstallation Setup and Testing*.

This section describes how to assign passwords to the initial accounts created during the MySQL installation procedure, if you have not already done so.

> **Note**
>
> On Windows, you can also perform the process described in this section during installation with MySQL Installer (see Installing MySQL on Microsoft Windows Using MySQL Installer). On all platforms, the MySQL distribution includes `mysql_secure_installation`, a command-line utility that automates much of the process of securing a MySQL installation. MySQL Workbench is available on all platforms, and also offers the ability to manage user accounts (see MySQL Workbench).

Passwords may have already been assigned under these circumstances:

- Installation On Windows performed using MySQL Installer give you the option of assigning passwords.
- Installation on Linux using a server RPM or Debian distribution from Oracle, if you have followed the instructions given in Installing MySQL on Linux Using RPM Packages from Oracle, Installing MySQL on Linux Using the MySQL Yum Repository, Installing MySQL on Linux Using Debian Packages from Oracle, or Installing MySQL on Linux Using the MySQL APT Repository.
- As of MySQL 5.7.6, if you initialized the data directory manually using `mysqld --initialize` and followed the instructions in Section 3.1.1, “Initializing the Data Directory Manually Using mysqld”, you should have assigned a password to the initial account.

The `mysql.user` grant table defines the initial MySQL user accounts and their access privileges. Current versions of MySQL 5.7 create only a `'root'@'localhost'` account, but for earlier versions, there might be multiple accounts such as described here:

- Some accounts have the user name `root`. These are superuser accounts that have all privileges and can do anything. If these `root` accounts have empty passwords, anyone can connect to the MySQL server as `root` *without a password* and be granted all privileges.
  - On Windows, `root` accounts are created that permit connections from the local host only. Connections can be made by specifying the host name `localhost`, the IP address `127.0.0.1`, or the IPv6 address `::1`. If the user selects the **Enable root access from remote machines** option during installation, the Windows installer creates another `root` account that permits connections from any host.
  - On Unix, each `root` account permits connections from the local host. Connections can be made by specifying the host name `localhost`, the IP address `127.0.0.1`, the IPv6 address `::1`, or the actual host name or IP address.
  - The `'root'@'localhost'` account also has a row in the `mysql.proxies_priv` table that enables granting the `PROXY` privilege for `''@''`, that is, for all users and all hosts. This enables `root` to set up proxy users, as well as to delegate to other accounts the authority to set up proxy users. See Section 5.9, “Proxy Users”.
- If accounts for anonymous users were created, these have an empty user name. The anonymous accounts have no password, so anyone can use them to connect to the MySQL server.
  - On Windows, there is one anonymous account that permits connections from the local host. Connections can be made by specifying a host name of `localhost`.
  - On Unix, each anonymous account permits connections from the local host. Connections can be made by specifying a host name of `localhost` for one of the accounts, or the actual host name or IP address for the other.

Checking Which Accounts Exist

Start the server if it is not running. For instructions, see Section 3.2, “Starting the Server”.

Assuming that no `root` password has been assigned, you should be able to connect to the server as `root` without one:

```
shell> mysql -u root
```

Once connected, determine which accounts exist in the `mysql.user` table and whether their passwords are empty:

- As of MySQL 5.7.6, use this statement:

  ```
  mysql> SELECT User, Host, HEX(authentication_string) FROM mysql.user;
  ```

  The statement uses `HEX()` because passwords stored in the `authentication_string` column might contain binary data that does not display well.
- Before MySQL 5.7.6, use this statement:

  ```
  mysql> SELECT User, Host, Password FROM mysql.user;
  ```

The `SELECT` statement results can vary depending on your version of MySQL and installation method. The following example output includes several `root` and anonymous-user accounts, none of which have passwords:

```
+------+--------------------+----------+
| User | Host               | Password |
+------+--------------------+----------+
| root | localhost          |          |
| root | myhost.example.com |          |
| root | 127.0.0.1          |          |
| root | ::1                |          |
|      | localhost          |          |
|      | myhost.example.com |          |
+------+--------------------+----------+
```

If the output on your system shows any accounts with empty passwords, your MySQL installation is unprotected until you do something about it:

- Assign a password to each MySQL `root` account that does not have one.
- To prevent clients from connecting as anonymous users without a password, either assign a password to each anonymous account or remove the accounts.

In addition, some installation methods create a `test` database and add rows to the `mysql.db` table that permit all accounts to access that database and other databases with names that start with `test_`. This is true even for accounts that otherwise have no special privileges such as the default anonymous accounts. This is convenient for testing but inadvisable on production servers. Administrators who want database access restricted only to accounts that have permissions granted explicitly for that purpose should remove these `mysql.db` table rows.

The following instructions describe how to set up passwords for the initial MySQL accounts, first for any `root` accounts, then for anonymous accounts. The instructions also cover how to remove anonymous accounts, should you prefer not to permit anonymous access at all, and describe how to remove permissive access to test databases.

Replace *`new_password`* in the examples with the password that you want to use. Replace *`host_name`* with the name of the server host. You can determine this name from the output of the `SELECT` statement shown earlier. For the output shown, *`host_name`* is `myhost.example.com`.

> **Note**
>
> For additional information about setting passwords, see Section 5.5, “Assigning Account Passwords”. If you forget your `root` password after setting it, see How to Reset the Root Password.
>
> To set up additional accounts, see Section 5.2, “Adding User Accounts”.

You might want to defer setting the passwords until later, to avoid the need to specify them while you perform additional setup or testing. However, be sure to set them before using your installation for production purposes.

Assigning root Account Passwords

To assign a password to an account, connect to the server as `root` using the `mysql` client and issue the appropriate SQL statement:

- As of MySQL 5.7.6, use `ALTER USER`:

```
mysql> ALTER USER user IDENTIFIED BY 'new_password';
```

- Before 5.7.6, use `SET PASSWORD`:

```
mysql> SET PASSWORD FOR user = PASSWORD('new_password');
```

The following instructions use `ALTER USER`. If your version of MySQL is older than 5.7.6, substitute equivalent `SET PASSWORD` statements.

To assign the `'root'@'localhost'` account a password, connect to the server as `root`:

```
shell> mysql -u root
```

Then issue an `ALTER USER` statement:

```
mysql> ALTER USER 'root'@'localhost' IDENTIFIED BY 'new_password';
```

Issue a similar `ALTER USER` statement for any other `root` account present in your `mysql.user` table that has no password. (Vary the host name appropriately.)

After an account has been assigned a password, you must supply that password whenever you connect to the server using the account. For example, to shut down the server with `mysqladmin`, use this command:

```
shell> mysqladmin -u root -p shutdown
Enter password: (enter root password here)
```

The `mysql` commands in the following instructions include a `-p` option based on the assumption that you have assigned the `root` account password using the preceding instructions and must specify that password when connecting to the server.

Assigning Anonymous Account Passwords

In MySQL 5.7, installation methods that create anonymous accounts tend to be for early versions for which `ALTER USER` cannot be used to assign passwords. Consequently, the instructions in this section use `SET PASSWORD`.

To assign the `''@'localhost'` anonymous account a password, connect to the server as `root`:

```
shell> mysql -u root -p
Enter password: (enter root password here)
```

Then issue a `SET PASSWORD` statement:

```
mysql> SET PASSWORD FOR ''@'localhost' = PASSWORD('new_password');
```

Issue a similar `SET PASSWORD` statement for any other anonymous account present in your `mysql.user` table that has no password. (Vary the host name appropriately.)

Removing Anonymous Accounts

If you prefer to remove any anonymous accounts rather than assigning them passwords, use `DROP USER`. To drop the `''@'localhost'` account, connect to the server as `root`:

```
shell> mysql -u root -p
Enter password: (enter root password here)
```

Then issue a `DROP USER` statement:

```
mysql> DROP USER ''@'localhost';
```

Issue a similar `DROP USER` statement for any other anonymous account that you want to drop. (Vary the host name appropriately.)

Securing Test Databases

Some installation methods create a `test` database and set up privileges for accessing it. If that is true on your system, the `mysql.db` table will contain rows that permit access by any user to the `test`

database and other databases with names that start with `test_`. (These rows have an empty `User` column value, which for access-checking purposes matches any user name.) This means that such databases can be used even by accounts that otherwise possess no privileges. If you want to remove any-user access to test databases, do so as follows:

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> DELETE FROM mysql.db WHERE Db LIKE 'test%';
mysql> FLUSH PRIVILEGES;
```

The `FLUSH` statement causes the server to reread the grant tables. Without it, the privilege change remains unnoticed by the server until you restart it.

With the preceding change, only users who have global database privileges or privileges granted explicitly for the `test` database can use it. However, if you prefer that the database not exist at all, drop it:

```
mysql> DROP DATABASE test;
```

3.5 Starting and Stopping MySQL Automatically

This section discusses methods for starting and stopping the MySQL server.

Generally, you start the `mysqld` server in one of these ways:

- Invoke `mysqld` directly. This works on any platform.
- On Windows, you can set up a MySQL service that runs automatically when Windows starts. See Starting MySQL as a Windows Service.
- On Unix and Unix-like systems, you can invoke `mysqld_safe`, which tries to determine the proper options for `mysqld` and then runs it with those options. See `mysqld_safe` — MySQL Server Startup Script.
- On Linux systems that support systemd, you can use it to control the server. See Managing MySQL Server with systemd.
- On systems that use System V-style run directories (that is, `/etc/init.d` and run-level specific directories), invoke `mysql.server`. This script is used primarily at system startup and shutdown. It usually is installed under the name `mysql`. The `mysql.server` script starts the server by invoking `mysqld_safe`. See `mysql.server` — MySQL Server Startup Script.
- On OS X, install a launchd daemon to enable automatic MySQL startup at system startup. The daemon starts the server by invoking `mysqld_safe`. For details, see Installing a MySQL Launch Daemon. A MySQL Preference Pane also provides control for starting and stopping MySQL through the System Preferences. See Installing and Using the MySQL Preference Pane.
- On Solaris/OpenSolaris, use the service management framework (SMF) system to initiate and control MySQL startup. For more information, see Installing MySQL on OpenSolaris Using IPS.

systemd, the `mysqld_safe` and `mysql.server` scripts, Solaris/OpenSolaris SMF, and the OS X Startup Item (or MySQL Preference Pane) can be used to start the server manually, or automatically at system startup time. systemd, `mysql.server`, and the Startup Item also can be used to stop the server.

The following table shows which option groups the server and startup scripts read from option files.

Table 3.1 MySQL Startup Scripts and Supported Server Option Groups

Script	Option Groups
`mysqld`	`[mysqld]`, `[server]`, `[mysqld-major_version]`

Script	Option Groups
`mysqld_safe`	`[mysqld]`, `[server]`, `[mysqld_safe]`
`mysql.server`	`[mysqld]`, `[mysql.server]`, `[server]`

`[mysqld-`*`major_version`*`]` means that groups with names like `[mysqld-5.6]` and `[mysqld-5.7]` are read by servers having versions 5.6.x, 5.7.x, and so forth. This feature can be used to specify options that can be read only by servers within a given release series.

For backward compatibility, `mysql.server` also reads the `[mysql_server]` group and `mysqld_safe` also reads the `[safe_mysqld]` group. To be current, you should update your option files to use the `[mysql.server]` and `[mysqld_safe]` groups instead.

For more information on MySQL configuration files and their structure and contents, see Using Option Files.

Chapter 4 The MySQL Access Privilege System

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The primary function of the MySQL privilege system is to authenticate a user who connects from a given host and to associate that user with privileges on a database such as `SELECT`, `INSERT`, `UPDATE`, and `DELETE`. Additional functionality includes the ability to have anonymous users and to grant privileges for MySQL-specific functions such as `LOAD DATA INFILE` and administrative operations.

There are some things that you cannot do with the MySQL privilege system:

- You cannot explicitly specify that a given user should be denied access. That is, you cannot explicitly match a user and then refuse the connection.
- You cannot specify that a user has privileges to create or drop tables in a database but not to create or drop the database itself.
- A password applies globally to an account. You cannot associate a password with a specific object such as a database, table, or routine.

The user interface to the MySQL privilege system consists of SQL statements such as `CREATE USER`, `GRANT`, and `REVOKE`. See Account Management Statements.

Internally, the server stores privilege information in the grant tables of the `mysql` database (that is, in the database named `mysql`). The MySQL server reads the contents of these tables into memory when it starts and bases access-control decisions on the in-memory copies of the grant tables.

The MySQL privilege system ensures that all users may perform only the operations permitted to them. As a user, when you connect to a MySQL server, your identity is determined by *the host from which you connect* and *the user name you specify*. When you issue requests after connecting, the system grants privileges according to your identity and *what you want to do*.

MySQL considers both your host name and user name in identifying you because there is no reason to assume that a given user name belongs to the same person on all hosts. For example, the user `joe` who connects from `office.example.com` need not be the same person as the user `joe` who connects from `home.example.com`. MySQL handles this by enabling you to distinguish users on different hosts that happen to have the same name: You can grant one set of privileges for connections by `joe` from `office.example.com`, and a different set of privileges for connections by `joe` from `home.example.com`. To see what privileges a given account has, use the `SHOW GRANTS` statement. For example:

```
SHOW GRANTS FOR 'joe'@'office.example.com';
SHOW GRANTS FOR 'joe'@'home.example.com';
```

MySQL access control involves two stages when you run a client program that connects to the server:

Stage 1: The server accepts or rejects the connection based on your identity and whether you can verify your identity by supplying the correct password.

Stage 2: Assuming that you can connect, the server checks each statement you issue to determine whether you have sufficient privileges to perform it. For example, if you try to select rows from a table

in a database or drop a table from the database, the server verifies that you have the `SELECT` privilege for the table or the `DROP` privilege for the database.

For a more detailed description of what happens during each stage, see Section 4.4, “Access Control, Stage 1: Connection Verification”, and Section 4.5, “Access Control, Stage 2: Request Verification”.

If your privileges are changed (either by yourself or someone else) while you are connected, those changes do not necessarily take effect immediately for the next statement that you issue. For details about the conditions under which the server reloads the grant tables, see Section 4.6, “When Privilege Changes Take Effect”.

For general security-related advice, see Chapter 2, *General Security Issues*. For help in diagnosing privilege-related problems, see Section 4.7, “Troubleshooting Problems Connecting to MySQL”.

4.1 Privileges Provided by MySQL

MySQL provides privileges that apply in different contexts and at different levels of operation:

- Administrative privileges enable users to manage operation of the MySQL server. These privileges are global because they are not specific to a particular database.
- Database privileges apply to a database and to all objects within it. These privileges can be granted for specific databases, or globally so that they apply to all databases.
- Privileges for database objects such as tables, indexes, views, and stored routines can be granted for specific objects within a database, for all objects of a given type within a database (for example, all tables in a database), or globally for all objects of a given type in all databases).

Information about account privileges is stored in the `user`, `db`, `tables_priv`, `columns_priv`, and `procs_priv` tables in the `mysql` database (see Section 4.2, “Grant Tables”). The MySQL server reads the contents of these tables into memory when it starts and reloads them under the circumstances indicated in Section 4.6, “When Privilege Changes Take Effect”. Access-control decisions are based on the in-memory copies of the grant tables.

Some releases of MySQL introduce changes to the structure of the grant tables to add new privileges or features. To make sure that you can take advantage of any new capabilities, update your grant tables to have the current structure whenever you update to a new version of MySQL. See `mysql_upgrade` — Check and Upgrade MySQL Tables.

The following table shows the privilege names used at the SQL level in the `GRANT` and `REVOKE` statements, along with the column name associated with each privilege in the grant tables and the context in which the privilege applies.

Table 4.1 Permissible Privileges for GRANT and REVOKE

Privilege	Column	Context
`CREATE`	`Create_priv`	databases, tables, or indexes
`DROP`	`Drop_priv`	databases, tables, or views
`GRANT OPTION`	`Grant_priv`	databases, tables, or stored routines
`LOCK TABLES`	`Lock_tables_priv`	databases
`REFERENCES`	`References_priv`	databases or tables
`EVENT`	`Event_priv`	databases
`ALTER`	`Alter_priv`	tables
`DELETE`	`Delete_priv`	tables
`INDEX`	`Index_priv`	tables
`INSERT`	`Insert_priv`	tables or columns

Privilege	Column	Context
SELECT	Select_priv	tables or columns
UPDATE	Update_priv	tables or columns
CREATE TEMPORARY TABLES	Create_tmp_table_priv	tables
TRIGGER	Trigger_priv	tables
CREATE VIEW	Create_view_priv	views
SHOW VIEW	Show_view_priv	views
ALTER ROUTINE	Alter_routine_priv	stored routines
CREATE ROUTINE	Create_routine_priv	stored routines
EXECUTE	Execute_priv	stored routines
FILE	File_priv	file access on server host
CREATE TABLESPACE	Create_tablespace_priv	server administration
CREATE USER	Create_user_priv	server administration
PROCESS	Process_priv	server administration
PROXY	see proxies_priv table	server administration
RELOAD	Reload_priv	server administration
REPLICATION CLIENT	Repl_client_priv	server administration
REPLICATION SLAVE	Repl_slave_priv	server administration
SHOW DATABASES	Show_db_priv	server administration
SHUTDOWN	Shutdown_priv	server administration
SUPER	Super_priv	server administration
ALL [PRIVILEGES]		server administration
USAGE		server administration

The following list provides a general description of each privilege available in MySQL. Particular SQL statements might have more specific privilege requirements than indicated here. If so, the description for the statement in question provides the details.

- The ALL or ALL PRIVILEGES privilege specifier is shorthand. It stands for “all privileges available at a given privilege level” (except GRANT OPTION). For example, granting ALL at the global or table level grants all global privileges or all table-level privileges.
- The ALTER privilege enables use of ALTER TABLE to change the structure of tables. ALTER TABLE also requires the CREATE and INSERT privileges. Renaming a table requires ALTER and DROP on the old table, CREATE, and INSERT on the new table.
- The ALTER ROUTINE privilege is needed to alter or drop stored routines (procedures and functions).
- The CREATE privilege enables creation of new databases and tables.
- The CREATE ROUTINE privilege is needed to create stored routines (procedures and functions).
- The CREATE TABLESPACE privilege is needed to create, alter, or drop tablespaces and log file groups.
- The CREATE TEMPORARY TABLES privilege enables the creation of temporary tables using the CREATE TEMPORARY TABLE statement.

  After a session has created a temporary table, the server performs no further privilege checks on the table. The creating session can perform any operation on the table, such as DROP TABLE, INSERT, UPDATE, or SELECT.

One implication of this behavior is that a session can manipulate its temporary tables even if the current user has no privilege to create them. Suppose that the current user does not have the `CREATE TEMPORARY TABLES` privilege but is able to execute a `DEFINER`-context stored procedure that executes with the privileges of a user who does have `CREATE TEMPORARY TABLES` and that creates a temporary table. While the procedure executes, the session uses the privileges of the defining user. After the procedure returns, the effective privileges revert to those of the current user, which can still see the temporary table and perform any operation on it.

To keep privileges for temporary and nontemporary tables separate, a common workaround for this situation is to create a database dedicated to the use of temporary tables. Then for that database, a user can be granted the `CREATE TEMPORARY TABLES` privilege, along with any other privileges required for temporary table operations done by that user.

- The `CREATE USER` privilege enables use of `ALTER USER`, `CREATE USER`, `DROP USER`, `RENAME USER`, and `REVOKE ALL PRIVILEGES`.
- The `CREATE VIEW` privilege enables use of `CREATE VIEW`.
- The `DELETE` privilege enables rows to be deleted from tables in a database.
- The `DROP` privilege enables you to drop (remove) existing databases, tables, and views. The `DROP` privilege is required in order to use the statement `ALTER TABLE ... DROP PARTITION` on a partitioned table. The `DROP` privilege is also required for `TRUNCATE TABLE`. *If you grant the `DROP` privilege for the `mysql` database to a user, that user can drop the database in which the MySQL access privileges are stored.*
- The `EVENT` privilege is required to create, alter, drop, or see events for the Event Scheduler.
- The `EXECUTE` privilege is required to execute stored routines (procedures and functions).
- The `FILE` privilege gives you permission to read and write files on the server host using the `LOAD DATA INFILE` and `SELECT ... INTO OUTFILE` statements and the `LOAD_FILE()` function. A user who has the `FILE` privilege can read any file on the server host that is either world-readable or readable by the MySQL server. (This implies the user can read any file in any database directory, because the server can access any of those files.) The `FILE` privilege also enables the user to create new files in any directory where the MySQL server has write access. This includes the server's data directory containing the files that implement the privilege tables. As a security measure, the server will not overwrite existing files.

  To limit the location in which files can be read and written, set the `secure_file_priv` system to a specific directory. See Server System Variables.
- The `GRANT OPTION` privilege enables you to give to other users or remove from other users those privileges that you yourself possess.
- The `INDEX` privilege enables you to create or drop (remove) indexes. `INDEX` applies to existing tables. If you have the `CREATE` privilege for a table, you can include index definitions in the `CREATE TABLE` statement.
- The `INSERT` privilege enables rows to be inserted into tables in a database. `INSERT` is also required for the `ANALYZE TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` table-maintenance statements.
- The `LOCK TABLES` privilege enables the use of explicit `LOCK TABLES` statements to lock tables for which you have the `SELECT` privilege. This includes the use of write locks, which prevents other sessions from reading the locked table.
- The `PROCESS` privilege pertains to display of information about the threads executing within the server (that is, information about the statements being executed by sessions). The privilege enables use of `SHOW PROCESSLIST` or `mysqladmin processlist` to see threads belonging to other accounts; you can always see your own threads. The `PROCESS` privilege also enables use of `SHOW ENGINE`.

- The PROXY privilege enables a user to impersonate or become known as another user. See Section 5.9, “Proxy Users”.

- The REFERENCES privilege is unused before MySQL 5.7.6. As of 5.7.6, creation of a foreign key constraint requires the REFERENCES privilege for the parent table.

- The RELOAD privilege enables use of the FLUSH statement. It also enables mysqladmin commands that are equivalent to FLUSH operations: flush-hosts, flush-logs, flush-privileges, flush-status, flush-tables, flush-threads, refresh, and reload.

  The reload command tells the server to reload the grant tables into memory. flush-privileges is a synonym for reload. The refresh command closes and reopens the log files and flushes all tables. The other flush-*xxx* commands perform functions similar to refresh, but are more specific and may be preferable in some instances. For example, if you want to flush just the log files, flush-logs is a better choice than refresh.

- The REPLICATION CLIENT privilege enables the use of SHOW MASTER STATUS, SHOW SLAVE STATUS, and SHOW BINARY LOGS.

- The REPLICATION SLAVE privilege should be granted to accounts that are used by slave servers to connect to the current server as their master. Without this privilege, the slave cannot request updates that have been made to databases on the master server.

- The SELECT privilege enables you to select rows from tables in a database. SELECT statements require the SELECT privilege only if they actually retrieve rows from a table. Some SELECT statements do not access tables and can be executed without permission for any database. For example, you can use SELECT as a simple calculator to evaluate expressions that make no reference to tables:

  ```
  SELECT 1+1;
  SELECT PI()*2;
  ```

  The SELECT privilege is also needed for other statements that read column values. For example, SELECT is needed for columns referenced on the right hand side of *col_name*=*expr* assignment in UPDATE statements or for columns named in the WHERE clause of DELETE or UPDATE statements.

- The SHOW DATABASES privilege enables the account to see database names by issuing the SHOW DATABASE statement. Accounts that do not have this privilege see only databases for which they have some privileges, and cannot use the statement at all if the server was started with the --skip-show-database option. Note that *any* global privilege is a privilege for the database.

- The SHOW VIEW privilege enables use of SHOW CREATE VIEW.

- The SHUTDOWN privilege enables use of the SHUTDOWN statement, the mysqladmin shutdown command, and the mysql_shutdown() C API function.

- The SUPER privilege enables an account to use CHANGE MASTER TO, KILL or mysqladmin kill to kill threads belonging to other accounts (you can always kill your own threads), PURGE BINARY LOGS, the mysqladmin debug command, enabling or disabling logging, performing updates even if the read_only system variable is enabled, starting and stopping replication on slave servers, specification of any account in the DEFINER attribute of stored programs and views, and enables you to connect (once) even if the connection limit controlled by the max_connections system variable is reached.

  The SUPER privilege is required to make configuration changes by modifying the global value of system variables. For some system variables, setting the session value also requires the SUPER privilege; if so, it is indicated in the variable description.

  To create or alter stored functions if binary logging is enabled, you may also need the SUPER privilege, as described in Binary Logging of Stored Programs.

- The `TRIGGER` privilege enables trigger operations. You must have this privilege for a table to create, drop, execute, or display triggers for that table.

  When a trigger is activated (by a user who has privileges to execute `INSERT`, `UPDATE`, or `DELETE` statements for the table associated with the trigger), trigger execution requires that the user who defined the trigger still have the `TRIGGER` privilege.

- The `UPDATE` privilege enables rows to be updated in tables in a database.

- The `USAGE` privilege specifier stands for “no privileges.” It is used at the global level with `GRANT` to modify account attributes such as resource limits or SSL characteristics without affecting existing account privileges.

It is a good idea to grant to an account only those privileges that it needs. You should exercise particular caution in granting the `FILE` and administrative privileges:

- The `FILE` privilege can be abused to read into a database table any files that the MySQL server can read on the server host. This includes all world-readable files and files in the server's data directory. The table can then be accessed using `SELECT` to transfer its contents to the client host.

- The `GRANT OPTION` privilege enables users to give their privileges to other users. Two users that have different privileges and with the `GRANT OPTION` privilege are able to combine privileges.

- The `ALTER` privilege may be used to subvert the privilege system by renaming tables.

- The `SHUTDOWN` privilege can be abused to deny service to other users entirely by terminating the server.

- The `PROCESS` privilege can be used to view the plain text of currently executing statements, including statements that set or change passwords.

- The `SUPER` privilege can be used to terminate other sessions or change how the server operates.

- Privileges granted for the `mysql` database itself can be used to change passwords and other access privilege information. Passwords are stored encrypted, so a malicious user cannot simply read them to know the plain text password. However, a user with write access to the `user` table `authentication_string` column can change an account's password, and then connect to the MySQL server using that account.

4.2 Grant Tables

The `mysql` system database includes several grant tables that contain information about user accounts and the privileges held by them. This section describes those tables. For information about other tables in the system database, see The mysql System Database.

Normally, to manipulate the contents of grant tables, you modify them indirectly by using account-management statements such as `CREATE USER`, `GRANT`, and `REVOKE` to set up accounts and control the privileges available to each one. See Account Management Statements. The discussion here describes the underlying structure of the grant tables and how the server uses their contents when interacting with clients.

> **Note**
>
> Direct modification of grant tables using statements such as `INSERT`, `UPDATE`, or `DELETE` is discouraged and done at your own risk. The server is free to ignore rows that become malformed as a result of such modifications.

These `mysql` database tables contain grant information:

- `user`: User accounts, global privileges, and other non-privilege columns

- `db`: Database-level privileges

- `tables_priv`: Table-level privileges
- `columns_priv`: Column-level privileges
- `procs_priv`: Stored procedure and function privileges
- `proxies_priv`: Proxy-user privileges

Each grant table contains scope columns and privilege columns:

- Scope columns determine the scope of each row in the tables; that is, the context in which the row applies. For example, a `user` table row with `Host` and `User` values of `'thomas.loc.gov'` and `'bob'` applies to authenticating connections made to the server from the host `thomas.loc.gov` by a client that specifies a user name of `bob`. Similarly, a `db` table row with `Host`, `User`, and `Db` column values of `'thomas.loc.gov'`, `'bob'` and `'reports'` applies when `bob` connects from the host `thomas.loc.gov` to access the `reports` database. The `tables_priv` and `columns_priv` tables contain scope columns indicating tables or table/column combinations to which each row applies. The `procs_priv` scope columns indicate the stored routine to which each row applies.
- Privilege columns indicate which privileges a table row grants; that is, which operations it permits to be performed. The server combines the information in the various grant tables to form a complete description of a user's privileges. Section 4.5, “Access Control, Stage 2: Request Verification”, describes the rules for this.

The server uses the grant tables in the following manner:

- The `user` table scope columns determine whether to reject or permit incoming connections. For permitted connections, any privileges granted in the `user` table indicate the user's global privileges. Any privileges granted in this table apply to *all* databases on the server.

  > **Caution**
  >
  > Because any global privilege is considered a privilege for all databases, any global privilege enables a user to see all database names with `SHOW DATABASES` or by examining the `SCHEMATA` table of `INFORMATION_SCHEMA`.

- The `db` table scope columns determine which users can access which databases from which hosts. The privilege columns determine the permitted operations. A privilege granted at the database level applies to the database and to all objects in the database, such as tables and stored programs.
- The `tables_priv` and `columns_priv` tables are similar to the `db` table, but are more fine-grained: They apply at the table and column levels rather than at the database level. A privilege granted at the table level applies to the table and to all its columns. A privilege granted at the column level applies only to a specific column.
- The `procs_priv` table applies to stored routines (procedures and functions). A privilege granted at the routine level applies only to a single procedure or function.
- The `proxies_priv` table indicates which users can act as proxies for other users and whether a user can grant the `PROXY` privilege to other users.

The server uses the `user` and `db` tables in the `mysql` database at both the first and second stages of access control (see Chapter 4, *The MySQL Access Privilege System*). The columns in the `user` and `db` tables are shown here.

Table 4.2 user and db Table Columns

Table Name	`user`	`db`
Scope columns	`Host`	`Host`
	`User`	`Db`
	`Password`	`User`
Privilege columns	`Select_priv`	`Select_priv`

Table Name	user	db
	Insert_priv	Insert_priv
	Update_priv	Update_priv
	Delete_priv	Delete_priv
	Index_priv	Index_priv
	Alter_priv	Alter_priv
	Create_priv	Create_priv
	Drop_priv	Drop_priv
	Grant_priv	Grant_priv
	Create_view_priv	Create_view_priv
	Show_view_priv	Show_view_priv
	Create_routine_priv	Create_routine_priv
	Alter_routine_priv	Alter_routine_priv
	Execute_priv	Execute_priv
	Trigger_priv	Trigger_priv
	Event_priv	Event_priv
	Create_tmp_table_priv	Create_tmp_table_priv
	Lock_tables_priv	Lock_tables_priv
	References_priv	References_priv
	Reload_priv	
	Shutdown_priv	
	Process_priv	
	File_priv	
	Show_db_priv	
	Super_priv	
	Repl_slave_priv	
	Repl_client_priv	
	Create_user_priv	
	Create_tablespace_priv	
Security columns	ssl_type	
	ssl_cipher	
	x509_issuer	
	x509_subject	
	plugin	
	authentication_string	
	password_expired	
	password_last_changed	
	password_lifetime	
	account_locked	
Resource control columns	max_questions	
	max_updates	
	max_connections	

Table Name	user	db
	max_user_connections	

The user table plugin, Password, and authentication_string columns store authentication plugin and credential information. In MySQL 5.7.6, the Password column was removed and all credentials are stored in the authentication_string column.

If an account row names a plugin in the plugin column, the server uses it to authenticate connection attempts for the account. It is up to the plugin whether it uses the Password and authentication_string column values.

As of MySQL 5.7.2, the plugin column must be nonempty.

Before MySQL 5.7.2, the plugin column for an account row is permitted to be empty. In this case, the server authenticates the account using the mysql_native_password or mysql_old_password plugin implicitly, depending on the format of the password hash in the Password column. If the Password value is empty or a 4.1 password hash (41 characters), the server uses mysql_native_password. If the password value is a pre-4.1 password hash (16 characters), the server uses mysql_old_password. (For additional information about these hash formats, see Section 2.2.4, “Password Hashing in MySQL”.) Clients must match the password in the Password column of the account row.

At startup, and at runtime when FLUSH PRIVILEGES is executed, the server checks user table rows. As of MySQL 5.7.2, for any row with an empty plugin column, the server writes a warning to the error log of this form:

```
[Warning] User entry 'user_name'@'host_name' has an empty plugin
value. The user will be ignored and no one can login with this user
anymore.
```

To address this problem, see Section 7.1.3, “Migrating Away from Pre-4.1 Password Hashing and the mysql_old_password Plugin”.

The password_expired column permits DBAs to expire account passwords and require users to reset their password. The default password_expired value is 'N', but can be set to 'Y' with the ALTER USER statement. After an account's password has been expired, all operations performed by the account in subsequent connections to the server result in an error until the user issues an ALTER USER statement (for MySQL 5.7.6 and up) or SET PASSWORD statement (before MySQL 5.7.6) to establish a new account password.

It is possible after password expiration to “reset” a password by setting it to its current value. As a matter of good policy, it is preferable to choose a different password.

password_last_changed (added in MySQL 5.7.4) is a TIMESTAMP column indicating when the password was last changed. The value is non-NULL only for accounts that use MySQL built-in authentication methods (accounts that use an authentication plugin of mysql_native_password, mysql_old_password, or sha256_password). The value is NULL for other accounts, such as those authenticated using an external authentication system.

password_last_changed is updated by the CREATE USER, ALTER USER, and SET PASSWORD statements, and by GRANT statements that create an account or change an account password.

password_lifetime (added in MySQL 5.7.4) indicates the account password lifetime, in days. If the password is past its lifetime (assessed using the password_last_changed column), the server considers the password expired when clients connect using the account. A value of *N* greater than zero means that the password must be changed every *N* days. A value of 0 disables automatic password expiration. If the value is NULL (the default), the global expiration policy applies, as defined by the default_password_lifetime system variable.

account_locked (added in MySQL 5.7.6) indicates whether the account is locked (see Section 5.10, “User Account Locking”).

During the second stage of access control, the server performs request verification to ensure that each client has sufficient privileges for each request that it issues. In addition to the `user` and `db` grant tables, the server may also consult the `tables_priv` and `columns_priv` tables for requests that involve tables. The latter tables provide finer privilege control at the table and column levels. They have the columns shown in the following table.

Table 4.3 tables_priv and columns_priv Table Columns

Table Name	`tables_priv`	`columns_priv`
Scope columns	`Host`	`Host`
	`Db`	`Db`
	`User`	`User`
	`Table_name`	`Table_name`
		`Column_name`
Privilege columns	`Table_priv`	`Column_priv`
	`Column_priv`	
Other columns	`Timestamp`	`Timestamp`
	`Grantor`	

The `Timestamp` and `Grantor` columns are set to the current timestamp and the `CURRENT_USER` value, respectively, but are otherwise unused.

For verification of requests that involve stored routines, the server may consult the `procs_priv` table, which has the columns shown in the following table.

Table 4.4 procs_priv Table Columns

Table Name	`procs_priv`
Scope columns	`Host`
	`Db`
	`User`
	`Routine_name`
	`Routine_type`
Privilege columns	`Proc_priv`
Other columns	`Timestamp`
	`Grantor`

The `Routine_type` column is an `ENUM` column with values of `'FUNCTION'` or `'PROCEDURE'` to indicate the type of routine the row refers to. This column enables privileges to be granted separately for a function and a procedure with the same name.

The `Timestamp` and `Grantor` columns are unused.

The `proxies_priv` table records information about proxy accounts. It has these columns:

- `Host`, `User`: The proxy account; that is, the account that has the `PROXY` privilege for the proxied account.
- `Proxied_host`, `Proxied_user`: The proxied account.
- `Grantor`, `Timestamp`: Unused.
- `With_grant`: Whether the proxy account can grant the `PROXY` privilege to other accounts.

For an account to be able to grant the `PROXY` privilege to other accounts, it must have a row in the `proxies_priv` table with `With_grant` set to 1 and `Proxied_host` and `Proxied_user`

set to indicate the account or accounts for which the privilege can be granted. For example, the `'root'@'localhost'` account created during MySQL installation has a row in the `proxies_priv` table that enables granting the `PROXY` privilege for `''@''`, that is, for all users and all hosts. This enables `root` to set up proxy users, as well as to delegate to other accounts the authority to set up proxy users. See Section 5.9, “Proxy Users”.

Scope columns in the grant tables contain strings. The default value for each is the empty string. The following table shows the number of characters permitted in each column.

Table 4.5 Grant Table Scope Column Lengths

Column Name	Maximum Permitted Characters
`Host`, `Proxied_host`	60
`User`, `Proxied_user`	32 (16 before MySQL 5.7.8)
`Password`	41
`Db`	64
`Table_name`	64
`Column_name`	64
`Routine_name`	64

For access-checking purposes, comparisons of `User`, `Proxied_user`, `Password`, `authentication_string`, `Db`, and `Table_name` values are case sensitive. Comparisons of `Host`, `Proxied_host`, `Column_name`, and `Routine_name` values are not case sensitive.

The `user` and `db` tables list each privilege in a separate column that is declared as `ENUM('N','Y') DEFAULT 'N'`. In other words, each privilege can be disabled or enabled, with the default being disabled.

The `tables_priv`, `columns_priv`, and `procs_priv` tables declare the privilege columns as `SET` columns. Values in these columns can contain any combination of the privileges controlled by the table. Only those privileges listed in the column value are enabled.

Table 4.6 Set-Type Privilege Column Values

Table Name	Column Name	Possible Set Elements
`tables_priv`	`Table_priv`	`'Select', 'Insert', 'Update', 'Delete', 'Create', 'Drop', 'Grant', 'References', 'Index', 'Alter', 'Create View', 'Show view', 'Trigger'`
`tables_priv`	`Column_priv`	`'Select', 'Insert', 'Update', 'References'`
`columns_priv`	`Column_priv`	`'Select', 'Insert', 'Update', 'References'`
`procs_priv`	`Proc_priv`	`'Execute', 'Alter Routine', 'Grant'`

Only the `user` table specifies administrative privileges, such as `RELOAD` and `SHUTDOWN`. Administrative operations are operations on the server itself and are not database-specific, so there is no reason to list these privileges in the other grant tables. Consequently, the server need consult only the `user` table to determine whether a user can perform an administrative operation.

The `FILE` privilege also is specified only in the `user` table. It is not an administrative privilege as such, but a user's ability to read or write files on the server host is independent of the database being accessed.

The server reads the contents of the grant tables into memory when it starts. You can tell it to reload the tables by issuing a `FLUSH PRIVILEGES` statement or executing a `mysqladmin flush-`

`privileges` or `mysqladmin reload` command. Changes to the grant tables take effect as indicated in Section 4.6, “When Privilege Changes Take Effect”.

When you modify an account, it is a good idea to verify that your changes have the intended effect. To check the privileges for a given account, use the `SHOW GRANTS` statement. For example, to determine the privileges that are granted to an account with user name and host name values of `bob` and `pc84.example.com`, use this statement:

```
SHOW GRANTS FOR 'bob'@'pc84.example.com';
```

To display nonprivilege properties of an account, use `SHOW CREATE USER`:

```
SHOW CREATE USER 'bob'@'pc84.example.com';
```

4.3 Specifying Account Names

MySQL account names consist of a user name and a host name. This enables creation of accounts for users with the same name who can connect from different hosts. This section describes how to write account names, including special values and wildcard rules.

In SQL statements such as `CREATE USER`, `GRANT`, and `SET PASSWORD`, account names follow these rules:

- Account name syntax is `'user_name'@'host_name'`.
- An account name consisting only of a user name is equivalent to `'user_name'@'%'`. For example, `'me'` is equivalent to `'me'@'%'`.
- The user name and host name need not be quoted if they are legal as unquoted identifiers. Quotes are necessary to specify a *`user_name`* string containing special characters (such as space or `-`), or a *`host_name`* string containing special characters or wildcard characters (such as `.` or `%`); for example, `'test-user'@'%.com'`.
- Quote user names and host names as identifiers or as strings, using either backticks (`` ` ``), single quotation marks (`'`), or double quotation marks (`"`). For string-quoting and identifier-quoting guidelines, see String Literals, and Schema Object Names.
- The user name and host name parts, if quoted, must be quoted separately. That is, write `'me'@'localhost'`, not `'me@localhost'`; the latter is actually equivalent to `'me@localhost'@'%'`.
- A reference to the `CURRENT_USER` or `CURRENT_USER()` function is equivalent to specifying the current client's user name and host name literally.

MySQL stores account names in grant tables in the `mysql` system database using separate columns for the user name and host name parts:

- The `user` table contains one row for each account. The `User` and `Host` columns store the user name and host name. This table also indicates which global privileges the account has.
- Other grant tables indicate privileges an account has for databases and objects within databases. These tables have `User` and `Host` columns to store the account name. Each row in these tables associates with the account in the `user` table that has the same `User` and `Host` values.
- For access-checking purposes, comparisons of User values are case sensitive. Comparisons of Host values are not case sensitive.

For additional detail about grant table structure, see Section 4.2, “Grant Tables”.

User names and host names have certain special values or wildcard conventions, as described following.

The user name part of an account name is either a nonblank value that literally matches the user name for incoming connection attempts, or a blank value (empty string) that matches any user name. An account with a blank user name is an anonymous user. To specify an anonymous user in SQL statements, use a quoted empty user name part, such as `''@'localhost'`.

The host name part of an account name can take many forms, and wildcards are permitted:

- A host value can be a host name or an IP address (IPv4 or IPv6). The name `'localhost'` indicates the local host. The IP address `'127.0.0.1'` indicates the IPv4 loopback interface. The IP address `'::1'` indicates the IPv6 loopback interface.
- The `%` and `_` wildcard characters are permitted in host name or IP address values. These have the same meaning as for pattern-matching operations performed with the `LIKE` operator. For example, a host value of `'%'` matches any host name, whereas a value of `'%.mysql.com'` matches any host in the `mysql.com` domain. `'192.168.1.%'` matches any host in the 192.168.1 class C network.

  Because IP wildcard values are permitted in host values (for example, `'192.168.1.%'` to match every host on a subnet), someone could try to exploit this capability by naming a host `192.168.1.somewhere.com`. To foil such attempts, MySQL does not perform matching on host names that start with digits and a dot. For example, if a host is named `1.2.example.com`, its name never matches the host part of account names. An IP wildcard value can match only IP addresses, not host names.
- For a host value specified as an IPv4 address, a netmask can be given to indicate how many address bits to use for the network number. Netmask notation cannot be used for IPv6 addresses.

  The syntax is *`host_ip/netmask`*. For example:

  ```
  CREATE USER 'david'@'192.58.197.0/255.255.255.0';
  ```

  This enables `david` to connect from any client host having an IP address *`client_ip`* for which the following condition is true:

  ```
  client_ip & netmask = host_ip
  ```

  That is, for the `CREATE USER` statement just shown:

  ```
  client_ip & 255.255.255.0 = 192.58.197.0
  ```

  IP addresses that satisfy this condition range from `192.58.197.0` to `192.58.197.255`.

  A netmask typically begins with bits set to 1, followed by bits set to 0. Examples:

  - `192.0.0.0/255.0.0.0`: Any host on the 192 class A network
  - `192.168.0.0/255.255.0.0`: Any host on the 192.168 class B network
  - `192.168.1.0/255.255.255.0`: Any host on the 192.168.1 class C network
  - `192.168.1.1`: Only the host with this specific IP address

The server performs matching of host values in account names against the client host using the value returned by the system DNS resolver for the client host name or IP address. Except in the case that the account host value is specified using netmask notation, the server performs this comparison as a string match, even for an account host value given as an IP address. This means that you should specify account host values in the same format used by DNS. Here are examples of problems to watch out for:

- Suppose that a host on the local network has a fully qualified name of `host1.example.com`. If DNS returns name lookups for this host as `host1.example.com`, use that name in account host values. If DNS returns just `host1`, use `host1` instead.

- If DNS returns the IP address for a given host as `192.168.1.2`, that will match an account host value of `192.168.1.2` but not `192.168.01.2`. Similarly, it will match an account host pattern like `192.168.1.%` but not `192.168.01.%`.

To avoid problems like these, it is advisable to check the format in which your DNS returns host names and addresses. Use values in the same format in MySQL account names.

4.4 Access Control, Stage 1: Connection Verification

When you attempt to connect to a MySQL server, the server accepts or rejects the connection based on these conditions:

- Your identity and whether you can verify your identity by supplying the correct password
- Whether your account is locked or unlocked

The server checks credentials first, then account locking state. A failure for either step causes the server to deny access to you completely. Otherwise, the server accepts the connection, and then enters Stage 2 and waits for requests.

Credential checking is performed using the three `user` table scope columns (`Host`, `User`, and `authentication_string`). Locking state is recorded in the `user` table `account_locked` column. The server accepts the connection only if the `Host` and `User` columns in some `user` table row match the client host name and user name, the client supplies the password specified in that row, and the `account_locked` value is `'N'`. The rules for permissible `Host` and `User` values are given in Section 4.3, “Specifying Account Names”. Account locking can be changed with the `ALTER USER` statement.

Your identity is based on two pieces of information:

- The client host from which you connect
- Your MySQL user name

If the `User` column value is nonblank, the user name in an incoming connection must match exactly. If the `User` value is blank, it matches any user name. If the `user` table row that matches an incoming connection has a blank user name, the user is considered to be an anonymous user with no name, not a user with the name that the client actually specified. This means that a blank user name is used for all further access checking for the duration of the connection (that is, during Stage 2).

The `authentication_string` column can be blank. This is not a wildcard and does not mean that any password matches. It means that the user must connect without specifying a password. If the server authenticates a client using a plugin, the authentication method that the plugin implements may or may not use the password in the `authentication_string` column. In this case, it is possible that an external password is also used to authenticate to the MySQL server.

Nonblank `authentication_string` values in the `user` table represent encrypted passwords. MySQL does not store passwords in cleartext form for anyone to see. Rather, the password supplied by a user who is attempting to connect is encrypted (using the password hashing method implemented by the account authentication plugin). The encrypted password then is used during the connection process when checking whether the password is correct. This is done without the encrypted password ever traveling over the connection. See Section 5.1, “User Names and Passwords”.

From MySQL's point of view, the encrypted password is the *real* password, so you should never give anyone access to it. In particular, *do not give nonadministrative users read access to tables in the `mysql` database*.

The following table shows how various combinations of `User` and `Host` values in the `user` table apply to incoming connections.

`User` Value	`Host` Value	Permissible Connections
`'fred'`	`'thomas.loc.gov'`	`fred`, connecting from `thomas.loc.gov`
`''`	`'thomas.loc.gov'`	Any user, connecting from `thomas.loc.gov`
`'fred'`	`'%'`	`fred`, connecting from any host
`''`	`'%'`	Any user, connecting from any host
`'fred'`	`'%.loc.gov'`	`fred`, connecting from any host in the `loc.gov` domain
`'fred'`	`'x.y.%'`	`fred`, connecting from `x.y.net`, `x.y.com`, `x.y.edu`, and so on; this is probably not useful
`'fred'`	`'192.168.10.177'`	`fred`, connecting from the host with IP address `192.168.10.177`
`'fred'`	`'192.168.10.%'`	`fred`, connecting from any host in the `192.168.10` class C subnet
`'fred'`	`'192.168.10.0/255.255.255.0'`	Same as previous example

It is possible for the client host name and user name of an incoming connection to match more than one row in the `user` table. The preceding set of examples demonstrates this: Several of the entries shown match a connection from `thomas.loc.gov` by `fred`.

When multiple matches are possible, the server must determine which of them to use. It resolves this issue as follows:

- Whenever the server reads the `user` table into memory, it sorts the rows.
- When a client attempts to connect, the server looks through the rows in sorted order.
- The server uses the first row that matches the client host name and user name.

The server uses sorting rules that order rows with the most-specific `Host` values first. Literal host names and IP addresses are the most specific. (The specificity of a literal IP address is not affected by whether it has a netmask, so `192.168.1.13` and `192.168.1.0/255.255.255.0` are considered equally specific.) The pattern `'%'` means “any host” and is least specific. The empty string `''` also means “any host” but sorts after `'%'`. Rows with the same `Host` value are ordered with the most-specific `User` values first (a blank `User` value means “any user” and is least specific). For rows with equally-specific `Host` and `User` values, the order is indeterminate.

To see how this works, suppose that the `user` table looks like this:

```
+-----------+----------+-
| Host      | User     | ...
+-----------+----------+-
| %         | root     | ...
| %         | jeffrey  | ...
| localhost | root     | ...
| localhost |          | ...
+-----------+----------+-
```

When the server reads the table into memory, it sorts the rows using the rules just described. The result after sorting looks like this:

```
+-----------+----------+-
| Host      | User     | ...
+-----------+----------+-
| localhost | root     | ...
| localhost |          | ...
| %         | jeffrey  | ...
| %         | root     | ...
+-----------+----------+-
```

When a client attempts to connect, the server looks through the sorted rows and uses the first match found. For a connection from `localhost` by `jeffrey`, two of the rows from the table match: the one with `Host` and `User` values of `'localhost'` and `''`, and the one with values of `'%'` and `'jeffrey'`. The `'localhost'` row appears first in sorted order, so that is the one the server uses.

Here is another example. Suppose that the `user` table looks like this:

```
+---------------+----------+-
| Host          | User     | ...
+---------------+----------+-
| %             | jeffrey  | ...
| thomas.loc.gov |          | ...
+---------------+----------+-
```

The sorted table looks like this:

```
+---------------+----------+-
| Host          | User     | ...
+---------------+----------+-
| thomas.loc.gov |          | ...
| %             | jeffrey  | ...
+---------------+----------+-
```

A connection by `jeffrey` from `thomas.loc.gov` is matched by the first row, whereas a connection by `jeffrey` from any host is matched by the second.

> **Note**
>
> It is a common misconception to think that, for a given user name, all rows that explicitly name that user are used first when the server attempts to find a match for the connection. This is not true. The preceding example illustrates this, where a connection from `thomas.loc.gov` by `jeffrey` is first matched not by the row containing `'jeffrey'` as the `User` column value, but by the row with no user name. As a result, `jeffrey` is authenticated as an anonymous user, even though he specified a user name when connecting.

If you are able to connect to the server, but your privileges are not what you expect, you probably are being authenticated as some other account. To find out what account the server used to authenticate you, use the `CURRENT_USER()` function. (See Information Functions.) It returns a value in *`user_name@host_name`* format that indicates the `User` and `Host` values from the matching `user` table row. Suppose that `jeffrey` connects and issues the following query:

```
mysql> SELECT CURRENT_USER();
+----------------+
| CURRENT_USER() |
+----------------+
| @localhost     |
+----------------+
```

The result shown here indicates that the matching `user` table row had a blank `User` column value. In other words, the server is treating `jeffrey` as an anonymous user.

Another way to diagnose authentication problems is to print out the `user` table and sort it by hand to see where the first match is being made.

4.5 Access Control, Stage 2: Request Verification

After you establish a connection, the server enters Stage 2 of access control. For each request that you issue through that connection, the server determines what operation you want to perform, then checks whether you have sufficient privileges to do so. This is where the privilege columns in the grant tables come into play. These privileges can come from any of the `user`, `db`, `tables_priv`, `columns_priv`,

or `procs_priv` tables. (You may find it helpful to refer to Section 4.2, “Grant Tables”, which lists the columns present in each of the grant tables.)

The `user` table grants privileges that are assigned to you on a global basis and that apply no matter what the default database is. For example, if the `user` table grants you the `DELETE` privilege, you can delete rows from any table in any database on the server host! It is wise to grant privileges in the `user` table only to people who need them, such as database administrators. For other users, you should leave all privileges in the `user` table set to `'N'` and grant privileges at more specific levels only. You can grant privileges for particular databases, tables, columns, or routines.

The `db` table grants database-specific privileges. Values in the scope columns of this table can take the following forms:

- A blank `User` value matches the anonymous user. A nonblank value matches literally; there are no wildcards in user names.
- The wildcard characters `%` and `_` can be used in the `Host` and `Db` columns. These have the same meaning as for pattern-matching operations performed with the `LIKE` operator. If you want to use either character literally when granting privileges, you must escape it with a backslash. For example, to include the underscore character (_) as part of a database name, specify it as `\_` in the `GRANT` statement.
- A `'%'` or blank `Host` value means “any host.”
- A `'%'` or blank `Db` value means “any database.”

The server reads the `db` table into memory and sorts it at the same time that it reads the `user` table. The server sorts the `db` table based on the `Host`, `Db`, and `User` scope columns. As with the `user` table, sorting puts the most-specific values first and least-specific values last, and when the server looks for matching rows, it uses the first match that it finds.

The `tables_priv`, `columns_priv`, and `procs_priv` tables grant table-specific, column-specific, and routine-specific privileges. Values in the scope columns of these tables can take the following forms:

- The wildcard characters `%` and `_` can be used in the `Host` column. These have the same meaning as for pattern-matching operations performed with the `LIKE` operator.
- A `'%'` or blank `Host` value means “any host.”
- The `Db`, `Table_name`, `Column_name`, and `Routine_name` columns cannot contain wildcards or be blank.

The server sorts the `tables_priv`, `columns_priv`, and `procs_priv` tables based on the `Host`, `Db`, and `User` columns. This is similar to `db` table sorting, but simpler because only the `Host` column can contain wildcards.

The server uses the sorted tables to verify each request that it receives. For requests that require administrative privileges such as `SHUTDOWN` or `RELOAD`, the server checks only the `user` table row because that is the only table that specifies administrative privileges. The server grants access if the row permits the requested operation and denies access otherwise. For example, if you want to execute `mysqladmin shutdown` but your `user` table row does not grant the `SHUTDOWN` privilege to you, the server denies access without even checking the `db` table. (It contains no `Shutdown_priv` column, so there is no need to do so.)

For database-related requests (`INSERT`, `UPDATE`, and so on), the server first checks the user's global privileges by looking in the `user` table row. If the row permits the requested operation, access is granted. If the global privileges in the `user` table are insufficient, the server determines the user's database-specific privileges by checking the `db` table:

The server looks in the `db` table for a match on the `Host`, `Db`, and `User` columns. The `Host` and `User` columns are matched to the connecting user's host name and MySQL user name. The `Db` column

is matched to the database that the user wants to access. If there is no row for the `Host` and `User`, access is denied.

After determining the database-specific privileges granted by the `db` table rows, the server adds them to the global privileges granted by the `user` table. If the result permits the requested operation, access is granted. Otherwise, the server successively checks the user's table and column privileges in the `tables_priv` and `columns_priv` tables, adds those to the user's privileges, and permits or denies access based on the result. For stored-routine operations, the server uses the `procs_priv` table rather than `tables_priv` and `columns_priv`.

Expressed in boolean terms, the preceding description of how a user's privileges are calculated may be summarized like this:

```
global privileges
OR (database privileges AND host privileges)
OR table privileges
OR column privileges
OR routine privileges
```

It may not be apparent why, if the global `user` row privileges are initially found to be insufficient for the requested operation, the server adds those privileges to the database, table, and column privileges later. The reason is that a request might require more than one type of privilege. For example, if you execute an `INSERT INTO ... SELECT` statement, you need both the `INSERT` and the `SELECT` privileges. Your privileges might be such that the `user` table row grants one privilege and the `db` table row grants the other. In this case, you have the necessary privileges to perform the request, but the server cannot tell that from either table by itself; the privileges granted by the rows in both tables must be combined.

4.6 When Privilege Changes Take Effect

When `mysqld` starts, it reads all grant table contents into memory. The in-memory tables become effective for access control at that point.

If you modify the grant tables indirectly using account-management statements such as `GRANT`, `REVOKE`, `SET PASSWORD`, or `RENAME USER`, the server notices these changes and loads the grant tables into memory again immediately.

If you modify the grant tables directly using statements such as `INSERT`, `UPDATE`, or `DELETE`, your changes have no effect on privilege checking until you either restart the server or tell it to reload the tables. If you change the grant tables directly but forget to reload them, your changes have *no effect* until you restart the server. This may leave you wondering why your changes seem to make no difference!

To tell the server to reload the grant tables, perform a flush-privileges operation. This can be done by issuing a `FLUSH PRIVILEGES` statement or by executing a `mysqladmin flush-privileges` or `mysqladmin reload` command.

A grant table reload affects privileges for each existing client connection as follows:

- Table and column privilege changes take effect with the client's next request.
- Database privilege changes take effect the next time the client executes a `USE db_name` statement.

  > **Note**
  >
  > Client applications may cache the database name; thus, this effect may not be visible to them without actually changing to a different database or flushing the privileges.

- Global privileges and passwords are unaffected for a connected client. These changes take effect only for subsequent connections.

If the server is started with the `--skip-grant-tables` option, it does not read the grant tables or implement any access control. Anyone can connect and do anything, *which is insecure.* To cause a server thus started to read the tables and enable access checking, flush the privileges.

4.7 Troubleshooting Problems Connecting to MySQL

If you encounter problems when you try to connect to the MySQL server, the following items describe some courses of action you can take to correct the problem.

- Make sure that the server is running. If it is not, clients cannot connect to it. For example, if an attempt to connect to the server fails with a message such as one of those following, one cause might be that the server is not running:

```
shell> mysql
ERROR 2003: Can't connect to MySQL server on 'host_name' (111)
shell> mysql
ERROR 2002: Can't connect to local MySQL server through socket
'/tmp/mysql.sock' (111)
```

- It might be that the server is running, but you are trying to connect using a TCP/IP port, named pipe, or Unix socket file different from the one on which the server is listening. To correct this when you invoke a client program, specify a `--port` option to indicate the proper port number, or a `--socket` option to indicate the proper named pipe or Unix socket file. To find out where the socket file is, you can use this command:

```
shell> netstat -ln | grep mysql
```

- Make sure that the server has not been configured to ignore network connections or (if you are attempting to connect remotely) that it has not been configured to listen only locally on its network interfaces. If the server was started with `--skip-networking`, it will not accept TCP/IP connections at all. If the server was started with `--bind-address=127.0.0.1`, it will listen for TCP/IP connections only locally on the loopback interface and will not accept remote connections.

- Check to make sure that there is no firewall blocking access to MySQL. Your firewall may be configured on the basis of the application being executed, or the port number used by MySQL for communication (3306 by default). Under Linux or Unix, check your IP tables (or similar) configuration to ensure that the port has not been blocked. Under Windows, applications such as ZoneAlarm or Windows Firewall may need to be configured not to block the MySQL port.

- The grant tables must be properly set up so that the server can use them for access control. For some distribution types (such as binary distributions on Windows, or RPM distributions on Linux), the installation process initializes the MySQL data directory, including the `mysql` database containing the grant tables. For distributions that do not do this, you must initialize the data directory manually. For details, see Chapter 3, *Postinstallation Setup and Testing*.

  To determine whether you need to initialize the grant tables, look for a `mysql` directory under the data directory. (The data directory normally is named `data` or `var` and is located under your MySQL installation directory.) Make sure that you have a file named `user.MYD` in the `mysql` database directory. If not, initialize the data directory. After doing so and starting the server, test the initial privileges by executing this command:

```
shell> mysql -u root
```

  The server should let you connect without error.

- After a fresh installation, you should connect to the server and set up your users and their access permissions:

```
shell> mysql -u root mysql
```

The server should let you connect with no password if you initialized MySQL using `mysqld --initialize-secure` to not create a password for the initial `root` account (see Section 3.1.1, “Initializing the Data Directory Manually Using mysqld”). That is a security risk, so setting the password for the `root` account is something you should do while you're setting up your other MySQL accounts. For instructions on setting the initial password, see Section 3.4, “Securing the Initial MySQL Accounts”.

- If you have updated an existing MySQL installation to a newer version, did you run the `mysql_upgrade` script? If not, do so. The structure of the grant tables changes occasionally when new capabilities are added, so after an upgrade you should always make sure that your tables have the current structure. For instructions, see `mysql_upgrade` — Check and Upgrade MySQL Tables.

- If a client program receives the following error message when it tries to connect, it means that the server expects passwords in a newer format than the client is capable of generating:

```
shell> mysql
Client does not support authentication protocol requested
by server; consider upgrading MySQL client
```

For information on how to deal with this, see Section 2.2.4, “Password Hashing in MySQL”, and Client does not support authentication protocol.

- Remember that client programs use connection parameters specified in option files or environment variables. If a client program seems to be sending incorrect default connection parameters when you have not specified them on the command line, check any applicable option files and your environment. For example, if you get `Access denied` when you run a client without any options, make sure that you have not specified an old password in any of your option files!

  You can suppress the use of option files by a client program by invoking it with the `--no-defaults` option. For example:

```
shell> mysqladmin --no-defaults -u root version
```

The option files that clients use are listed in Using Option Files. Environment variables are listed in MySQL Program Environment Variables.

- If you get the following error, it means that you are using an incorrect `root` password:

```
shell> mysqladmin -u root -pxxxx ver
Access denied for user 'root'@'localhost' (using password: YES)
```

If the preceding error occurs even when you have not specified a password, it means that you have an incorrect password listed in some option file. Try the `--no-defaults` option as described in the previous item.

For information on changing passwords, see Section 5.5, “Assigning Account Passwords”.

If you have lost or forgotten the `root` password, see How to Reset the Root Password.

- If you change a password by using `SET PASSWORD`, `INSERT`, or `UPDATE`, you must encrypt the password using the `PASSWORD()` function. If you do not use `PASSWORD()` for these statements, the password will not work. For example, the following statement assigns a password, but fails to encrypt it, so the user is not able to connect afterward:

```
SET PASSWORD FOR 'abe'@'host_name' = 'eagle';
```

Instead, set the password like this:

```
```

```
SET PASSWORD FOR 'abe'@'host_name' = PASSWORD('eagle');
```

The `PASSWORD()` function is unnecessary when you specify a password using the `CREATE USER` or `GRANT` statements or the `mysqladmin password` command. Each of those automatically uses `PASSWORD()` to encrypt the password. See Section 5.5, “Assigning Account Passwords”, and CREATE USER Syntax.

- `localhost` is a synonym for your local host name, and is also the default host to which clients try to connect if you specify no host explicitly.

  You can use a `--host=127.0.0.1` option to name the server host explicitly. This will make a TCP/IP connection to the local `mysqld` server. You can also use TCP/IP by specifying a `--host` option that uses the actual host name of the local host. In this case, the host name must be specified in a `user` table row on the server host, even though you are running the client program on the same host as the server.

- The `Access denied` error message tells you who you are trying to log in as, the client host from which you are trying to connect, and whether you were using a password. Normally, you should have one row in the `user` table that exactly matches the host name and user name that were given in the error message. For example, if you get an error message that contains `using password: NO`, it means that you tried to log in without a password.

- If you get an `Access denied` error when trying to connect to the database with `mysql -u user_name`, you may have a problem with the `user` table. Check this by executing `mysql -u root mysql` and issuing this SQL statement:

  ```
  SELECT * FROM user;
  ```

  The result should include a row with the `Host` and `User` columns matching your client's host name and your MySQL user name.

- If the following error occurs when you try to connect from a host other than the one on which the MySQL server is running, it means that there is no row in the `user` table with a `Host` value that matches the client host:

  ```
  Host ... is not allowed to connect to this MySQL server
  ```

  You can fix this by setting up an account for the combination of client host name and user name that you are using when trying to connect.

  If you do not know the IP address or host name of the machine from which you are connecting, you should put a row with `'%'` as the `Host` column value in the `user` table. After trying to connect from the client machine, use a `SELECT USER()` query to see how you really did connect. Then change the `'%'` in the `user` table row to the actual host name that shows up in the log. Otherwise, your system is left insecure because it permits connections from any host for the given user name.

  On Linux, another reason that this error might occur is that you are using a binary MySQL version that is compiled with a different version of the `glibc` library than the one you are using. In this case, you should either upgrade your operating system or `glibc`, or download a source distribution of MySQL version and compile it yourself. A source RPM is normally trivial to compile and install, so this is not a big problem.

- If you specify a host name when trying to connect, but get an error message where the host name is not shown or is an IP address, it means that the MySQL server got an error when trying to resolve the IP address of the client host to a name:

  ```
  shell> mysqladmin -u root -pxxxx -h some_hostname ver
  Access denied for user 'root'@'' (using password: YES)
  ```

If you try to connect as `root` and get the following error, it means that you do not have a row in the `user` table with a `User` column value of `'root'` and that `mysqld` cannot resolve the host name for your client:

```
Access denied for user ''@'unknown'
```

These errors indicate a DNS problem. To fix it, execute `mysqladmin flush-hosts` to reset the internal DNS host cache. See DNS Lookup Optimization and the Host Cache.

Some permanent solutions are:

- Determine what is wrong with your DNS server and fix it.
- Specify IP addresses rather than host names in the MySQL grant tables.
- Put an entry for the client machine name in `/etc/hosts` on Unix or `\windows\hosts` on Windows.
- Start `mysqld` with the `--skip-name-resolve` option.
- Start `mysqld` with the `--skip-host-cache` option.
- On Unix, if you are running the server and the client on the same machine, connect to `localhost`. For connections to `localhost`, MySQL programs attempt to connect to the local server by using a Unix socket file, unless there are connection parameters specified to ensure that the client makes a TCP/IP connection. For more information, see Connecting to the MySQL Server.
- On Windows, if you are running the server and the client on the same machine and the server supports named pipe connections, connect to the host name `.` (period). Connections to `.` use a named pipe rather than TCP/IP.

- If `mysql -u root` works but `mysql -h your_hostname -u root` results in `Access denied` (where *`your_hostname`* is the actual host name of the local host), you may not have the correct name for your host in the `user` table. A common problem here is that the `Host` value in the `user` table row specifies an unqualified host name, but your system's name resolution routines return a fully qualified domain name (or vice versa). For example, if you have a row with host `'pluto'` in the `user` table, but your DNS tells MySQL that your host name is `'pluto.example.com'`, the row does not work. Try adding a row to the `user` table that contains the IP address of your host as the `Host` column value. (Alternatively, you could add a row to the `user` table with a `Host` value that contains a wildcard; for example, `'pluto.%'`. However, use of `Host` values ending with `%` is *insecure* and is *not* recommended!)

- If `mysql -u user_name` works but `mysql -u user_name some_db` does not, you have not granted access to the given user for the database named *`some_db`*.

- If `mysql -u user_name` works when executed on the server host, but `mysql -h host_name -u user_name` does not work when executed on a remote client host, you have not enabled access to the server for the given user name from the remote host.

- If you cannot figure out why you get `Access denied`, remove from the `user` table all rows that have `Host` values containing wildcards (rows that contain `'%'` or `'_'` characters). A very common error is to insert a new row with `Host='%'` and `User='some_user'`, thinking that this enables you to specify `localhost` to connect from the same machine. The reason that this does not work is that the default privileges include a row with `Host='localhost'` and `User=''`. Because that row has a `Host` value `'localhost'` that is more specific than `'%'`, it is used in preference to the new row when connecting from `localhost`! The correct procedure is to insert a second row with `Host='localhost'` and `User='some_user'`, or to delete the row with `Host='localhost'` and

`User=''`. After deleting the row, remember to issue a `FLUSH PRIVILEGES` statement to reload the grant tables. See also Section 4.4, “Access Control, Stage 1: Connection Verification”.

- If you are able to connect to the MySQL server, but get an `Access denied` message whenever you issue a `SELECT ... INTO OUTFILE` or `LOAD DATA INFILE` statement, your row in the `user` table does not have the `FILE` privilege enabled.
- If you change the grant tables directly (for example, by using `INSERT`, `UPDATE`, or `DELETE` statements) and your changes seem to be ignored, remember that you must execute a `FLUSH PRIVILEGES` statement or a `mysqladmin flush-privileges` command to cause the server to reload the privilege tables. Otherwise, your changes have no effect until the next time the server is restarted. Remember that after you change the `root` password with an `UPDATE` statement, you will not need to specify the new password until after you flush the privileges, because the server will not know you've changed the password yet!
- If your privileges seem to have changed in the middle of a session, it may be that a MySQL administrator has changed them. Reloading the grant tables affects new client connections, but it also affects existing connections as indicated in Section 4.6, “When Privilege Changes Take Effect”.
- If you have access problems with a Perl, PHP, Python, or ODBC program, try to connect to the server with `mysql -u user_name db_name` or `mysql -u user_name -pyour_pass db_name`. If you are able to connect using the `mysql` client, the problem lies with your program, not with the access privileges. (There is no space between `-p` and the password; you can also use the `--password=your_pass` syntax to specify the password. If you use the `-p` or `--password` option with no password value, MySQL prompts you for the password.)
- For testing purposes, start the `mysqld` server with the `--skip-grant-tables` option. Then you can change the MySQL grant tables and use the `SHOW GRANTS` statement to check whether your modifications have the desired effect. When you are satisfied with your changes, execute `mysqladmin flush-privileges` to tell the `mysqld` server to reload the privileges. This enables you to begin using the new grant table contents without stopping and restarting the server.
- If everything else fails, start the `mysqld` server with a debugging option (for example, `--debug=d,general,query`). This prints host and user information about attempted connections, as well as information about each command issued. See The DBUG Package.
- If you have any other problems with the MySQL grant tables and feel you must post the problem to the mailing list, always provide a dump of the MySQL grant tables. You can dump the tables with the `mysqldump mysql` command. To file a bug report, see the instructions at How to Report Bugs or Problems. In some cases, you may need to restart `mysqld` with `--skip-grant-tables` to run `mysqldump`.

Chapter 5 MySQL User Account Management

Table of Contents

This section describes how to set up accounts for clients of your MySQL server. It discusses the following topics:

- The meaning of account names and passwords as used in MySQL and how that compares to names and passwords used by your operating system
- How to set up new accounts and remove existing accounts
- How to change passwords
- Guidelines for using passwords securely

See also Account Management Statements, which describes the syntax and use for all user-management SQL statements.

5.1 User Names and Passwords

MySQL stores accounts in the `user` table of the `mysql` system database. An account is defined in terms of a user name and the client host or hosts from which the user can connect to the server. For information about account representation in the `user` table, see Section 4.2, “Grant Tables”.

The account may also have a password. MySQL supports authentication plugins, so it is possible that an account authenticates using some external authentication method. See Section 5.8, “Pluggable Authentication”.

There are several distinctions between the way user names and passwords are used by MySQL and your operating system:

- User names, as used by MySQL for authentication purposes, have nothing to do with user names (login names) as used by Windows or Unix. On Unix, most MySQL clients by default try to log in using the current Unix user name as the MySQL user name, but that is for convenience only. The default can be overridden easily, because client programs permit any user name to be specified with a `-u` or `--user` option. This means that anyone can attempt to connect to the server using any user name, so you cannot make a database secure in any way unless all MySQL accounts have passwords. Anyone who specifies a user name for an account that has no password is able to connect successfully to the server.
- MySQL user names can be up to 32 characters long (16 characters before MySQL 5.7.8). Operating system user names may be of a different maximum length. For example, Unix user names typically are limited to eight characters.

> **Warning**
>
> The limit on MySQL user name length is hardcoded in MySQL servers and clients, and trying to circumvent it by modifying the definitions of the tables in the `mysql` database *does not work*.
>
> You should never alter the structure of tables in the `mysql` database in any manner whatsoever except by means of the procedure that is described in `mysql_upgrade` — Check and Upgrade MySQL Tables. Attempting to redefine MySQL's system tables in any other fashion results in undefined (and unsupported!) behavior. The server is free to ignore rows that become malformed as a result of such modifications.

- To authenticate client connections for accounts that use MySQL native authentication (implemented by the `mysql_native_password` authentication plugin), the server uses passwords stored in the `user` table. These passwords are distinct from passwords for logging in to your operating system. There is no necessary connection between the “external” password you use to log in to a Windows or Unix machine and the password you use to access the MySQL server on that machine.

  If the server authenticates a client using some other plugin, the authentication method that the plugin implements may or may not use a password stored in the `user` table. In this case, it is possible that an external password is also used to authenticate to the MySQL server.

- Passwords stored in the `user` table are encrypted using plugin-specific algorithms. For information about MySQL native password hashing, see Section 2.2.4, “Password Hashing in MySQL”.

- If the user name and password contain only ASCII characters, it is possible to connect to the server regardless of character set settings. To connect when the user name or password contain non-ASCII characters, the client should call the `mysql_options()` C API function with the `MYSQL_SET_CHARSET_NAME` option and appropriate character set name as arguments. This causes authentication to take place using the specified character set. Otherwise, authentication will fail unless the server default character set is the same as the encoding in the authentication defaults.

  Standard MySQL client programs support a `--default-character-set` option that causes `mysql_options()` to be called as just described. In addition, character set autodetection is supported as described in Connection Character Sets and Collations. For programs that use a connector that is not based on the C API, the connector may provide an equivalent to `mysql_options()` that can be used instead. Check the connector documentation.

  The preceding notes do not apply for `ucs2`, `utf16`, and `utf32`, which are not permitted as client character sets.

The MySQL installation process populates the grant tables with an initial `root` account, as described in Section 3.4, “Securing the Initial MySQL Accounts”, which also discusses how to assign passwords to it. Thereafter, you normally set up, modify, and remove MySQL accounts using statements such as `CREATE USER`, `DROP USER`, `GRANT`, and `REVOKE`. See Account Management Statements.

To connect to a MySQL server with a command-line client, specify user name and password options as necessary for the account that you want to use:

```
shell> mysql --user=finley --password db_name
```

If you prefer short options, the command looks like this:

```
shell> mysql -u finley -p db_name
```

If you omit the password value following the `--password` or `-p` option on the command line (as just shown), the client prompts for one. Alternatively, the password can be specified on the command line:

```
```

```
shell> mysql --user=finley --password=password db_name
shell> mysql -u finley -ppassword db_name
```

If you use the `-p` option, there must be *no space* between `-p` and the following password value.

Specifying a password on the command line should be considered insecure. See Section 2.2.1, “End-User Guidelines for Password Security”. You can use an option file or a login path file to avoid giving the password on the command line. See Using Option Files, and `mysql_config_editor` — MySQL Configuration Utility.

For additional information about specifying user names, passwords, and other connection parameters, see Connecting to the MySQL Server.

5.2 Adding User Accounts

You can create MySQL accounts two ways:

- By using account-management statements intended for creating accounts and establishing their privileges, such as `CREATE USER` and `GRANT`. These statements cause the server to make appropriate modifications to the underlying grant tables.
- By manipulating the MySQL grant tables directly with statements such as `INSERT`, `UPDATE`, or `DELETE`.

The preferred method is to use account-management statements because they are more concise and less error-prone than manipulating the grant tables directly. All such statements are described in Account Management Statements. Direct grant table manipulation is discouraged, and is not described here. The server is free to ignore rows that become malformed as a result of such modifications.

Another option for creating accounts is to use the GUI tool MySQL Workbench. Also, several third-party programs offer capabilities for MySQL account administration. `phpMyAdmin` is one such program.

The following examples show how to use the `mysql` client program to set up new accounts. These examples assume that privileges have been set up according to the defaults described in Section 3.4, “Securing the Initial MySQL Accounts”. This means that to make changes, you must connect to the MySQL server as the MySQL `root` user, which has the `CREATE USER` privilege.

First, use the `mysql` program to connect to the server as the MySQL `root` user:

```
shell> mysql --user=root mysql
```

If you have assigned a password to the `root` account, you must also supply a `--password` or `-p` option.

After connecting to the server as `root`, you can add new accounts. The following example uses `CREATE USER` and `GRANT` statements to set up four accounts:

```
mysql> CREATE USER 'finley'@'localhost' IDENTIFIED BY 'some_pass';
mysql> GRANT ALL PRIVILEGES ON *.* TO 'finley'@'localhost'
    ->     WITH GRANT OPTION;
mysql> CREATE USER 'finley'@'%' IDENTIFIED BY 'some_pass';
mysql> GRANT ALL PRIVILEGES ON *.* TO 'finley'@'%'
    ->     WITH GRANT OPTION;
mysql> CREATE USER 'admin'@'localhost' IDENTIFIED BY 'admin_pass';
mysql> GRANT RELOAD,PROCESS ON *.* TO 'admin'@'localhost';
mysql> CREATE USER 'dummy'@'localhost';
```

The accounts created by those statements have the following properties:

- Two accounts have a user name of `finley` and a password of `some_pass`. Both are superuser accounts with full privileges to do anything. The `'finley'@'localhost'` account can be used only when connecting from the local host. The `'finley'@'%'` account uses the `'%'` wildcard for the host part, so it can be used to connect from any host.

The `'finley'@'localhost'` account is necessary if there is an anonymous-user account for `localhost`. Without the `'finley'@'localhost'` account, that anonymous-user account takes precedence when `finley` connects from the local host and `finley` is treated as an anonymous user. The reason for this is that the anonymous-user account has a more specific `Host` column value than the `'finley'@'%'` account and thus comes earlier in the `user` table sort order. (`user` table sorting is discussed in Section 4.4, “Access Control, Stage 1: Connection Verification”.)

- The `'admin'@'localhost'` account has a password of `admin_pass`. This account can be used only by `admin` to connect from the local host. It is granted the `RELOAD` and `PROCESS` administrative privileges. These privileges enable the `admin` user to execute the `mysqladmin reload`, `mysqladmin refresh`, and `mysqladmin flush-xxx` commands, as well as `mysqladmin processlist` . No privileges are granted for accessing any databases. You could add such privileges using `GRANT` statements.

- The `'dummy'@'localhost'` account has no password (which is insecure and not recommended). This account can be used only to connect from the local host. No privileges are granted. It is assumed that you will grant specific privileges to the account using `GRANT` statements.

To see the privileges for an account, use `SHOW GRANTS`:

```
mysql> SHOW GRANTS FOR 'admin'@'localhost';
+-----------------------------------------------------+
| Grants for admin@localhost                          |
+-----------------------------------------------------+
| GRANT RELOAD, PROCESS ON *.* TO 'admin'@'localhost' |
+-----------------------------------------------------+
```

To see nonprivilege properties for an account, use `SHOW CREATE USER`:

```
mysql> SHOW CREATE USER 'admin'@'localhost'\G
*************************** 1. row ***************************
CREATE USER for admin@localhost: CREATE USER 'admin'@'localhost'
IDENTIFIED WITH 'mysql_native_password'
AS '*67ACDEBDAB923990001F0FFB017EB8ED41861105'
REQUIRE NONE PASSWORD EXPIRE DEFAULT ACCOUNT UNLOCK
```

The next examples create three accounts and grant them access to specific databases. Each of them has a user name of `custom` and password of `obscure`:

```
mysql> CREATE USER 'custom'@'localhost' IDENTIFIED BY 'obscure';
mysql> GRANT SELECT,INSERT,UPDATE,DELETE,CREATE,DROP
    ->     ON bankaccount.*
    ->     TO 'custom'@'localhost';
mysql> CREATE USER 'custom'@'host47.example.com' IDENTIFIED BY 'obscure';
mysql> GRANT SELECT,INSERT,UPDATE,DELETE,CREATE,DROP
    ->     ON expenses.*
    ->     TO 'custom'@'host47.example.com';
mysql> CREATE USER 'custom'@'%.example.com' IDENTIFIED BY 'obscure';
mysql> GRANT SELECT,INSERT,UPDATE,DELETE,CREATE,DROP
    ->     ON customer.*
    ->     TO 'custom'@'%.example.com';
```

The three accounts can be used as follows:

- The first account can access the `bankaccount` database, but only from the local host.

- The second account can access the `expenses` database, but only from the host `host47.example.com`.

- The third account can access the `customer` database, from any host in the `example.com` domain. This account has access from all machines in the domain due to use of the `%` wildcard character in the host part of the account name.

5.3 Removing User Accounts

To remove an account, use the `DROP USER` statement, which is described in DROP USER Syntax. For example:

```
mysql> DROP USER 'jeffrey'@'localhost';
```

5.4 Setting Account Resource Limits

One means of restricting client use of MySQL server resources is to set the global `max_user_connections` system variable to a nonzero value. This limits the number of simultaneous connections that can be made by any given account, but places no limits on what a client can do once connected. In addition, setting `max_user_connections` does not enable management of individual accounts. Both types of control are of interest to MySQL administrators.

To address such concerns, MySQL permits limits for individual accounts on use of these server resources:

- The number of queries an account can issue per hour
- The number of updates an account can issue per hour
- The number of times an account can connect to the server per hour
- The number of simultaneous connections to the server by an account

Any statement that a client can issue counts against the query limit, unless its results are served from the query cache. Only statements that modify databases or tables count against the update limit.

An “account” in this context corresponds to a row in the `mysql.user` table. That is, a connection is assessed against the `User` and `Host` values in the `user` table row that applies to the connection. For example, an account `'usera'@'%.example.com'` corresponds to a row in the `user` table that has `User` and `Host` values of `usera` and `%.example.com`, to permit `usera` to connect from any host in the `example.com` domain. In this case, the server applies resource limits in this row collectively to all connections by `usera` from any host in the `example.com` domain because all such connections use the same account.

Before MySQL 5.0.3, an “account” was assessed against the actual host from which a user connects. This older method of accounting may be selected by starting the server with the `--old-style-user-limits` option. In this case, if `usera` connects simultaneously from `host1.example.com` and `host2.example.com`, the server applies the account resource limits separately to each connection. If `usera` connects again from `host1.example.com`, the server applies the limits for that connection together with the existing connection from that host.

To establish resource limits for an account at account-creation time, use the `CREATE USER` statement. To modify the limits for an existing account, use `ALTER USER`. (Before MySQL 5.7.6, use `GRANT`, for new or existing accounts.) Provide a `WITH` clause that names each resource to be limited. The default value for each limit is zero (no limit). For example, to create a new account that can access the `customer` database, but only in a limited fashion, issue these statements:

```
mysql> CREATE USER 'francis'@'localhost' IDENTIFIED BY 'frank'
    ->     WITH MAX_QUERIES_PER_HOUR 20
    ->          MAX_UPDATES_PER_HOUR 10
    ->          MAX_CONNECTIONS_PER_HOUR 5
    ->          MAX_USER_CONNECTIONS 2;
```

The limit types need not all be named in the `WITH` clause, but those named can be present in any order. The value for each per-hour limit should be an integer representing a count per hour. For `MAX_USER_CONNECTIONS`, the limit is an integer representing the maximum number of simultaneous connections by the account. If this limit is set to zero, the global `max_user_connections` system

variable value determines the number of simultaneous connections. If `max_user_connections` is also zero, there is no limit for the account.

To modify limits for an existing account, use an `ALTER USER` statement. The following statement changes the query limit for `francis` to 100:

```
mysql> ALTER USER 'francis'@'localhost' WITH MAX_QUERIES_PER_HOUR 100;
```

The statement modifies only the limit value specified and leaves the account otherwise unchanged.

To remove a limit, set its value to zero. For example, to remove the limit on how many times per hour `francis` can connect, use this statement:

```
mysql> ALTER USER 'francis'@'localhost' WITH MAX_CONNECTIONS_PER_HOUR 0;
```

As mentioned previously, the simultaneous-connection limit for an account is determined from the `MAX_USER_CONNECTIONS` limit and the `max_user_connections` system variable. Suppose that the global `max_user_connections` value is 10 and three accounts have individual resource limits specified as follows:

```
ALTER USER 'user1'@'localhost' WITH MAX_USER_CONNECTIONS 0;
ALTER USER 'user2'@'localhost' WITH MAX_USER_CONNECTIONS 5;
ALTER USER 'user3'@'localhost' WITH MAX_USER_CONNECTIONS 20;
```

`user1` has a connection limit of 10 (the global `max_user_connections` value) because it has a `MAX_USER_CONNECTIONS` limit of zero. `user2` and `user3` have connection limits of 5 and 20, respectively, because they have nonzero `MAX_USER_CONNECTIONS` limits.

The server stores resource limits for an account in the `user` table row corresponding to the account. The `max_questions`, `max_updates`, and `max_connections` columns store the per-hour limits, and the `max_user_connections` column stores the `MAX_USER_CONNECTIONS` limit. (See Section 4.2, “Grant Tables”.)

Resource-use counting takes place when any account has a nonzero limit placed on its use of any of the resources.

As the server runs, it counts the number of times each account uses resources. If an account reaches its limit on number of connections within the last hour, the server rejects further connections for the account until that hour is up. Similarly, if the account reaches its limit on the number of queries or updates, the server rejects further queries or updates until the hour is up. In all such cases, the server issues appropriate error messages.

Resource counting occurs per account, not per client. For example, if your account has a query limit of 50, you cannot increase your limit to 100 by making two simultaneous client connections to the server. Queries issued on both connections are counted together.

The current per-hour resource-use counts can be reset globally for all accounts, or individually for a given account:

- To reset the current counts to zero for all accounts, issue a `FLUSH USER_RESOURCES` statement. The counts also can be reset by reloading the grant tables (for example, with a `FLUSH PRIVILEGES` statement or a `mysqladmin reload` command).
- The counts for an individual account can be reset to zero by setting any of its limits again. Specify a limit value equal to the value currently assigned to the account.

Per-hour counter resets do not affect the `MAX_USER_CONNECTIONS` limit.

All counts begin at zero when the server starts. Counts do not carry over through server restarts.

For the `MAX_USER_CONNECTIONS` limit, an edge case can occur if the account currently has open the maximum number of connections permitted to it: A disconnect followed quickly by a connect can result

in an error (ER_TOO_MANY_USER_CONNECTIONS or ER_USER_LIMIT_REACHED) if the server has not fully processed the disconnect by the time the connect occurs. When the server finishes disconnect processing, another connection will once more be permitted.

5.5 Assigning Account Passwords

Required credentials for clients that connect to the MySQL server can include a password. This section describes how to assign passwords for MySQL accounts.

MySQL stores passwords in the user table in the mysql system database. Operations that assign or modify passwords are permitted only to users with the CREATE USER privilege, or, alternatively, privileges for the mysql database (INSERT privilege to create new accounts, UPDATE privilege to modify existing accounts). If the read_only system variable is enabled, use of account-modification statements such as CREATE USER or SET PASSWORD additionally requires the SUPER privilege.

The discussion here summarizes syntax only for the most common password-assignment statements. For complete details on other possibilities, see CREATE USER Syntax, ALTER USER Syntax, GRANT Syntax, and SET PASSWORD Syntax.

MySQL hashes passwords stored in the mysql.user table to obfuscate them. For most statements described here, MySQL automatically hashes the password specified. An exception is SET PASSWORD ... = PASSWORD('*auth_string*'), for which you use the PASSWORD() function explicitly to hash the password. There are also syntaxes for CREATE USER, ALTER USER, GRANT, and SET PASSWORD that permit hashed values to be specified literally; for details, see the descriptions of those statements.

MySQL uses plugins to perform client authentication; see Section 5.8, “Pluggable Authentication”. The authentication plugin associated with an account determines the algorithm used to hash passwords for that account.

To assign a password when you create a new account, use CREATE USER and include an IDENTIFIED BY clause:

```
mysql> CREATE USER 'jeffrey'@'localhost'
    -> IDENTIFIED BY 'mypass';
```

For this CREATE USER syntax, MySQL automatically hashes the password before storing it in the mysql.user table.

CREATE USER also supports syntax for specifying the account authentication plugin. See CREATE USER Syntax.

To assign or change a password for an existing account, use one of the following methods:

- Use the ALTER USER statement with an IDENTIFIED BY clause:

  ```
  mysql> ALTER USER 'jeffrey'@'localhost'
      -> IDENTIFIED BY 'mypass';
  ```

  If you are not connected as an anonymous user, you can change your own password without naming your own account literally:

  ```
  mysql> ALTER USER USER()
      -> IDENTIFIED BY 'mypass';
  ```

  For these ALTER USER syntaxes, MySQL automatically hashes the password before storing it in the mysql.user table.

  ALTER USER syntax for changing passwords is available as of MySQL 5.7.6.

- Use SET PASSWORD with the PASSWORD() function:

```
mysql> SET PASSWORD FOR
    -> 'jeffrey'@'localhost' = PASSWORD('mypass');
```

If you are not connected as an anonymous user, you can change your own password by omitting the `FOR` clause:

```
mysql> SET PASSWORD = PASSWORD('mypass');
```

The `PASSWORD()` function hashes the password using the hashing method determined by the value of the `old_passwords` system variable value. If `SET PASSWORD` rejects the hashed password value returned by `PASSWORD()` as not being in the correct format, it may be necessary to change `old_passwords` to change the hashing method. See SET PASSWORD Syntax.

> **Note**
>
> Use of `SET PASSWORD ... = PASSWORD('auth_string')` for password modification is deprecated as of MySQL 5.7.6. Use `ALTER USER` instead.

- Use `SET PASSWORD` without the `PASSWORD()` function:

  For this syntax, the meaning *differs in MySQL 5.7.6 and higher from earlier versions*:

  - As of MySQL 5.7.6, `SET PASSWORD` interprets the string as a cleartext string and hashes it appropriately for the account authentication plugin before storing it in the `mysql.user` account row.

    ```
    mysql> SET PASSWORD FOR
        -> 'jeffrey'@'localhost' = 'mypass';
    ```

  - Before MySQL 5.7.6, `SET PASSWORD` interprets the string as a hashed password value to be stored directly.

    ```
    mysql> SET PASSWORD FOR
        -> 'jeffrey'@'localhost' = '*6C8989366EAF75BB670AD8EA7A7FC1176A95CEF4';
    ```

    The string must be hashed in the format required by the account authentication plugin. A string not hashed appropriately causes client connections for the account to fail with an `Access denied` error.

- Use a `GRANT USAGE` statement at the global level (`ON *.*`) to change an account password without affecting the account's current privileges:

  ```
  mysql> GRANT USAGE ON *.* TO 'jeffrey'@'localhost'
      -> IDENTIFIED BY 'mypass';
  ```

  For this `GRANT` syntax, MySQL automatically hashes the password before storing it in the `mysql.user` table.

  > **Note**
  >
  > Use of `GRANT` for password modification is deprecated as of MySQL 5.7.6. Use `ALTER USER` instead.

- To change an account password from the command line, use the `mysqladmin` command:

  ```
  shell> mysqladmin -u user_name -h host_name password "new_password"
  ```

The account for which this command sets the password is the one with a `mysql.user` table row that matches *`user_name`* in the `User` column and the client host *from which you connect* in the `Host` column.

For password changes made using `mysqladmin`, MySQL automatically hashes the password before storing it in the `mysql.user` table.

5.6 Password Expiration Policy

MySQL enables database administrators to expire account passwords manually, and to establish a policy for automatic password expiration.

To expire a password manually, the database administrator uses the `ALTER USER` statement:

```
ALTER USER 'jeffrey'@'localhost' PASSWORD EXPIRE;
```

This operation marks the password expired in the corresponding `mysql.user` table row.

Automatic password expiration is available in MySQL 5.7.4 and later. The `mysql.user` table indicates for each account when its password was last changed, and the server automatically treats the password as expired at client connection time if it is past its permitted lifetime. This works with no explicit manual password expiration.

The `default_password_lifetime` system variable defines the global automatic password expiration policy. It applies to accounts that use MySQL built-in authentication methods (accounts that use an authentication plugin of `mysql_native_password`, `mysql_old_password`, or `sha256_password`).

The default `default_password_lifetime` value is 0, which disables automatic password expiration. If the value of `default_password_lifetime` is a positive integer *`N`*, it indicates the permitted password lifetime; passwords must be changed every *`N`* days.

> **Note**
>
> From MySQL 5.7.4 to 5.7.10, the default `default_password_lifetime` value is 360 (passwords must be changed approximately once per year). For those versions, be aware that, if you make no changes to the `default_password_lifetime` variable or to individual user accounts, all user passwords will expire after 360 days, and all user accounts will start running in restricted mode when this happens. Clients (which are effectively users) connecting to the server will then get an error indicating that the password must be changed: `ERROR 1820 (HY000): You must reset your password using ALTER USER statement before executing this statement.`
>
> However, this is easy to miss for clients that automatically connect to the server, such as connections made from scripts. To avoid having such clients suddenly stop working due to a password expiring, make sure to change the password expiration settings for those clients, like this:
>
> ```
> ALTER USER 'script'@'localhost' PASSWORD EXPIRE NEVER
> ```
>
> Alternatively, set the `default_password_lifetime` variable to `0`, thus disabling automatic password expiration for all users.

Examples:

- To establish a global policy that passwords have a lifetime of approximately six months, start the server with these lines in an option file:

```
[mysqld]
default_password_lifetime=180
```

- To establish a global policy such that passwords never expire, set `default_password_lifetime` to 0:

```
[mysqld]
default_password_lifetime=0
```

- `default_password_lifetime` can also be changed at runtime (this requires the `SUPER` privilege):

```
SET GLOBAL default_password_lifetime = 180;
SET GLOBAL default_password_lifetime = 0;
```

No matter the global policy, it can be overridden for individual accounts with `ALTER USER`:

- Require the password to be changed every 90 days:

```
ALTER USER 'jeffrey'@'localhost' PASSWORD EXPIRE INTERVAL 90 DAY;
```

- Disable password expiration:

```
ALTER USER 'jeffrey'@'localhost' PASSWORD EXPIRE NEVER;
```

- Defer to the global expiration policy:

```
ALTER USER 'jeffrey'@'localhost' PASSWORD EXPIRE DEFAULT;
```

These `ALTER USER` statements update the corresponding `mysql.user` table row.

When a client successfully connects, the server determines whether the account password is expired:

- The server checks whether the password has been manually expired and, if so, restricts the session.
- Otherwise, the server checks whether the password is past its lifetime according to the automatic password expiration policy. If so, the server considers the password expired and restricts the session.

A restricted client operates in “sandbox mode,”, which limits the operations permitted to the client (see Section 5.7, “Password Expiration and Sandbox Mode”). Operations performed by a restricted client result in an error until the user establishes a new account password:

```
mysql> SELECT 1;
ERROR 1820 (HY000): You must SET PASSWORD before executing this statement
mysql> ALTER USER USER() IDENTIFIED BY 'new_password';
Query OK, 0 rows affected (0.01 sec)
mysql> SELECT 1;
+---+
| 1 |
+---+
| 1 |
+---+
1 row in set (0.00 sec)
```

This restricted mode of operation permits `SET` statements, which is useful before MySQL 5.7.6 if `SET PASSWORD` must be used instead of `ALTER USER` and the account password has a hashing format that requires `old_passwords` to be set to a value different from its default.

It is possible for an administrative user to reset the account password, but any existing sessions for that account remain restricted. A client using the account must disconnect and reconnect before statements can be executed successfully.

> **Note**
>
> It is possible to “reset” a password by setting it to its current value. As a matter of good policy, it is preferable to choose a different password.

5.7 Password Expiration and Sandbox Mode

MySQL provides password-expiration capability to enable database administrators to expire account passwords and require users to reset their password. This section describes how password expiration works.

To expire an account password, use the `ALTER USER` statement. For example:

```
ALTER USER 'myuser'@'localhost' PASSWORD EXPIRE;
```

This statement modifies the row of the `mysql.user` table associated with the named account, setting the `password_expired` column to `'Y'`. This does not affect any current connections the account has open. For each subsequent connection that uses the account, the server either disconnects the client or handles the client in “sandbox mode,” in which the server permits to the client only those operations necessary to reset the expired password. The action taken by the server depends on both client and server settings.

If the server disconnects the client, it returns an `ER_MUST_CHANGE_PASSWORD_LOGIN` error:

```
shell> mysql -u myuser -p
Password: ******
ERROR 1862 (HY000): Your password has expired. To log in you must
change it using a client that supports expired passwords.
```

If the server puts the client in sandbox mode, these operations are permitted within the client session:

- The client can reset the account password with `ALTER USER` or `SET PASSWORD`. This modifies the row of the `mysql.user` table associated with the current account, setting the `password_expired` column to `'N'`. After the password has been reset, the server restores normal access for the session, as well as for subsequent connections that use the account.

  It is possible to “reset” a password by setting it to its current value. As a matter of good policy, it is preferable to choose a different password.

- The client can use `SET` statements, which is useful before MySQL 5.7.6 if `SET PASSWORD` must be used instead of `ALTER USER` and the account password has a hashing format that requires `old_passwords` to be set to a value different from its default.

For any operation not permitted within the session, the server returns an `ER_MUST_CHANGE_PASSWORD` error:

```
mysql> USE performance_schema;
ERROR 1820 (HY000): You must SET PASSWORD before executing this statement
mysql> SELECT 1;
ERROR 1820 (HY000): You must SET PASSWORD before executing this statement
```

For noninteractive invocations of the `mysql` client (for example, in batch mode), the server normally disconnects the client if the password is expired. To permit `mysql` to stay connected so that the password can be changed (using the statements just described), add the `--connect-expired-password` option to the `mysql` command.

As mentioned previously, whether the server disconnects an expired-password client or puts it in sandbox mode depends on a combination of client and server settings. The following discussion describes the relevant settings and how they interact.

On the client side, a given client indicates whether it can handle sandbox mode for expired passwords. For clients that use the C client library, there are two ways to do this:

- Pass the `MYSQL_OPT_CAN_HANDLE_EXPIRED_PASSWORDS` flag to `mysql_options()` prior to connecting:

  ```
  arg = 1;
  result = mysql_options(mysql,
                         MYSQL_OPT_CAN_HANDLE_EXPIRED_PASSWORDS, &arg);
  ```

  The `mysql` client enables `MYSQL_OPT_CAN_HANDLE_EXPIRED_PASSWORDS` if invoked interactively or the `--connect-expired-password` option is given.

- Pass the `CLIENT_CAN_HANDLE_EXPIRED_PASSWORDS` flag to `mysql_real_connect()` at connection time:

  ```
  mysql = mysql_real_connect(mysql,
                             host, user, password, "test",
                             port, unix_socket,
                             CLIENT_CAN_HANDLE_EXPIRED_PASSWORDS);
  ```

Other MySQL Connectors have their own conventions for indicating readiness to handle sandbox mode. See the relevant Connector documentation.

On the server side, if a client indicates that it can handle expired passwords, the server puts it in sandbox mode.

If a client does not indicate that it can handle expired passwords (or uses an older version of the client library that cannot so indicate), the server action depends on the value of the `disconnect_on_expired_password` system variable:

- If `disconnect_on_expired_password` is enabled (the default), the server disconnects the client with an `ER_MUST_CHANGE_PASSWORD_LOGIN` error.
- If `disconnect_on_expired_password` is disabled, the server puts the client in sandbox mode.

The preceding client and server settings apply only for accounts with expired passwords. If a client connects using a nonexpired password, the server handles the client normally.

5.8 Pluggable Authentication

When a client connects to the MySQL server, the server uses the user name provided by the client and the client host to select the appropriate account row from the `mysql.user` table. The server then authenticates the client, determining from the account row which authentication plugin applies for the client:

- If the account row specifies a plugin, the server invokes it to authenticate the user. If the server cannot find the plugin, an error occurs.
- If the account row specifies no plugin name, the server authenticates the account using either the `mysql_native_password` or `mysql_old_password` plugin, depending on whether the password hash value in the `Password` column used native hashing or the older pre-4.1 hashing method. Clients must match the password in the `Password` column of the account row. As of MySQL 5.7.2, the server requires the plugin value to be nonempty, and as of 5.7.5, support for `mysql_old_password` is removed.

The plugin returns a status to the server indicating whether the user is permitted to connect.

Pluggable authentication enables two important capabilities:

- **External authentication:** Pluggable authentication makes it possible for clients to connect to the MySQL server with credentials that are appropriate for authentication methods other than native authentication based on passwords stored in the `mysql.user` table. For example, plugins can be created to use external authentication methods such as PAM, Windows login IDs, LDAP, or Kerberos.
- **Proxy users:** If a user is permitted to connect, an authentication plugin can return to the server a user name different from the name of the connecting user, to indicate that the connecting user is a proxy for another user. While the connection lasts, the proxy user is treated, for purposes of access control, as having the privileges of a different user. In effect, one user impersonates another. For more information, see Section 5.9, “Proxy Users”.

Several authentication plugins are available in MySQL:

- Plugins that perform native authentication that matches the password against the `Password` column of the account row. The `mysql_native_password` plugin implements authentication based on the native password hashing method. The `mysql_old_password` plugin implements native authentication based on the older (pre-4.1) password hashing method (and is deprecated and removed in MySQL 5.7.5). See Section 7.1.1, “The Native Authentication Plugin”, and Section 7.1.2, “The Old Native Authentication Plugin”. Native authentication using `mysql_native_password` is the default for new accounts, unless the `default_authentication_plugin` system variable is set otherwise.
- A plugin that performs authentication using SHA-256 password hashing. This plugin matches the password against the `authentication_string` column of the account row. This is stronger encryption than that available with native authentication. See Section 7.1.4, “The SHA-256 Authentication Plugin”.
- A plugin prevents all client connections to any account that uses it. Use cases for such a plugin includes accounts that must be able to execute stored programs and views with elevated privileges without exposing those privileges to ordinary users, and proxy accounts that should never permit direct login. See Section 7.1.7, “The No-Login Authentication Plugin”.
- A client-side plugin that sends the password to the server without hashing or encryption. This plugin can be used by server-side plugins that require access to the password exactly as provided by the client user. See Section 7.1.8, “The Cleartext Client-Side Authentication Plugin”.
- A plugin that authenticates clients that connect from the local host through the Unix socket file. See Section 7.1.9, “The Socket Peer-Credential Authentication Plugin”.
- A test plugin that authenticates using MySQL native authentication. This plugin is intended for testing and development purposes, and as an example of how to write an authentication plugin. See Section 7.1.10, “The Test Authentication Plugin”.

> **Note**
>
> For information about current restrictions on the use of pluggable authentication, including which connectors support which plugins, see Restrictions on Pluggable Authentication.
>
> Third-party connector developers should read that section to determine the extent to which a connector can take advantage of pluggable authentication capabilities and what steps to take to become more compliant.

If you are interested in writing your own authentication plugins, see Writing Authentication Plugins.

Authentication Plugin Usage Instructions

This section provides general instructions for installing and using authentication plugins.

In general, pluggable authentication uses corresponding plugins on the server and client sides, so you use a given authentication method like this:

- On the server host, install the library containing the appropriate server plugin, if necessary, so that the server can use it to authenticate client connections. Similarly, on each client host, install the library containing the appropriate client plugin for use by client programs.
- Create MySQL accounts that specify use of the plugin for authentication.
- When a client connects, the server plugin tells the client program which client plugin to use for authentication.

The instructions here use an example authentication plugin included in MySQL distributions (see Section 7.1.10, “The Test Authentication Plugin”). The procedure is similar for other authentication plugins; substitute the appropriate plugin and file names.

The example authentication plugin has these characteristics:

- The server-side plugin name is `test_plugin_server`.
- The client-side plugin name is `auth_test_plugin`.
- Both plugins are located in the shared library file named `auth_test_plugin.so` in the plugin directory (the directory named by the `plugin_dir` system variable). The file name suffix might differ on your system.

Install and use the example authentication plugin as follows:

1. Make sure that the plugin library is installed on the server and client hosts.
2. Install the server-side test plugin at server startup or at runtime:
   - To install the plugin at startup, use the `--plugin-load` option. With this plugin-loading method, the option must be given each time you start the server. For example, use these lines in a `my.cnf` option file:

     ```
     [mysqld]
     plugin-load=test_plugin_server=auth_test_plugin.so
     ```

   - To install the plugin at runtime, use the `INSTALL PLUGIN` statement:

     ```
     INSTALL PLUGIN test_plugin_server SONAME 'auth_test_plugin.so';
     ```

     This installs the plugin permanently and need be done only once.
3. Verify that the plugin is installed. For example, use `SHOW PLUGINS`:

   ```
   mysql> SHOW PLUGINS\G
   ...
   *************************** 21. row ***************************
      Name: test_plugin_server
    Status: ACTIVE
      Type: AUTHENTICATION
   Library: auth_test_plugin.so
   License: GPL
   ```

   For other ways to check the plugin, see Obtaining Server Plugin Information.
4. To specify that a MySQL user must be authenticated using a specific server plugin, name the plugin in the `IDENTIFIED WITH` clause of the `CREATE USER` statement that creates the user:

   ```
   ```

```
CREATE USER 'testuser'@'localhost' IDENTIFIED WITH test_plugin_server;
```

5. Connect to the server using a client program. The test plugin authenticates the same way as native MySQL authentication, so provide the usual `--user` and `--password` options that you normally use to connect to the server. For example:

   ```
   shell> mysql --user=your_name --password=your_pass
   ```

   For connections by `testuser`, the server sees that the account must be authenticated using the server-side plugin named `test_plugin_server` and communicates to the client program which client-side plugin it must use—in this case, `auth_test_plugin`.

   In the case that the account uses the authentication method that is the default for both the server and the client program, the server need not communicate to the client which plugin to use, and a round trip in client/server negotiation can be avoided. This is true for accounts that use native MySQL authentication (`mysql_native_password`).

   The `--default-auth=plugin_name` option can be specified on the `mysql` command line as a hint about which client-side plugin the program can expect to use, although the server will override this if the user account requires a different plugin.

   If the client program does not find the plugin, specify a `--plugin-dir=dir_name` option to indicate where the plugin is located.

   > **Note**
   >
   > If you start the server with the `--skip-grant-tables` option, authentication plugins are not used even if loaded because the server performs no client authentication and permits any client to connect. Because this is insecure, you might want to use `--skip-grant-tables` in conjunction with `--skip-networking` to prevent remote clients from connecting.

5.9 Proxy Users

Authentication to the MySQL server occurs by means of authentication plugins. The plugin that authenticates a given connection may request that the connecting (external) user be treated as a different user for privilege-checking purposes. This enables the external user to be a proxy for the second user; that is, to have the privileges of the second user:

- The external user is a “proxy user” (a user who can impersonate or become known as another user).
- The second user is a “proxied user” (a user whose identity can be taken on by a proxy user).

This section describes how the proxy user capability works. For general information about authentication plugins, see Section 5.8, “Pluggable Authentication”. For information about specific plugins, see Section 7.1, “Authentication Plugins”. For information about writing authentication plugins that support proxy users, see Implementing Proxy User Support in Authentication Plugins.

For proxying to occur for a given authentication plugin, these conditions must be satisfied:

- A proxy user account must be set up to be authenticated by the plugin. Use the `CREATE USER` statement to associate an account with a plugin, or `ALTER USER` to change its plugin.
- For a client connecting to the proxy account to be treated as a proxy user, the plugin must return a user name different from the client user name, to indicate the user name for the proxied account.
- The proxy user account must have the `PROXY` privilege for the proxied account. Use the `GRANT` statement for this.

The proxy mechanism permits mapping only the client user name to the proxied user name. There is no provision for mapping host names. When a connecting client matches a proxy account, the server

attempts to find a match for a proxied account using the user name returned by the authentication plugin and the host name of the proxy account.

Consider the following definitions:

```
-- create proxy user
CREATE USER 'employee_ext'@'localhost'
  IDENTIFIED WITH my_auth_plugin AS 'my_auth_string';
-- create proxied user
CREATE USER 'employee'@'localhost'
  IDENTIFIED BY 'employee_pass';
-- grant PROXY privilege for proxy user to proxied user
GRANT PROXY
  ON 'employee'@'localhost'
  TO 'employee_ext'@'localhost';
```

When a client connects as `employee_ext` from the local host, MySQL uses `my_auth_plugin` to perform authentication. Suppose that `my_auth_plugin` returns a user name of `employee` to the server, based on the content of `'my_auth_string'` and perhaps by consulting some external authentication system. The name `employee` differs from `employee_ext`, so returning `employee` serves as a request to the server to treat the `employee_ext` client, for purposes of privilege checking, as the `employee` local user.

In this case, `employee_ext` is the proxy user and `employee` is the proxied user.

The server verifies that proxy authentication for `employee` is possible for the `employee_ext` user by checking whether `employee_ext` (the proxy user) has the `PROXY` privilege for `employee` (the proxied user). If this privilege has not been granted, an error occurs.

When proxying occurs, the `USER()` and `CURRENT_USER()` functions can be used to see the difference between the connecting user (the proxy user) and the account whose privileges apply during the current session (the proxied user). For the example just described, those functions return these values:

```
mysql> SELECT USER(), CURRENT_USER();
+------------------------+--------------------+
| USER()                 | CURRENT_USER()     |
+------------------------+--------------------+
| employee_ext@localhost | employee@localhost |
+------------------------+--------------------+
```

In the `CREATE USER` statement that creates the proxy user account, the `IDENTIFIED WITH` clause that names the authentication plugin is optionally followed by an `AS 'auth_string'` clause specifying a string that the server passes to the plugin when the user connects. If present, the string provides information that helps the plugin determine how to map the external client user name to a proxied user name. It is up to each plugin whether it requires the `AS` clause. If so, the format of the authentication string depends on how the plugin intends to use it. Consult the documentation for a given plugin for information about the authentication string values it accepts.

Granting the Proxy Privilege

The `PROXY` privilege is needed to enable an external user to connect as and have the privileges of another user. To grant this privilege, use the `GRANT` statement. For example:

```
GRANT PROXY ON 'proxied_user' TO 'proxy_user';
```

The statement creates a row in the `mysql.proxies_priv` grant table.

At connection time, *`proxy_user`* must represent a valid externally authenticated MySQL user, and *`proxied_user`* must represent a valid locally authenticated user. Otherwise, the connection attempt fails.

The corresponding REVOKE syntax is:

```
REVOKE PROXY ON 'proxied_user' FROM 'proxy_user';
```

MySQL GRANT and REVOKE syntax extensions work as usual. For example:

```
GRANT PROXY ON 'a' TO 'b', 'c', 'd';
GRANT PROXY ON 'a' TO 'd' WITH GRANT OPTION;
GRANT PROXY ON 'a' TO ''@'';
REVOKE PROXY ON 'a' FROM 'b', 'c', 'd';
```

In the preceding example, ''@'' is the default proxy user and means “any user.” Default proxy user are discussed in Default Proxy Users.

The PROXY privilege can be granted in these cases:

- By a user that has GRANT PROXY ... WITH GRANT OPTION for *proxied_user*.
- By *proxied_user* for itself: The value of USER() must exactly match CURRENT_USER() and *proxied_user*, for both the user name and host name parts of the account name.

The initial root account created during MySQL installation has the PROXY ... WITH GRANT OPTION privilege for ''@'', that is, for all users and all hosts. This enables root to set up proxy users, as well as to delegate to other accounts the authority to set up proxy users. For example, root can do this:

```
CREATE USER 'admin'@'localhost' IDENTIFIED BY 'test';
GRANT PROXY ON ''@'' TO 'admin'@'localhost' WITH GRANT OPTION;
```

Those statements create an admin user that can manage all GRANT PROXY mappings. For example, admin can do this:

```
GRANT PROXY ON sally TO joe;
```

Default Proxy Users

To specify that some or all users should connect using a given authentication plugin, create a “blank” MySQL user, associate it with that plugin for authentication, and let the plugin return the real authenticated user name (if different from the blank user). For example, suppose that there exists a plugin named ldap_auth that implements LDAP authentication and maps connecting users onto either a developer or manager account. To set up proxying of users onto these accounts, use the following statements:

```
-- create default proxy user
CREATE USER ''@'' IDENTIFIED WITH ldap_auth AS 'O=Oracle, OU=MySQL';
-- create proxied users
CREATE USER 'developer'@'localhost' IDENTIFIED BY 'developer_pass';
CREATE USER 'manager'@'localhost' IDENTIFIED BY 'manager_pass';
-- grant PROXY privilege for default proxy user to proxied users
GRANT PROXY ON 'manager'@'localhost' TO ''@'';
GRANT PROXY ON 'developer'@'localhost' TO ''@'';
```

Now assume that a client tries to connect as follows:

```
mysql --user=myuser --password='myuser_pass' ...
```

The server will not find myuser defined as a MySQL user. But because there is a blank user account (''@''), that matches the client user name and host name, the server authenticates the client against that account: The server invokes the ldap_auth authentication plugin and passes myuser and myuser_pass to it as the user name and password.

If the `ldap_auth` plugin finds in the LDAP directory that `myuser_pass` is not the correct password for `myuser`, authentication fails and the server rejects the connection.

If the password is correct and `ldap_auth` finds that `myuser` is a developer, it returns the user name `developer` to the MySQL server, rather than `myuser`. Returning a user name different from the client user name of `myuser` signals to the server that it should treat `myuser` as a proxy. The server verifies that `''@''` can authenticate as `developer` (because it has the `PROXY` privilege to do so) and accepts the connection. The session proceeds with `myuser` having the privileges of `developer`, the proxied user. (These privileges should be set up by the DBA using `GRANT` statements, not shown.) The `USER()` and `CURRENT_USER()` functions return these values:

```
mysql> SELECT USER(), CURRENT_USER();
+------------------+--------------------+
| USER()           | CURRENT_USER()     |
+------------------+--------------------+
| myuser@localhost | developer@localhost |
+------------------+--------------------+
```

If the plugin instead finds in the LDAP directory that `myuser` is a manager, it returns `manager` as the user name and the session proceeds with `myuser` having the privileges of `manager`.

```
mysql> SELECT USER(), CURRENT_USER();
+------------------+------------------+
| USER()           | CURRENT_USER()   |
+------------------+------------------+
| myuser@localhost | manager@localhost |
+------------------+------------------+
```

For simplicity, external authentication cannot be multilevel: Neither the credentials for `developer` nor those for `manager` are taken into account in the preceding example. However, they are still used if a client tries to connect and authenticate directly as the `developer` or `manager` account, which is why those accounts should be assigned passwords.

Default Proxy User and Anonymous User Conflicts

If you intend to create a default proxy user, check for other existing “match any user” accounts that take precedence over the default proxy user and thus prevent that user from working as intended.

In the preceding discussion, the default proxy user account has `''` in the host part, which matches any host. If you set up a default proxy user, take care to also check whether nonproxy accounts exist with the same user part and `'%'` in the host part, because `'%'` also matches any host, but has precedence over `''` by the rules that the server uses to sort account rows internally (see Section 4.4, “Access Control, Stage 1: Connection Verification”).

Suppose that a MySQL installation includes these two accounts:

```
-- create default proxy user
CREATE USER ''@''
  IDENTIFIED WITH some_plugin AS 'some_auth_string';
-- create anonymous user
CREATE USER ''@'%'
  IDENTIFIED BY 'some_password';
```

The first account (`''@''`) is intended as the default proxy user, used to authenticate connections for users who do not otherwise match a more-specific account. The second account (`''@'%'`) is an anonymous-user account, which might have been created, for example, to enable users without their own account to connect anonymously.

Both accounts have the same user part (`''`), which matches any user. And each account has a host part that matches any host. Nevertheless, there is a priority in account matching for connection

attempts because the matching rules sort a host of `'%'` ahead of `''`. For accounts that do not match any more-specific account, the server attempts to authenticate them against `''@'%'` (the anonymous user) rather than `''@''` (the default proxy user). The result is that the default proxy account is never used.

To avoid this problem, use one of the following strategies:

- Remove the anonymous account so that it does not conflict with the default proxy user. This might be a good idea anyway if you want to associate every connection with a named user.
- Use a more-specific default proxy user that matches ahead of the anonymous user. For example, to permit only `localhost` proxy connections, use `''@'localhost'`:

  ```
  CREATE USER ''@'localhost'
    IDENTIFIED WITH some_plugin AS 'some_auth_string';
  ```

  In addition, modify any `GRANT PROXY` statements to name `''@'localhost'` rather than `''@''` as the proxy user.

  Be aware that this strategy prevents anonymous-user connections from `localhost`.
- Create multiple proxy users, one for local connections and one for “everything else” (remote connections). This can be useful particularly when local users should have different privileges from remote users.

  Create the proxy users:

  ```
  -- create proxy user for local connections
  CREATE USER ''@'localhost'
    IDENTIFIED WITH some_plugin AS 'some_auth_string';
  -- create proxy user for remote connections
  CREATE USER ''@'%'
    IDENTIFIED WITH some_plugin AS 'some_auth_string';
  ```

  Create the proxied users:

  ```
  -- create proxied user for local connections
  CREATE USER 'developer'@'localhost'
    IDENTIFIED BY 'some_password';
  -- create proxied user for remote connections
  CREATE USER 'developer'@'%'
    IDENTIFIED BY 'some_password';
  ```

  Grant the proxy privilege to each proxy user for the corresponding proxied user:

  ```
  GRANT PROXY ON 'developer'@'localhost' TO ''@'localhost';
  GRANT PROXY ON 'developer'@'%' TO ''@'%';
  ```

  Finally, grant appropriate privileges to the local and remote proxied users (not shown).

  Assume that the `some_plugin`/`'some_auth_string'` combination causes `some_plugin` to map the client user name to `developer`. Local connections match the `''@'localhost'` proxy user, which maps to the `'developer'@'localhost'` proxied user. Remote connections match the `''@'%'` proxy user, which maps to the `'developer'@'%'` proxied user.

Server Support for Proxy User Mapping

Some authentication plugins implement proxy user mapping for themselves. As of MySQL 5.7.7, the MySQL server itself can map proxy users according to granted proxy privileges. If the `check_proxy_users` system variable is enabled, the server performs proxy user mapping for any authentication plugins that request it:

- By default, `check_proxy_users` is disabled, so the server performs no proxy user mapping even for authentication plugins that request it.
- With `check_proxy_users` enabled, it may also be necessary to enable plugin-specific system variables to take advantage of server proxy user mapping support:
  - For the `mysql_native_password` plugin, enable `mysql_native_password_proxy_users`.
  - For the `sha256_password` plugin, enable `sha256_password_proxy_users`.

Proxy user mapping performed by the server is subject to some restrictions:

- The server will not proxy to or from an anonymous user, even if the associated `PROXY` privilege is granted.
- When a single account has been granted proxy privileges for more than one account, server proxy user mapping is nondeterministic. Therefore, granting proxy privileges for multiple accounts to a single account is discouraged.

Proxy User System Variables

Two system variables help trace the proxy login process:

- `proxy_user`: This value is `NULL` if proxying is not used. Otherwise, it indicates the proxy user account. For example, if a client authenticates through the `''@''` proxy account, this variable is set as follows:

```
mysql> SELECT @@proxy_user;
+--------------+
| @@proxy_user |
+--------------+
| ''@''        |
+--------------+
```

- `external_user`: Sometimes the authentication plugin may use an external user to authenticate to the MySQL server. For example, when using Windows native authentication, a plugin that authenticates using the windows API does not need the login ID passed to it. However, it still uses a Windows user ID to authenticate. The plugin may return this external user ID (or the first 512 UTF-8 bytes of it) to the server using the `external_user` read-only session variable. If the plugin does not set this variable, its value is `NULL`.

5.10 User Account Locking

As of version 5.7.6, MySQL supports locking and unlocking user accounts using the `ACCOUNT LOCK` and `ACCOUNT UNLOCK` clauses for the `CREATE USER` and `ALTER USER` statements:

- When used with `CREATE USER`, these clauses specify the initial locking state for a new account. In the absence of either clause, the account is created in an unlocked state.
- When used with `ALTER USER`, these clauses specify the new locking state for an existing account. In the absence of either clause, the account locking state remains unchanged.

Account locking state is recorded in the `account_locked` column of the `mysql.user` table. The output from `SHOW CREATE USER` indicates whether an account is locked or unlocked.

If a client attempts to connect to a locked account, the attempt fails. The server increments the `Locked_connects` status variable that indicates the number of attempts to connect to a locked account, returns an `ER_ACCOUNT_HAS_BEEN_LOCKED` error, and writes a message to the error log:

```
Access denied for user 'user_name'@'host_name'.
```

```
Account is locked.
```

Locking an account does not affect being able to connect using a proxy user that assumes the identity of the locked account. It also does not affect the ability to execute stored programs or views that have a `DEFINER` clause naming the locked account. That is, the ability to use a proxied account or stored programs or views is not affected by locking the account.

The account-locking capability depends on the presence of the `account_locked` column in the `mysql.user` table. For upgrades to MySQL 5.7.6 and later from older versions, run `mysql_upgrade` to ensure that this column exists. For nonupgraded installations that have no `account_locked` column, the server treats all accounts as unlocked, and using the `ACCOUNT LOCK` or `ACCOUNT UNLOCK` clauses produces an error.

5.11 SQL-Based MySQL Account Activity Auditing

Applications can use the following guidelines to perform SQL-based auditing that ties database activity to MySQL accounts.

MySQL accounts correspond to rows in the `mysql.user` table. When a client connects successfully, the server authenticates the client to a particular row in this table. The `User` and `Host` column values in this row uniquely identify the account and correspond to the *`'user_name'@'host_name'`* format in which account names are written in SQL statements.

The account used to authenticate a client determines which privileges the client has. Normally, the `CURRENT_USER()` function can be invoked to determine which account this is for the client user. Its value is constructed from the `User` and `Host` columns of the `user` table row for the account.

However, there are circumstances under which the `CURRENT_USER()` value corresponds not to the client user but to a different account. This occurs in contexts when privilege checking is not based the client's account:

- Stored routines (procedures and functions) defined with the `SQL SECURITY DEFINER` characteristic
- Views defined with the `SQL SECURITY DEFINER` characteristic
- Triggers and events

In those contexts, privilege checking is done against the `DEFINER` account and `CURRENT_USER()` refers to that account, not to the account for the client who invoked the stored routine or view or who caused the trigger to activate. To determine the invoking user, you can call the `USER()` function, which returns a value indicating the actual user name provided by the client and the host from which the client connected. However, this value does not necessarily correspond directly to an account in the `user` table, because the `USER()` value never contains wildcards, whereas account values (as returned by `CURRENT_USER()`) may contain user name and host name wildcards.

For example, a blank user name matches any user, so an account of `''@'localhost'` enables clients to connect as an anonymous user from the local host with any user name. In this case, if a client connects as `user1` from the local host, `USER()` and `CURRENT_USER()` return different values:

```
mysql> SELECT USER(), CURRENT_USER();
+----------------+----------------+
| USER()         | CURRENT_USER() |
+----------------+----------------+
| user1@localhost | @localhost     |
+----------------+----------------+
```

The host name part of an account can contain wildcards, too. If the host name contains a `'%'` or `'_'` pattern character or uses netmask notation, the account can be used for clients connecting from multiple hosts and the `CURRENT_USER()` value will not indicate which one. For example, the account `'user2'@'%.example.com'` can be used by `user2` to connect from any host in the `example.com`

domain. If `user2` connects from `remote.example.com`, `USER()` and `CURRENT_USER()` return different values:

```
mysql> SELECT USER(), CURRENT_USER();
+--------------------------+--------------------+
| USER()                   | CURRENT_USER()     |
+--------------------------+--------------------+
| user2@remote.example.com | user2@%.example.com |
+--------------------------+--------------------+
```

If an application must invoke `USER()` for user auditing (for example, if it does auditing from within triggers) but must also be able to associate the `USER()` value with an account in the `user` table, it is necessary to avoid accounts that contain wildcards in the `User` or `Host` column. Specifically, do not permit `User` to be empty (which creates an anonymous-user account), and do not permit pattern characters or netmask notation in `Host` values. All accounts must have a nonempty `User` value and literal `Host` value.

With respect to the previous examples, the `''@'localhost'` and `'user2'@'%.example.com'` accounts should be changed not to use wildcards:

```
RENAME USER ''@'localhost' TO 'user1'@'localhost';
RENAME USER 'user2'@'%.example.com' TO 'user2'@'remote.example.com';
```

If `user2` must be able to connect from several hosts in the `example.com` domain, there should be a separate account for each host.

To extract the user name or host name part from a `CURRENT_USER()` or `USER()` value, use the `SUBSTRING_INDEX()` function:

```
mysql> SELECT SUBSTRING_INDEX(CURRENT_USER(),'@',1);
+--------------------------------------+
| SUBSTRING_INDEX(CURRENT_USER(),'@',1) |
+--------------------------------------+
| user1                                |
+--------------------------------------+
mysql> SELECT SUBSTRING_INDEX(CURRENT_USER(),'@',-1);
+---------------------------------------+
| SUBSTRING_INDEX(CURRENT_USER(),'@',-1) |
+---------------------------------------+
| localhost                             |
+---------------------------------------+
```

Chapter 6 Using Secure Connections

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With an unencrypted connection between the MySQL client and the server, someone with access to the network could watch all your traffic and inspect the data being sent or received between client and server.

When you must move information over a network in a secure fashion, an unencrypted connection is unacceptable. To make any kind of data unreadable, use encryption. Encryption algorithms must include security elements to resist many kinds of known attacks such as changing the order of encrypted messages or replaying data twice.

MySQL supports secure (encrypted) connections between clients and the server using the TLS (Transport Layer Security) protocol. TLS is sometimes referred to as SSL (Secure Sockets Layer) but MySQL does not actually use the SSL protocol for secure connections because it provides weak encryption (see Section 6.3, “Secure Connection Protocols and Ciphers”).

TLS uses encryption algorithms to ensure that data received over a public network can be trusted. It has mechanisms to detect data change, loss, or replay. TLS also incorporates algorithms that provide identity verification using the X509 standard.

X509 makes it possible to identify someone on the Internet. In basic terms, there should be some entity called a “Certificate Authority” (or CA) that assigns electronic certificates to anyone who needs them. Certificates rely on asymmetric encryption algorithms that have two encryption keys (a public key and a secret key). A certificate owner can present the certificate to another party as proof of identity. A certificate consists of its owner's public key. Any data encrypted using this public key can be decrypted only using the corresponding secret key, which is held by the owner of the certificate.

MySQL can be compiled for secure-connection support using OpenSSL or yaSSL. For a comparison of the two packages, see Section 6.1, “OpenSSL Versus yaSSL” For information about the encryption protocols and ciphers each package supports, see Section 6.3, “Secure Connection Protocols and Ciphers”.

MySQL performs encryption on a per-connection basis, and use of encryption for a given user can be optional or mandatory. This enables you to choose an encrypted or unencrypted connection according to the requirements of individual applications. For information on how to require users to use encrypted connections, see the discussion of the `REQUIRE` clause of the `CREATE USER` statement in CREATE USER Syntax. See also the description of the `require_secure_transport` system variable at Server System Variables

Several improvements were made to secure-connection support in MySQL 5.7. The following timeline summarizes the changes:

- 5.7.3: On the client side, an explicit `--ssl` option is no longer advisory but prescriptive. Given a server enabled to support secure connections, a client program can require a secure conection by

specifying only the `--ssl` option. The connection attempt fails if a secure connection cannot be established. Other `--ssl-xxx` options on the client side mean that a secure connection is advisory (the connection attempt falls back to an unencrypted connection if a secure connection cannot be established).

- 5.7.5: The server-side `--ssl` option value is enabled by default.

  For servers compiled using OpenSSL, the `auto_generate_certs` and `sha256_password_auto_generate_rsa_keys` system variables are available to enable autogeneration and autodiscovery of SSL/RSA certificate and key files at startup. For certificate and key autodiscovery, if `--ssl` is enabled and other `--ssl-xxx` options are not given to configure secure connections explicitly, the server attempts to enable support for secure connections automatically at startup if it discovers the requisite certificate and key files in the data directory.

- 5.7.6: The `mysql_ssl_rsa_setup` utility is available to make it easier to manually generate SSL/RSA certificate and key files. Autodiscovery of SSL/RSA files at startup is expanded to apply to all servers, whether compiled using OpenSSL or yaSSL. (This means that `auto_generate_certs` need not be enabled for autodiscovery to occur.)

  If the server discovers at startup that the CA certificate is self-signed, it writes a warning to its error log. (The certificate will be self-signed if created automatically by the server or manually using `mysql_ssl_rsa_setup`.)

- 5.7.7: The C client library attempts to establish a secure connection by default whenever the server supports secure connections. This affects client programs as follows:

  - In the absence of an `--ssl` option, the client falls back to an unencrypted connection if a secure connection cannot be established.
  - To require a secure connection and fail if one cannot be established, invoke the client with an explicit `--ssl` option or a synonym (`--ssl=1`, `--enable-ssl`).
  - To use an unencrypted connection, invoke the client with an `--ssl=0` option or a synonym (`--skip-ssl`, `--disable-ssl`).

  This change also affects subsequent releases of MySQL Connectors that are based on the C client library: Connector/C, Connector/C++, and Connector/ODBC.

- 5.7.8: The `require_secure_transport` system variable is available to control whether client connections to the server must use some form of secure transport.

- 5.7.10: TLS protocol support is extended from TLSv1 to also include TLSv1.1 and TLSv1.2. The `tls_version` system variable on the server side and `--tls-version` option on the client side enable the level of support to be selected. See Section 6.3, “Secure Connection Protocols and Ciphers”.

- 5.7.11: MySQL client programs support an `--ssl-mode` option that enables you to specify the security state of the connection to the server. The `--ssl-mode` option comprises the capabilities of the client-side `--ssl` and `--ssl-verify-server-cert` options. Consequently, both of those options are deprecated, to be removed in MySQL 8.0.

Secure connections are available through the MySQL C API using the `mysql_ssl_set()` and `mysql_options()` functions. See mysql_ssl_set(), and mysql_options().

Replication uses the C API, so secure connections can be used between master and slave servers. See Setting Up Replication to Use Secure Connections.

It is also possible to connect securely from within an SSH connection to the MySQL server host. For an example, see Section 6.7, “Connecting to MySQL Remotely from Windows with SSH”.

6.1 OpenSSL Versus yaSSL

MySQL can be compiled using OpenSSL or yaSSL, both of which enable secure conections based on the OpenSSL API:

- MySQL Enterprise Edition binary distributions are compiled using OpenSSL. It is not possible to use yaSSL with MySQL Enterprise Edition.
- MySQL Community Edition binary distributions are compiled using yaSSL.
- MySQL Community Edition source distributions can be compiled using either OpenSSL or yaSSL (see Section 6.2, “Building MySQL with Support for Secure Connections”).

OpenSSL and yaSSL offer the same basic functionality, but MySQL distributions compiled using OpenSSL have additional features:

- OpenSSL supports a wider range of encryption ciphers from which to choose for the `--ssl-cipher` option. OpenSSL supports the `--ssl-capath`, `--ssl-crl`, and `--ssl-crlpath` options. See Section 6.5, “Command Options for Secure Connections”.
- Accounts that authenticate using the `sha256_password` plugin can use RSA key files for secure password exchange over unencrypted connections. See Section 7.1.4, “The SHA-256 Authentication Plugin”.
- The server can automatically generate missing SSL and RSA certificate and key files at startup. See Section 6.6.1, “Creating SSL and RSA Certificates and Keys using MySQL”.
- OpenSSL supports more encryption modes for the `AES_ENCRYPT()` and `AES_DECRYPT()` functions. See Encryption and Compression Functions

Certain OpenSSL-related system and status variables are present only if MySQL was compiled using OpenSSL:

- `auto_generate_certs` (added in MySQL 5.7.5)
- `sha256_password_auto_generate_rsa_keys` (added in MySQL 5.7.5)
- `sha256_password_private_key_path`
- `sha256_password_public_key_path`
- `Rsa_public_key`

To determine whether your server was compiled using OpenSSL, test the existence of any of those variables. For example, this statement returns a row if OpenSSL was used and an empty result if yaSSL was used:

```
SHOW STATUS LIKE 'Rsa_public_key';
```

Such tests assume that your server version is not older than the first appearance of the variable tested. For example, you cannot test for `auto_generate_certs` before MySQL 5.7.6.

6.2 Building MySQL with Support for Secure Connections

To use SSL connections between the MySQL server and client programs, your system must support either OpenSSL or yaSSL:

- MySQL Enterprise Edition binary distributions are compiled using OpenSSL. It is not possible to use yaSSL with MySQL Enterprise Edition.
- MySQL Community Edition binary distributions are compiled using yaSSL.

- MySQL Community Edition source distributions can be compiled using either OpenSSL or yaSSL.

If you compile MySQL from a source distribution, `CMake` configures the distribution to use yaSSL by default. To compile using OpenSSL instead, use this procedure:

1. Ensure OpenSSL 1.0.1 or higher is installed on your system. To obtain OpenSSL, visit http://www.openssl.org.

   If the installed OpenSSL version is lower than 1.0.1, `CMake` produces an error at MySQL configuration time.

2. To use OpenSSL, add the `-DWITH_SSL=system` option to the `CMake` command you normally use to configure the MySQL source distribution. For example:

   ```
   shell> cmake . -DWITH_SSL=system
   ```

   That command configures the distribution to use the installed OpenSSL library. Alternatively, to explicitly specify the path name to the OpenSSL installation, use the following syntax. This can be useful if you have multiple versions of OpenSSL installed, to prevent `CMake` from choosing the wrong one:

   ```
   shell> cmake . -DWITH_SSL=path_name
   ```

   See MySQL Source-Configuration Options.

3. Compile and install the distribution.

To check whether a `mysqld` server supports secure connections, examine the value of the `have_ssl` system variable:

```
mysql> SHOW VARIABLES LIKE 'have_ssl';
+---------------+-------+
| Variable_name | Value |
+---------------+-------+
| have_ssl      | YES   |
+---------------+-------+
```

If the value is `YES`, the server supports secure connections. If the value is `DISABLED`, the server is capable of supporting secure connections but was not started with the appropriate `--ssl-xxx` options to enable secure connections to be used; see Section 6.4, “Configuring MySQL to Use Secure Connections”.

To determine whether a server was compiled using OpenSSL or yaSSL, check the existence of any of the system or status variables that are present only for OpenSSL. See Section 6.1, “OpenSSL Versus yaSSL”

6.3 Secure Connection Protocols and Ciphers

To determine which encryption protocol and cipher are in use for an encrypted connection, use the following statements to check the values of the `Ssl_version` and `Ssl_cipher` status variables:

```
mysql> SHOW SESSION STATUS LIKE 'Ssl_version';
+---------------+-------+
| Variable_name | Value |
+---------------+-------+
| Ssl_version   | TLSv1 |
+---------------+-------+
mysql> SHOW SESSION STATUS LIKE 'Ssl_cipher';
+---------------+--------------------------+
| Variable_name | Value                    |
```

```
+---------------+---------------------------+
| Ssl_cipher    | DHE-RSA-AES128-GCM-SHA256 |
+---------------+---------------------------+
```

If the connection is not encrypted, both variables have an empty value.

MySQL supports encrypted connections using TLS protocols:

- When compiled using OpenSSL 1.0.1 or higher, MySQL supports the TLSv1, TLSv1.1, and TLSv1.2 protocols.
- When compiled using the bundled version of yaSSL, MySQL supports the TLSv1 and TLSv1.1 protocols.

The value of the `tls_version` system variable determines which protocols the server is permitted to use from those that are available. The `tls_version` value is a comma-separated list containing one or more of these protocols (not case sensitive): TLSv1, TLSv1.1, TLSv1.2. By default, this variable lists all protocols supported by the SSL library used to compile MySQL (`TLSv1,TLSv1.1,TLSv1.2` for OpenSSL, `TLSv1,TLSv1.1` for yaSSL). To determine the value of `tls_version` at runtime, use this statement:

```
mysql> SHOW GLOBAL VARIABLES LIKE 'tls_version';
+---------------+-----------------------+
| Variable_name | Value                 |
+---------------+-----------------------+
| tls_version   | TLSv1,TLSv1.1,TLSv1.2 |
+---------------+-----------------------+
```

To change the value of `tls_version`, set it at server startup. For example, to prohibit connections that use the less-secure TLSv1 protocol, use these lines in the server `my.cnf` file:

```
[mysqld]
tls_version=TLSv1.1,TLSv1.2
```

To be even more restrict and permit only TLSv1.2 connections, set `tls_version` like this (assuming that your server is compiled using OpenSSL because yaSSL does not support TLSv1.2):

```
[mysqld]
tls_version=TLSv1.2
```

For client programs, the `--tls-version` option enables specifying the TLS protocols permitted per client invocation. The value format is the same as for `tls_version`.

By default, MySQL attempts to use the highest TLS protocol version available, depending on which SSL library was used to compile the server and client, which key size is used, and whether the server or client are restricted from using some protocols; for example, by means of `tls_version`/`--tls-version`:

- If the server and client are compiled using OpenSSL, TLSv1.2 is used if possible.
- If either or both the server and client are compiled using yaSSL, TLSv1.1 is used if possible.
- TLSv1.2 does not work with all ciphers that have a key size of 512 bits or less. To use this protocol with such a key, use `--ssl-cipher` to specify the cipher name explicitly:

  ```
  AES128-SHA
  AES128-SHA256
  AES256-SHA
  AES256-SHA256
  CAMELLIA128-SHA
  CAMELLIA256-SHA
  ```

```
DES-CBC3-SHA
DHE-RSA-AES256-SHA
RC4-MD5
RC4-SHA
SEED-SHA
```

- For better security, use a certificate with an RSA key size of of 2048 bits or more.

> **Note**
>
> Prior to MySQL 5.7.10, MySQL supports only TLSv1, for both OpenSSL and yaSSL, and no system variable or client option exist for specifying which TLS protocols to permit.

If the server and client protocol capabilities have no protocol in common, the server terminates the connection request. For example, if the server is configured with `tls_version=TLSv1.1,TLSv1.2`, connection attempts will fail for clients invoked with `--tls-version=TLSv1`, and for older clients that do not support the `--tls-version` option and implicitly support only TLSv1.

To determine which ciphers a given server supports, use the following statement to check the value of the `Ssl_cipher_list` status variable:

```
SHOW SESSION STATUS LIKE 'Ssl_cipher_list';
```

The set of available ciphers depends on your MySQL version and whether MySQL was compiled using OpenSSL or yaSSL, and (for OpenSSL) the library version used to compile MySQL.

As of MySQL 5.7.10, order of ciphers passed by MySQL to the SSL library is significant. More secure ciphers are mentioned first in the list, and the first cipher supported by the provided certificate is selected.

MySQL passes this cipher list to OpenSSL:

```
ECDHE-ECDSA-AES128-GCM-SHA256
ECDHE-ECDSA-AES256-GCM-SHA384
ECDHE-RSA-AES128-GCM-SHA256
ECDHE-RSA-AES256-GCM-SHA384
ECDHE-ECDSA-AES128-SHA256
ECDHE-RSA-AES128-SHA256
ECDHE-ECDSA-AES256-SHA384
ECDHE-RSA-AES256-SHA384
DHE-RSA-AES128-GCM-SHA256
DHE-DSS-AES128-GCM-SHA256
DHE-RSA-AES128-SHA256
DHE-DSS-AES128-SHA256
DHE-DSS-AES256-GCM-SHA384
DHE-RSA-AES256-SHA256
DHE-DSS-AES256-SHA256
ECDHE-RSA-AES128-SHA
ECDHE-ECDSA-AES128-SHA
ECDHE-RSA-AES256-SHA
ECDHE-ECDSA-AES256-SHA
DHE-DSS-AES128-SHA
DHE-RSA-AES128-SHA
TLS_DHE_DSS_WITH_AES_256_CBC_SHA
DHE-RSA-AES256-SHA
AES128-GCM-SHA256
DH-DSS-AES128-GCM-SHA256
ECDH-ECDSA-AES128-GCM-SHA256
AES256-GCM-SHA384
DH-DSS-AES256-GCM-SHA384
ECDH-ECDSA-AES256-GCM-SHA384
AES128-SHA256
DH-DSS-AES128-SHA256
ECDH-ECDSA-AES128-SHA256
AES256-SHA256
```

```
DH-DSS-AES256-SHA256
ECDH-ECDSA-AES256-SHA384
AES128-SHA
DH-DSS-AES128-SHA
ECDH-ECDSA-AES128-SHA
AES256-SHA
DH-DSS-AES256-SHA
ECDH-ECDSA-AES256-SHA
DHE-RSA-AES256-GCM-SHA384
DH-RSA-AES128-GCM-SHA256
ECDH-RSA-AES128-GCM-SHA256
DH-RSA-AES256-GCM-SHA384
ECDH-RSA-AES256-GCM-SHA384
DH-RSA-AES128-SHA256
ECDH-RSA-AES128-SHA256
DH-RSA-AES256-SHA256
ECDH-RSA-AES256-SHA384
ECDHE-RSA-AES128-SHA
ECDHE-ECDSA-AES128-SHA
ECDHE-RSA-AES256-SHA
ECDHE-ECDSA-AES256-SHA
DHE-DSS-AES128-SHA
DHE-RSA-AES128-SHA
TLS_DHE_DSS_WITH_AES_256_CBC_SHA
DHE-RSA-AES256-SHA
AES128-SHA
DH-DSS-AES128-SHA
ECDH-ECDSA-AES128-SHA
AES256-SHA
DH-DSS-AES256-SHA
ECDH-ECDSA-AES256-SHA
DH-RSA-AES128-SHA
ECDH-RSA-AES128-SHA
DH-RSA-AES256-SHA
ECDH-RSA-AES256-SHA
DES-CBC3-SHA
```

MySQL passes this cipher list to yaSSL:

```
DHE-RSA-AES256-SHA
DHE-RSA-AES128-SHA
AES128-RMD
DES-CBC3-RMD
DHE-RSA-AES256-RMD
DHE-RSA-AES128-RMD
DHE-RSA-DES-CBC3-RMD
AES256-SHA
RC4-SHA
RC4-MD5
DES-CBC3-SHA
DES-CBC-SHA
EDH-RSA-DES-CBC3-SHA
EDH-RSA-DES-CBC-SHA
AES128-SHA:AES256-RMD
```

As of MySQL 5.7.10, these cipher restrictions are in place:

- The following ciphers are permanently restricted:

  ```
  !DHE-DSS-DES-CBC3-SHA
  !DHE-RSA-DES-CBC3-SHA
  !ECDH-RSA-DES-CBC3-SHA
  !ECDH-ECDSA-DES-CBC3-SHA
  !ECDHE-RSA-DES-CBC3-SHA
  !ECDHE-ECDSA-DES-CBC3-SHA
  ```

- The following categories of ciphers are permanently restricted:

  ```
  ```

```
!aNULL
!eNULL
!EXPORT
!LOW
!MD5
!DES
!RC2
!RC4
!PSK
!SSLv3
```

If the server is started using a compatible certificate that uses any of the preceding restricted ciphers or cipher categories, the server starts with support for secure connections disabled.

6.4 Configuring MySQL to Use Secure Connections

To enable secure connections, the proper options must be used to specify the appropriate certificate and key files. For a complete list of options related to establishment of secure connections, see Section 6.5, “Command Options for Secure Connections”.

If you need to create the required certificate and key files, see Section 6.6, “Creating SSL and RSA Certificates and Keys”.

Server-Side Configuration for Secure Connections

To start the MySQL server so that it permits clients to connect securely, use options that identify the certificate and key files the server uses when establishing a secure connection:

- `--ssl-ca` identifies the Certificate Authority (CA) certificate.
- `--ssl-cert` identifies the server public key certificate. This can be sent to the client and authenticated against the CA certificate that it has.
- `--ssl-key` identifies the server private key.

For example, start the server with these lines in the `my.cnf` file, changing the file names as necessary:

```
[mysqld]
ssl-ca=ca.pem
ssl-cert=server-cert.pem
ssl-key=server-key.pem
```

Each option names a file in PEM format. If you have a MySQL source distribution, you can test your setup using the demonstration certificate and key files in its `mysql-test/std_data` directory.

As of MySQL 5.7.5, the server-side `--ssl` option value is enabled by default. Also as of MySQL 5.7.5, MySQL servers compiled using OpenSSL can generate missing certificate and key files automatically at startup. See Section 6.6.1, “Creating SSL and RSA Certificates and Keys using MySQL”.

The server performs certificate and key file autodiscovery as of MySQL 5.7.5 (for servers compiled using OpenSSL) or 5.7.6 (for servers compiled using yaSSL). If `--ssl` is enabled (possibly along with `--ssl-cipher`) and other `--ssl-xxx` options are not given to configure secure connections explicitly, the server attempts to enable support for secure connections automatically at startup:

- If the server discovers valid certificate and key files named `ca.pem`, `server-cert.pem`, and `server-key.pem` in the data directory, it enables support for secure connections by clients. (The files need not have been autogenerated; what matters is that they have the indicated names and are valid.)
- If the server does not find valid certificate and key files in the data directory, it continues executing but does not enable secure connections.

If the server automatically enables support for secure connections, it writes a message to the error log. As of MySQL 5.7.6, if the server discovers that the CA certificate is self-signed, it writes a warning to the error log. (The certificate will be self-signed if created automatically by the server or manually using `mysql_ssl_rsa_setup`.)

For any certificate and key files that the server discovers and uses automatically, it uses the file names to set the corresponding system variables (`ssl_ca`, `ssl_cert`, `ssl_key`).

For further control over whether clients must connect securely, use the `require_secure_transport` system variable; see Server System Variables. For information about permitted encryption protocols and ciphers, see Section 6.3, “Secure Connection Protocols and Ciphers”.

Client-Side Configuration for Secure Connections

For client programs, options for secure connections are similar to those used on the server side, but `--ssl-cert` and `--ssl-key` identify the client public and private key:

- `--ssl-ca` identifies the Certificate Authority (CA) certificate. This option, if used, must specify the same certificate used by the server.
- `--ssl-cert` identifies the client public key certificate.
- `--ssl-key` identifies the client private key.

To connect securely to a MySQL server that supports secure connections, the options that a client must specify depend on the encryption requirements of the MySQL account used by the client. (See the discussion of the `REQUIRE` clause in CREATE USER Syntax.)

Suppose that you want to connect using an account that has no special encryption requirements or was created using a `CREATE USER` statement that includes the `REQUIRE SSL` option. As a recommended set of secure-connection options, start the server with at least `--ssl-cert` and `--ssl-key`, and invoke the client with `--ssl-ca`. A client can connect securely like this:

```
shell> mysql --ssl-ca=ca.pem
```

To require that a client certificate also be specified, create the account using the `REQUIRE X509` option. Then the client must also specify the proper client key and certificate files or the server will reject the connection:

```
shell> mysql --ssl-ca=ca.pem \
      --ssl-cert=client-cert.pem \
      --ssl-key=client-key.pem
```

To prevent use of encryption and override other `--ssl-xxx` options, invoke the client program with `--ssl-mode=DISABLED`, `--ssl=0`, or a synonym (`--skip-ssl`, `--disable-ssl`):

```
shell> mysql --ssl-mode=DISABLED
```

As of MySQL 5.7.7, client programs attempt to establish a secure connection by default whenever the server supports secure connections:

- In the absence of an `--ssl-mode` or `--ssl` option, the client falls back to an unencrypted connection if a secure connection cannot be established.
- To require a secure connection and fail if one cannot be established, invoke the client with `--ssl-mode=REQUIRED`, `--ssl`, or a synonym (`--ssl=1`, `--enable-ssl`).
- To use an unencrypted connection, invoke the client with `--ssl-mode=DISABLED`, `--ssl=0`, or a synonym (`--skip-ssl`, `--disable-ssl`).

From MySQL 5.7.3 to 5.7.6, `--ssl` on the client side is prescriptive (not advisory as before MySQL 5.7.3): With `--ssl`, connection attempts fail if a secure connection cannot be established.

Before MySQL 5.7.3, `--ssl` on the client side is advisory: `--ssl` permits but does not require the client to connect to the server using encryption. Therefore, this option is not sufficient in itself to cause a secure connection to be used. For example, if you specify this option for a client program but the server has not been configured to support secure connections, the client falls back to an unencrypted connection.

For information about permitted encryption protocols and ciphers, see Section 6.3, "Secure Connection Protocols and Ciphers".

A client can determine whether the current connection with the server uses encryption by checking the value of the `Ssl_cipher` status variable. If the value is empty, the connection is not encrypted. Otherwise, the connection is encrypted and the value indicates the encryption cipher. For example:

```
mysql> SHOW STATUS LIKE 'Ssl_cipher';
+---------------+--------------------+
| Variable_name | Value              |
+---------------+--------------------+
| Ssl_cipher    | DHE-RSA-AES256-SHA |
+---------------+--------------------+
```

For the `mysql` client, an alternative is to use the `STATUS` or `\s` command and check the `SSL` line:

```
mysql> \s
...
SSL: Cipher in use is DHE-RSA-AES256-SHA
...
```

Or:

```
mysql> \s
...
SSL: Not in use
...
```

C API Configuration for Secure Connections

The C API enables application programs to use secure connections:

- To establish a secure connection, use the `mysql_ssl_set()` C API function to set the appropriate certificate options before calling `mysql_real_connect()`. See mysql_ssl_set(). To require the use of a secure connection, call `mysql_options()` with the `MYSQL_OPT_SSL_MODE` option (use the `MYSQL_OPT_SSL_ENFORCE` option before MySQL 5.7.11). To establish permitted encryption protocols, call `mysql_options()` with the `MYSQL_OPT_TLS_VERSION` option.
- To determine whether encryption is in use after the connection is established, use `mysql_get_ssl_cipher()`. A non-`NULL` return value indicates an encrypted connection and names the cipher used for encryption. A `NULL` return value indicates that encryption is not being used. See mysql_get_ssl_cipher().

Replication uses the C API, so secure connections can be used between master and slave servers. See Setting Up Replication to Use Secure Connections.

6.5 Command Options for Secure Connections

This section describes options that specify whether to use secure connections and the names of certificate and key files. These options can be given on the command line or in an option file. For examples of suggested use and how to check whether a connection is secure, see Section 6.4, "Configuring MySQL to Use Secure Connections".

Table 6.1 Secure-Connection Option Summary

Format	Description	Introduced
--skip-ssl	Do not use secure connection	
--ssl	Enable secure connection	
--ssl-ca	Path of file that contains list of trusted SSL CAs	
--ssl-capath	Path of directory that contains trusted SSL CA certificates in PEM format	
--ssl-cert	Path of file that contains X509 certificate in PEM format	
--ssl-cipher	List of permitted ciphers to use for connection encryption	
--ssl-crl	Path of file that contains certificate revocation lists	
--ssl-crlpath	Path of directory that contains certificate revocation list files	
--ssl-key	Path of file that contains X509 key in PEM format	
--ssl-mode	Security state of connection to server	5.7.11
--ssl-verify-server-cert	Verify server certificate Common Name value against host name used when connecting to server	
--tls-version	Protocols permitted for secure connections	5.7.10

- `--ssl`

  This option has different effects on the server and client sides.

  > **Note**
  >
  > The client-side `--ssl` option is deprecated as of MySQL 5.7.11 and is removed in MySQL 8.0. For client programs, it is preferable to use `--ssl-mode` instead:
  >
  > - Use `--ssl-mode=REQUIRED` instead of `--ssl=1` or `--enable-ssl`.
  > - Use `--ssl-mode=DISABLED` instead of `--ssl=0`, `--skip-ssl`, or `--disable-ssl`.
  > - No explicit `--ssl-mode` option is equivalent to no explicit `--ssl` option.
  >
  > The server-side `--ssl` option is *not* deprecated.

  For the MySQL server, this option specifies that the server permits but does not require secure connections. The option is enabled on the server side by default as of MySQL 5.7.5, and disabled before 5.7.5. Also as of MySQL 5.7.5, MySQL servers compiled using OpenSSL can generate missing certificate and key files automatically at startup. See Section 6.6.1, “Creating SSL and RSA Certificates and Keys using MySQL”.

  The server performs certificate and key file autodiscovery as of MySQL 5.7.5 (for servers compiled using OpenSSL) or 5.7.6 (for servers compiled using yaSSL). If `--ssl` is enabled (possibly along with `--ssl-cipher`) and other `--ssl-xxx` options are not given to configure secure connections explicitly, the server attempts to enable support for secure connections automatically at startup:

  - If the server discovers valid certificate and key files named `ca.pem`, `server-cert.pem`, and `server-key.pem` in the data directory, it enables support for secure connections by clients. (The files need not have been autogenerated; what matters is that they have the indicated names and are valid.)
  - If the server does not find valid certificate and key files in the data directory, it continues executing but does not enable secure connections.

For MySQL client programs, the `--ssl` option is used as follows:

- As of MySQL 5.7.7, client programs attempt to establish a secure connection by default whenever the server supports secure connections:
  - In the absence of an `--ssl` option, the client falls back to an unencrypted connection if a secure connection cannot be established.
  - To require a secure connection and fail if one cannot be established, invoke the client with `--ssl` or a synonym (`--ssl=1`, `--enable-ssl`).
  - To use an unencrypted connection, invoke the client with `--ssl=0` or a synonym (`--skip-ssl`, `--disable-ssl`).
- From MySQL 5.7.3 to 5.7.6, `--ssl` is prescriptive (not advisory as before MySQL 5.7.3): With `--ssl`, connection attempts fail if a secure connection cannot be established.
- Before MySQL 5.7.3, `--ssl` is advisory: `--ssl` permits but does not require the client to connect to the server using encryption. Therefore, this option is not sufficient in itself to cause a secure connection to be used. For example, if you specify this option for a client program but the server has not been configured to support secure connections, the client falls back to an unencrypted connection.

If other `--ssl-xxx` options are given in the absence of `--ssl`, the client attempts to connect securely. If the server is configured to support secure connections, the connection attempt fails if a secure connection cannot be established. If the server is not configured for secure connections, the client falls back to an unencrypted connection.

As a recommended set of options to enable secure connections, use at least `--ssl-cert` and `--ssl-key` on the server side and `--ssl-ca` on the client side. See Section 6.4, “Configuring MySQL to Use Secure Connections”.

`--ssl` is implied by other `--ssl-xxx` options, as indicated in the descriptions for those options.

The `--ssl` option in negated form overrides other `--ssl-xxx` options and indicates that encryption should *not* be used. To do this, specify the option as `--ssl=0` or a synonym (`--skip-ssl`, `--disable-ssl`). For example, you might have options specified in the `[client]` group of your option file to use secure connections by default when you invoke MySQL client programs. To use an unencrypted connection instead, invoke the client program with `--ssl=0` on the command line to override the options in the option file.

To require use of secure connections by a MySQL account, use `CREATE USER` to create the account with at least a `REQUIRE SSL` clause, or use `ALTER USER` for an existing account to add a `REQUIRE` clause. Connections for the account will be rejected unless MySQL supports secure connections and the server and client have been started with the proper secure-connection options.

The `REQUIRE` clause permits other encryption-related options, which can be used to enforce stricter requirements than `REQUIRE SSL`. For additional details about which command options may or must be specified by clients that connect using accounts configured using the various `REQUIRE` options, see the description of `REQUIRE` in CREATE USER Syntax.

- `--ssl-ca=file_name`

  The path to a file in PEM format that contains a list of trusted SSL certificate authorities. This option implies `--ssl` when used on the server side, and on the client side before MySQL 5.7.3.

  If you use encryption when establishing a client connection, to tell the client not to authenticate the server certificate, specify neither `--ssl-ca` nor `--ssl-capath`. The server still verifies the client

according to any applicable requirements established for the client account, and it still uses any `--ssl-ca` or `--ssl-capath` option values specified at server startup.

- `--ssl-capath=dir_name`

  The path to a directory that contains trusted SSL certificate authority certificates in PEM format. This option implies `--ssl` when used on the server side, and on the client side before MySQL 5.7.3.

  If you use encryption when establishing a client connection, to tell the client not to authenticate the server certificate, specify neither `--ssl-ca` nor `--ssl-capath`. The server still verifies the client according to any applicable requirements established for the client account, and it still uses any `--ssl-ca` or `--ssl-capath` option values specified at server startup.

  MySQL distributions compiled using OpenSSL support the `--ssl-capath` option (see Section 6.1, “OpenSSL Versus yaSSL”). Distributions compiled using yaSSL do not because yaSSL does not look in any directory and does not follow a chained certificate tree. yaSSL requires that all components of the CA certificate tree be contained within a single CA certificate tree and that each certificate in the file has a unique SubjectName value. To work around this yaSSL limitation, concatenate the individual certificate files comprising the certificate tree into a new file and specify that file as the value of the `--ssl-ca` option.

- `--ssl-cert=file_name`

  The name of the SSL certificate file in PEM format to use for establishing a secure connection. This option implies `--ssl` when used on the server side, and on the client side before MySQL 5.7.3.

- `--ssl-cipher=cipher_list`

  A list of permissible ciphers to use for connection encryption. If no cipher in the list is supported, encrypted connections will not work. This option implies `--ssl` when used on the server side, and on the client side before MySQL 5.7.3.

  For greatest portability, *`cipher_list`* should be a list of one or more cipher names, separated by colons. This format is understood both by OpenSSL and yaSSL. Examples:

  ```
  --ssl-cipher=AES128-SHA
  --ssl-cipher=DHE-RSA-AES256-SHA:AES128-SHA
  ```

  OpenSSL supports a more flexible syntax for specifying ciphers, as described in the OpenSSL documentation at http://www.openssl.org/docs/apps/ciphers.html. yaSSL does not, so attempts to use that extended syntax fail for a MySQL distribution compiled using yaSSL.

  For information about which encryption ciphers MySQL supports, see Section 6.3, “Secure Connection Protocols and Ciphers”.

- `--ssl-crl=file_name`

  The path to a file containing certificate revocation lists in PEM format. This option implies `--ssl` when used on the server side, and on the client side before MySQL 5.7.3.

  If neither `--ssl-crl` nor `--ssl-crlpath` is given, no CRL checks are performed, even if the CA path contains certificate revocation lists.

  MySQL distributions compiled using OpenSSL support the `--ssl-crl` option (see Section 6.1, “OpenSSL Versus yaSSL”). Distributions compiled using yaSSL do not because revocation lists do not work with yaSSL.

- `--ssl-crlpath=dir_name`

  The path to a directory that contains files containing certificate revocation lists in PEM format. This option implies `--ssl` when used on the server side, and on the client side before MySQL 5.7.3.

If neither `--ssl-crl` nor `--ssl-crlpath` is given, no CRL checks are performed, even if the CA path contains certificate revocation lists.

MySQL distributions compiled using OpenSSL support the `--ssl-crlpath` option (see Section 6.1, “OpenSSL Versus yaSSL”). Distributions compiled using yaSSL do not because revocation lists do not work with yaSSL.

- `--ssl-key=`*`file_name`*

  The name of the SSL key file in PEM format to use for establishing a secure connection. This option implies `--ssl` when used on the server side, and on the client side before MySQL 5.7.3.

  If the key file is protected by a passphrase, the program prompts the user for the passphrase. The password must be given interactively; it cannot be stored in a file. If the passphrase is incorrect, the program continues as if it could not read the key.

  For better security, use a certificate with an RSA key size of of 2048 bits or more.

- `--ssl-mode=`*`mode`*

  This option is available only for client programs, not the server. It specifies the security state of the connection to the server. The following option values are permitted:

  - `PREFERRED`: Establish a secure (encrypted) connection if the server supports secure connections. Fall back to an unencrypted connection otherwise. This is the default if `--ssl-mode` is not specified.
  - `DISABLED`: Establish an unencrypted connection. This is like the legacy `--ssl=0` option or its synonyms (`--skip-ssl`, `--disable-ssl`).
  - `REQUIRED`: Establish a secure connection if the server supports secure connections. The connection attempt fails if a secure connection cannot be established.
  - `VERIFY_CA`: Like `REQUIRED`, but additionally verify the server TLS certificate against the configured Certificate Authority (CA) certificates. The connection attempt fails if no valid matching CA certificates are found.
  - `VERIFY_IDENTITY`: Like `VERIFY_CA`, but additionally verify that the server certificate matches the host to which the connection is attempted. This is like the legacy `--ssl-verify-server-cert` option.

  Use of the `--ssl-ca` or `--ssl-capath` option implies `--ssl-mode=VERIFY_CA`, if `--ssl-mode` is not explicitly set otherwise.

  If `--ssl-mode` is explicit, use of a value other than `VERIFY_CA` or `VERIFY_IDENTITY` with an explicit `--ssl-ca` or `--ssl-capath` option produces a warning that no verification of the server certificate will be done, despite CA certificate options being specified.

  The `--ssl-mode` option was added in MySQL 5.7.11.

  To require use of secure connections by a MySQL account, use `CREATE USER` to create the account with at least a `REQUIRE SSL` clause, or use `ALTER USER` for an existing account to add a `REQUIRE` clause. Connections for the account will be rejected unless MySQL supports secure connections and the server and client have been started with the proper secure-connection options.

  The `REQUIRE` clause permits other encryption-related options, which can be used to enforce stricter requirements than `REQUIRE SSL`. For additional details about which command options may or must be specified by clients that connect using accounts configured using the various `REQUIRE` options, see the description of `REQUIRE` in CREATE USER Syntax.

- `--ssl-verify-server-cert`

  > **Note**
  >
  > This option is deprecated as of MySQL 5.7.11 and is removed in MySQL 8.0. It is preferable to use `--ssl-mode=VERIFY_IDENTITY` instead.

  This option is available only for client programs, not the server. It causes the client to check the server's Common Name value in the certificate that the server sends to the client. The client verifies that name against the host name the client uses for connecting to the server, and the connection fails if there is a mismatch. For encrypted connections, this option helps prevent man-in-the-middle attacks. Verification is disabled by default.

- `--tls-version=`*`protocol_list`*

  For client programs, the protocols permitted by the client for encrypted connections. The value is a comma-separated list containing one or more protocol names. The protocols that can be named for this option depend on the SSL library used to compile MySQL. For details, see Section 6.3, “Secure Connection Protocols and Ciphers”.

  This option was added in MySQL 5.7.10.

  On the server side, the `tls_version` system variable can be used instead.

6.6 Creating SSL and RSA Certificates and Keys

The following discussion describes how to create the files required for SSL and RSA support in MySQL. File creation can be performed using facilities provided by MySQL itself, or by invoking the `openssl` command directly.

SSL certificate and key files enable MySQL to support secure connections using SSL. See Section 6.4, “Configuring MySQL to Use Secure Connections”.

RSA key files enable MySQL to support secure password exchange over unencrypted connections for accounts authenticated by the `sha256_password` plugin. See Section 7.1.4, “The SHA-256 Authentication Plugin”.

6.6.1 Creating SSL and RSA Certificates and Keys using MySQL

MySQL provides two ways to create the SSL certificate and key files and RSA key-pair files required to support secure connections using SSL and secure password exchange using RSA over unencrypted connections, if those files are missing:

- The server can autogenerate these files at startup.
- Users can invoke the `mysql_ssl_rsa_setup` utility manually.

> **Important**
>
> Server autogeneration and `mysql_ssl_rsa_setup` help lower the barrier to using SSL by making it easier to generate the required files. However, certificates generated by these methods are self-signed, which may not be very secure. After you gain experience using such files, consider obtaining certificate/key material from a registered certificate authority.

Automatic Generation of SSL and RSA Files

As of MySQL 5.7.5, MySQL servers have the capability of automatically generating missing SSL and RSA files at startup, for MySQL distributions compiled using OpenSSL. The `auto_generate_certs` and `sha256_password_auto_generate_rsa_keys` system variables control automatic generation of these files. Both variables are enabled by default. They can be enabled at startup and inspected but not set at runtime.

At startup, the server automatically generates server-side and client-side SSL certificate and key files in the data directory if the `auto_generate_certs` system variable is enabled, no SSL options other than `--ssl` are specified, and the server-side SSL files are missing from the data directory. These files enable secure client connections using SSL; see Section 6.4, “Configuring MySQL to Use Secure Connections”.

1. The server checks the data directory for SSL files with the following names:

```
ca.pem
server-cert.pem
server-key.pem
```

2. If any of those files are present, the server creates no SSL files. Otherwise, it creates them, plus some additional files:

```
ca.pem               Self-signed CA certificate
ca-key.pem           CA private key
server-cert.pem      Server certificate
server-key.pem       Server private key
client-cert.pem      Client certificate
client-key.pem       Client private key
```

3. If the server autogenerates SSL files, it uses the names of the `ca.pem`, `server-cert.pem`, and `server-key.pem` files to set the corresponding system variables (`ssl_ca`, `ssl_cert`, `ssl_key`).

At startup, the server automatically generates RSA private/public key-pair files in the data directory if the `sha256_password_auto_generate_rsa_keys` system variable is enabled, no RSA options are specified, and the RSA files are missing from the data directory. These files enable secure password exchange using RSA over unencrypted connections for accounts authenticated by the `sha256_password` plugin; see Section 7.1.4, “The SHA-256 Authentication Plugin”.

1. The server checks the data directory for RSA files with the following names:

```
private_key.pem      Private member of private/public key pair
public_key.pem       Public member of private/public key pair
```

2. If any of these files are present, the server creates no RSA files. Otherwise, it creates them.

3. If the server autogenerates the RSA files, it uses their names to set the corresponding system variables (`sha256_password_private_key_path`, `sha256_password_public_key_path`).

Manual Generation of SSL and RSA Files Using mysql_ssl_rsa_setup

As of MySQL 5.7.6, MySQL distributions include a `mysql_ssl_rsa_setup` utility that can be invoked manually to generate SSL and RSA files. This utility is included with all MySQL distributions (whether compiled using OpenSSL or yaSSL), but it does require that the `openssl` command be available. For usage instructions, see `mysql_ssl_rsa_setup` — Create SSL/RSA Files.

SSL and RSA File Characteristics

SSL and RSA files created automatically by the server or by invoking `mysql_ssl_rsa_setup` have these characteristics:

- SSL and RSA keys are 2048 bit.
- The SSL CA certificate is self signed.
- The SSL server and client certificates are signed with the CA certificate and key, using the `sha256WithRSAEncryption` signature algorithm.
- SSL certificates use these Common Name (CN) values, with the appropriate certificate type (CA, Server, Client):

```
ca.pem:         MySQL_Server_suffix_Auto_Generated_CA_Certificate
server-cert.pm: MySQL_Server_suffix_Auto_Generated_Server_Certificate
client-cert.pm: MySQL_Server_suffix_Auto_Generated_Client_Certificate
```

The *`suffix`* value is based on the MySQL version number. For files generated by `mysql_ssl_rsa_setup`, the suffix can be specified explicitly using the `--suffix` option.

For files generated by the server, if the resulting CN values exceed 64 characters, the *`_suffix`* portion of the name is omitted.

- SSL files have blank values for Country (C), State or Province (ST), Organization (O), Organization Unit Name (OU) and email address.
- SSL files created by the server or by `mysql_ssl_rsa_setup` are valid for ten years from the time of generation. (Before MySQL 5.7.6, files created by the server are valid for one year.)
- RSA files do not expire.
- SSL files have different serial numbers for each certificate/key pair (1 for CA, 2 for Server, 3 for Client).
- Files created automatically by the server are owned by the account that runs the server. Files created using `mysql_ssl_rsa_setup` are owned by the user who invoked that program. This can be changed on systems that support the `chown()` system call if the program is invoked by `root` and the `--uid` option is given to specify the user who should own the files.
- On Unix and Unix-like systems, the file access mode is 644 for certificate files (that is, world readable) and 600 for key files (that is, accessible only by the account that runs the server).

To see the contents of an SSL certificate (for example, to check the range of dates over which it is valid), invoke `openssl` directly:

```
shell> openssl x509 -text -in ca.pem
shell> openssl x509 -text -in server-cert.pem
shell> openssl x509 -text -in client-cert.pem
```

It is also possible to check SSL certificate expiration information using this SQL statement:

```
mysql> SHOW STATUS LIKE 'Ssl_server_not%';
+-----------------------+-------------------------+
| Variable_name         | Value                   |
+-----------------------+-------------------------+
| Ssl_server_not_after  | Apr 28 14:16:39 2025 GMT |
| Ssl_server_not_before | May  1 14:16:39 2015 GMT |
+-----------------------+-------------------------+
```

6.6.2 Creating SSL Certificates and Keys Using openssl

This section describes how to use the `openssl` command to set up SSL certificate and key files for use by MySQL servers and clients. The first example shows a simplified procedure such as you might use from the command line. The second shows a script that contains more detail. The first two examples are intended for use on Unix and both use the `openssl` command that is part of OpenSSL. The third example describes how to set up SSL files on Windows.

> **Note**
>
> There are easier alternatives to generating the files required for SSL than the procedure described here: Let the server autogenerate them or use the `mysql_ssl_rsa_setup` program. See Section 6.6.1, “Creating SSL and RSA Certificates and Keys using MySQL”.

Important

Whatever method you use to generate the certificate and key files, the Common Name value used for the server and client certificates/keys must each differ from the Common Name value used for the CA certificate. Otherwise, the certificate and key files will not work for servers compiled using OpenSSL. A typical error in this case is:

```
ERROR 2026 (HY000): SSL connection error:
error:00000001:lib(0):func(0):reason(1)
```

Example 1: Creating SSL Files from the Command Line on Unix

The following example shows a set of commands to create MySQL server and client certificate and key files. You will need to respond to several prompts by the `openssl` commands. To generate test files, you can press Enter to all prompts. To generate files for production use, you should provide nonempty responses.

```
# Create clean environment
shell> rm -rf newcerts
shell> mkdir newcerts && cd newcerts
# Create CA certificate
shell> openssl genrsa 2048 > ca-key.pem
shell> openssl req -new -x509 -nodes -days 3600 \
         -key ca-key.pem -out ca.pem
# Create server certificate, remove passphrase, and sign it
# server-cert.pem = public key, server-key.pem = private key
shell> openssl req -newkey rsa:2048 -days 3600 \
         -nodes -keyout server-key.pem -out server-req.pem
shell> openssl rsa -in server-key.pem -out server-key.pem
shell> openssl x509 -req -in server-req.pem -days 3600 \
         -CA ca.pem -CAkey ca-key.pem -set_serial 01 -out server-cert.pem
# Create client certificate, remove passphrase, and sign it
# client-cert.pem = public key, client-key.pem = private key
shell> openssl req -newkey rsa:2048 -days 3600 \
         -nodes -keyout client-key.pem -out client-req.pem
shell> openssl rsa -in client-key.pem -out client-key.pem
shell> openssl x509 -req -in client-req.pem -days 3600 \
         -CA ca.pem -CAkey ca-key.pem -set_serial 01 -out client-cert.pem
```

After generating the certificates, verify them:

```
shell> openssl verify -CAfile ca.pem server-cert.pem client-cert.pem
server-cert.pem: OK
client-cert.pem: OK
```

To see the contents of a certificate (for example, to check the range of dates over which a certificate is valid), invoke `openssl` like this:

```
shell> openssl x509 -text -in ca.pem
shell> openssl x509 -text -in server-cert.pem
shell> openssl x509 -text -in client-cert.pem
```

Now you have a set of files that can be used as follows:

- `ca.pem`: Use this as the argument to `--ssl-ca` on the server and client sides. (The CA certificate, if used, must be the same on both sides.)
- `server-cert.pem`, `server-key.pem`: Use these as the arguments to `--ssl-cert` and `--ssl-key` on the server side.
- `client-cert.pem`, `client-key.pem`: Use these as the arguments to `--ssl-cert` and `--ssl-key` on the client side.

To use the files for SSL connections, see Section 6.4, “Configuring MySQL to Use Secure Connections”.

Example 2: Creating SSL Files Using a Script on Unix

Here is an example script that shows how to set up SSL certificate and key files for MySQL. After executing the script, use the files for SSL connections as described in Section 6.4, “Configuring MySQL to Use Secure Connections”.

```
DIR=`pwd`/openssl
PRIV=$DIR/private
mkdir $DIR $PRIV $DIR/newcerts
cp /usr/share/ssl/openssl.cnf $DIR
replace ./demoCA $DIR -- $DIR/openssl.cnf
# Create necessary files: $database, $serial and $new_certs_dir
# directory (optional)
touch $DIR/index.txt
echo "01" > $DIR/serial
#
# Generation of Certificate Authority(CA)
#
openssl req -new -x509 -keyout $PRIV/cakey.pem -out $DIR/ca.pem \
    -days 3600 -config $DIR/openssl.cnf
# Sample output:
# Using configuration from /home/finley/openssl/openssl.cnf
# Generating a 1024 bit RSA private key
# ................++++++
# .........++++++
# writing new private key to '/home/finley/openssl/private/cakey.pem'
# Enter PEM pass phrase:
# Verifying password - Enter PEM pass phrase:
# -----
# You are about to be asked to enter information that will be
# incorporated into your certificate request.
# What you are about to enter is what is called a Distinguished Name
# or a DN.
# There are quite a few fields but you can leave some blank
# For some fields there will be a default value,
# If you enter '.', the field will be left blank.
# -----
# Country Name (2 letter code) [AU]:FI
# State or Province Name (full name) [Some-State]:.
# Locality Name (eg, city) []:
# Organization Name (eg, company) [Internet Widgits Pty Ltd]:MySQL AB
# Organizational Unit Name (eg, section) []:
# Common Name (eg, YOUR name) []:MySQL admin
# Email Address []:
#
# Create server request and key
#
openssl req -new -keyout $DIR/server-key.pem -out \
    $DIR/server-req.pem -days 3600 -config $DIR/openssl.cnf
# Sample output:
# Using configuration from /home/finley/openssl/openssl.cnf
# Generating a 1024 bit RSA private key
# ..++++++
# ..........++++++
# writing new private key to '/home/finley/openssl/server-key.pem'
# Enter PEM pass phrase:
# Verifying password - Enter PEM pass phrase:
# -----
# You are about to be asked to enter information that will be
# incorporated into your certificate request.
# What you are about to enter is what is called a Distinguished Name
# or a DN.
# There are quite a few fields but you can leave some blank
# For some fields there will be a default value,
# If you enter '.', the field will be left blank.
# -----
# Country Name (2 letter code) [AU]:FI
```

```
# State or Province Name (full name) [Some-State]:.
# Locality Name (eg, city) []:
# Organization Name (eg, company) [Internet Widgits Pty Ltd]:MySQL AB
# Organizational Unit Name (eg, section) []:
# Common Name (eg, YOUR name) []:MySQL server
# Email Address []:
#
# Please enter the following 'extra' attributes
# to be sent with your certificate request
# A challenge password []:
# An optional company name []:
#
# Remove the passphrase from the key
#
openssl rsa -in $DIR/server-key.pem -out $DIR/server-key.pem
#
# Sign server cert
#
openssl ca -cert $DIR/ca.pem -policy policy_anything \
    -out $DIR/server-cert.pem -config $DIR/openssl.cnf \
    -infiles $DIR/server-req.pem
# Sample output:
# Using configuration from /home/finley/openssl/openssl.cnf
# Enter PEM pass phrase:
# Check that the request matches the signature
# Signature ok
# The Subjects Distinguished Name is as follows
# countryName           :PRINTABLE:'FI'
# organizationName      :PRINTABLE:'MySQL AB'
# commonName            :PRINTABLE:'MySQL admin'
# Certificate is to be certified until Sep 13 14:22:46 2003 GMT
# (365 days)
# Sign the certificate? [y/n]:y
#
#
# 1 out of 1 certificate requests certified, commit? [y/n]y
# Write out database with 1 new entries
# Data Base Updated
#
# Create client request and key
#
openssl req -new -keyout $DIR/client-key.pem -out \
    $DIR/client-req.pem -days 3600 -config $DIR/openssl.cnf
# Sample output:
# Using configuration from /home/finley/openssl/openssl.cnf
# Generating a 1024 bit RSA private key
# ..................................++++++
# ..........................................++++++
# writing new private key to '/home/finley/openssl/client-key.pem'
# Enter PEM pass phrase:
# Verifying password - Enter PEM pass phrase:
# -----
# You are about to be asked to enter information that will be
# incorporated into your certificate request.
# What you are about to enter is what is called a Distinguished Name
# or a DN.
# There are quite a few fields but you can leave some blank
# For some fields there will be a default value,
# If you enter '.', the field will be left blank.
# -----
# Country Name (2 letter code) [AU]:FI
# State or Province Name (full name) [Some-State]:.
# Locality Name (eg, city) []:
# Organization Name (eg, company) [Internet Widgits Pty Ltd]:MySQL AB
# Organizational Unit Name (eg, section) []:
# Common Name (eg, YOUR name) []:MySQL user
# Email Address []:
#
# Please enter the following 'extra' attributes
# to be sent with your certificate request
# A challenge password []:
# An optional company name []:
```

```
#
# Remove the passphrase from the key
#
openssl rsa -in $DIR/client-key.pem -out $DIR/client-key.pem
#
# Sign client cert
#
openssl ca -cert $DIR/ca.pem -policy policy_anything \
    -out $DIR/client-cert.pem -config $DIR/openssl.cnf \
    -infiles $DIR/client-req.pem
# Sample output:
# Using configuration from /home/finley/openssl/openssl.cnf
# Enter PEM pass phrase:
# Check that the request matches the signature
# Signature ok
# The Subjects Distinguished Name is as follows
# countryName           :PRINTABLE:'FI'
# organizationName      :PRINTABLE:'MySQL AB'
# commonName            :PRINTABLE:'MySQL user'
# Certificate is to be certified until Sep 13 16:45:17 2003 GMT
# (365 days)
# Sign the certificate? [y/n]:y
#
#
# 1 out of 1 certificate requests certified, commit? [y/n]y
# Write out database with 1 new entries
# Data Base Updated
#
# Create a my.cnf file that you can use to test the certificates
#
cat <<EOF > $DIR/my.cnf
[client]
ssl-ca=$DIR/ca.pem
ssl-cert=$DIR/client-cert.pem
ssl-key=$DIR/client-key.pem
[mysqld]
ssl-ca=$DIR/ca.pem
ssl-cert=$DIR/server-cert.pem
ssl-key=$DIR/server-key.pem
EOF
```

Example 3: Creating SSL Files on Windows

Download OpenSSL for Windows if it is not installed on your system. An overview of available packages can be seen here:

```
http://www.slproweb.com/products/Win32OpenSSL.html
```

Choose the Win32 OpenSSL Light or Win64 OpenSSL Light package, depending on your architecture (32-bit or 64-bit). The default installation location will be `C:\OpenSSL-Win32` or `C:\OpenSSL-Win64`, depending on which package you downloaded. The following instructions assume a default location of `C:\OpenSSL-Win32`. Modify this as necessary if you are using the 64-bit package.

If a message occurs during setup indicating `'...critical component is missing: Microsoft Visual C++ 2008 Redistributables'`, cancel the setup and download one of the following packages as well, again depending on your architecture (32-bit or 64-bit):

- Visual C++ 2008 Redistributables (x86), available at:

  ```
  http://www.microsoft.com/downloads/details.aspx?familyid=9B2DA534-3E03-4391-8A4D-074B9F2BC1BF
  ```

- Visual C++ 2008 Redistributables (x64), available at:

  ```
  http://www.microsoft.com/downloads/details.aspx?familyid=bd2a6171-e2d6-4230-b809-9a8d7548c1b6
  ```

After installing the additional package, restart the OpenSSL setup procedure.

During installation, leave the default `C:\OpenSSL-Win32` as the install path, and also leave the default option `'Copy OpenSSL DLL files to the Windows system directory'` selected.

When the installation has finished, add `C:\OpenSSL-Win32\bin` to the Windows System Path variable of your server:

1. On the Windows desktop, right-click the **My Computer** icon, and select **Properties**.
2. Select the **Advanced** tab from the **System Properties** menu that appears, and click the **Environment Variables** button.
3. Under **System Variables**, select **Path**, then click the **Edit** button. The **Edit System Variable** dialogue should appear.
4. Add `';C:\OpenSSL-Win32\bin'` to the end (notice the semicolon).
5. Press OK 3 times.
6. Check that OpenSSL was correctly integrated into the Path variable by opening a new command console (`Start>Run>cmd.exe`) and verifying that OpenSSL is available:

```
Microsoft Windows [Version ...]
Copyright (c) 2006 Microsoft Corporation. All rights reserved.
C:\Windows\system32>cd \
C:\>openssl
OpenSSL> exit <<< If you see the OpenSSL prompt, installation was successful.
C:\>
```

Depending on your version of Windows, the preceding path-setting instructions might differ slightly.

After OpenSSL has been installed, use instructions similar to those from Example 1 (shown earlier in this section), with the following changes:

- Change the following Unix commands:

```
# Create clean environment
shell> rm -rf newcerts
shell> mkdir newcerts && cd newcerts
```

  On Windows, use these commands instead:

```
# Create clean environment
C:\> md c:\newcerts
C:\> cd c:\newcerts
```

- When a `'\'` character is shown at the end of a command line, this `'\'` character must be removed and the command lines entered all on a single line.

After generating the certificate and key files, to use them for SSL connections, see Section 6.4, “Configuring MySQL to Use Secure Connections”.

6.6.3 Creating RSA Keys Using openssl

This section describes how to use the `openssl` command to set up the RSA key files that enable MySQL to support secure password exchange over unencrypted connections for accounts authenticated by the `sha256_password` plugin.

> **Note**
>
> There are easier alternatives to generating the files required for RSA than the procedure described here: Let the server autogenerate them or use the

> `mysql_ssl_rsa_setup` program. See Section 6.6.1, “Creating SSL and RSA Certificates and Keys using MySQL”.

To create the RSA private and public key-pair files, run these commands while logged into the system account used to run the MySQL server so the files will be owned by that account:

```
openssl genrsa -out private_key.pem 2048
openssl rsa -in private_key.pem -pubout -out public_key.pem
```

Those commands create 2,048-bit keys. To create stronger keys, use a larger value.

Then set the access modes for the key files. The private key should be readable only by the server, whereas the public key can be freely distributed to client users:

```
chmod 400 private_key.pem
chmod 444 public_key.pem
```

6.7 Connecting to MySQL Remotely from Windows with SSH

This section describes how to get a secure connection to a remote MySQL server with SSH. The information was provided by David Carlson <dcarlson@mplcomm.com>.

1. Install an SSH client on your Windows machine. For a comparison of SSH clients, see http://en.wikipedia.org/wiki/Comparison_of_SSH_clients.
2. Start your Windows SSH client. Set `Host_Name = yourmysqlserver_URL_or_IP`. Set `userid=your_userid` to log in to your server. This `userid` value might not be the same as the user name of your MySQL account.
3. Set up port forwarding. Either do a remote forward (Set `local_port: 3306`, `remote_host: yourmysqlservername_or_ip`, `remote_port: 3306`) or a local forward (Set `port: 3306`, `host: localhost`, `remote port: 3306`).
4. Save everything, otherwise you will have to redo it the next time.
5. Log in to your server with the SSH session you just created.
6. On your Windows machine, start some ODBC application (such as Access).
7. Create a new file in Windows and link to MySQL using the ODBC driver the same way you normally do, except type in `localhost` for the MySQL host server, not `yourmysqlservername`.

At this point, you should have an ODBC connection to MySQL, encrypted using SSH.

Chapter 7 Security Plugins

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MySQL includes several plugins that implement security features:

- Plugins for authenticating attempts by clients to connect to MySQL Server. Plugins are available for several authentication protocols. For general discussion of the authentication process, see Section 5.8, “Pluggable Authentication”. For characteristics of specific authentication plugins, see Section 7.1, “Authentication Plugins”.
- A password-validation plugin for implementing password strength policies and assessing the strength of potential passwords. See Section 7.2, “The Password Validation Plugin”.
- A keyring plugin that provides secure storage for sensitive information. See Section 7.3, “The MySQL Keyring”.
- (MySQL Enterprise Edition only) MySQL Enterprise Audit, implemented using a server plugin, uses the open MySQL Audit API to enable standard, policy-based monitoring and logging of connection and query activity executed on specific MySQL servers. Designed to meet the Oracle audit specification, MySQL Enterprise Audit provides an out of box, easy to use auditing and compliance solution for applications that are governed by both internal and external regulatory guidelines.

- (MySQL Enterprise Edition only) MySQL Enterprise Firewall, an application-level firewall that enables database administrators to permit or deny SQL statement execution based on matching against whitelists of accepted statement patterns. This helps harden MySQL Server against attacks such as SQL injection or attempts to exploit applications by using them outside of their legitimate query workload characteristics.

7.1 Authentication Plugins

The following sections describe the authentication plugins available in MySQL.

The default plugin is `mysql_native_password` unless the `default_authentication_plugin` system variable is set otherwise.

7.1.1 The Native Authentication Plugin

MySQL includes two plugins that implement native authentication; that is, authentication against passwords stored in the `Password` column of the `mysql.user` table. This section describes `mysql_native_password`, which implements authentication against the `mysql.user` table using the native password hashing method. For information about `mysql_old_password`, which implements authentication using the older (pre-4.1) password hashing method, see Section 7.1.2, “The Old Native Authentication Plugin”. For information about these password hashing methods, see Section 2.2.4, “Password Hashing in MySQL”.

The `mysql_native_password` native authentication plugin is backward compatible. Clients older than MySQL 5.5.7 do not support authentication *plugins* but do use the native authentication *protocol*, so they can connect to servers from MySQL 5.5.7 and up.

The following table shows the plugin names on the server and client sides.

Table 7.1 MySQL Native Password Authentication Plugin

Server-side plugin name	`mysql_native_password`
Client-side plugin name	`mysql_native_password`
Library file name	None (plugins are built in)

The plugin exists in both client and server form:

- The server-side plugin is built into the server, need not be loaded explicitly, and cannot be disabled by unloading it.
- The client-side plugin is built into the `libmysqlclient` client library as of MySQL 5.5.7 and available to any program linked against `libmysqlclient` from that version or newer.
- MySQL client programs use `mysql_native_password` by default. The `--default-auth` option can be used as a hint about which client-side plugin the program can expect to use:

```
shell> mysql --default-auth=mysql_native_password ...
```

If an account row specifies no plugin name, the server authenticates the account using either the `mysql_native_password` or `mysql_old_password` plugin, depending on whether the password hash value in the `Password` column used native hashing or the older pre-4.1 hashing method. Clients must match the password in the `Password` column of the account row. As of MySQL 5.7.2, the server requires the plugin value to be nonempty, and as of 5.7.5, support for `mysql_old_password` is removed.

For general information about pluggable authentication in MySQL, see Section 5.8, “Pluggable Authentication”.

7.1.2 The Old Native Authentication Plugin

MySQL includes two plugins that implement native authentication; that is, authentication against passwords stored in the `Password` column of the `mysql.user` table. This section describes `mysql_old_password`, which implements authentication against the `mysql.user` table using the older (pre-4.1) password hashing method. For information about `mysql_native_password`, which implements authentication using the native password hashing method, see Section 7.1.1, "The Native Authentication Plugin". For information about these password hashing methods, see Section 2.2.4, "Password Hashing in MySQL".

> **Note**
>
> Passwords that use the pre-4.1 hashing method are less secure than passwords that use the native password hashing method and should be avoided. Pre-4.1 passwords are deprecated and support for them (including the `mysql_old_password` plugin) is removed in MySQL 5.7.5. For account upgrade instructions, see Section 7.1.3, "Migrating Away from Pre-4.1 Password Hashing and the mysql_old_password Plugin".

The `mysql_old_password` native authentication plugin is backward compatible. Clients older than MySQL 5.5.7 do not support authentication *plugins* but do use the native authentication *protocol*, so they can connect to servers from MySQL 5.5.7 and up.

The following table shows the plugin names on the server and client sides.

Table 7.2 MySQL Old Native Authentication Plugin

Server-side plugin name	`mysql_old_password`
Client-side plugin name	`mysql_old_password`
Library file name	None (plugins are built in)

The plugin exists in both client and server form:

- The server-side plugin is built into the server, need not be loaded explicitly, and cannot be disabled by unloading it.
- The client-side plugin is built into the `libmysqlclient` client library as of MySQL 5.5.7 and available to any program linked against `libmysqlclient` from that version or newer.
- MySQL client programs can use the `--default-auth` option to specify the `mysql_old_password` plugin as a hint about which client-side plugin the program can expect to use:

```
shell> mysql --default-auth=mysql_old_password ...
```

If an account row specifies no plugin name, the server authenticates the account using either the `mysql_native_password` or `mysql_old_password` plugin, depending on whether the password hash value in the `Password` column used native hashing or the older pre-4.1 hashing method. Clients must match the password in the `Password` column of the account row. As of MySQL 5.7.2, the server requires the plugin value to be nonempty, and as of 5.7.5, support for `mysql_old_password` is removed.

For general information about pluggable authentication in MySQL, see Section 5.8, "Pluggable Authentication". For information about setting up proxy users, see Section 5.9, "Proxy Users".

7.1.3 Migrating Away from Pre-4.1 Password Hashing and the mysql_old_password Plugin

The MySQL server authenticates connection attempts for each account listed in the `mysql.user` table using the authentication plugin named in the `plugin` column. If the `plugin` column is empty, the server authenticates the account as follows:

- Before MySQL 5.7.2, the server uses the `mysql_native_password` or `mysql_old_password` plugin implicitly, depending on the format of the password hash in the `Password` column. If the `Password` value is empty or a 4.1 password hash (41 characters), the server uses `mysql_native_password`. If the password value is a pre-4.1 password hash (16 characters), the server uses `mysql_old_password`. (For additional information about these hash formats, see Section 2.2.4, “Password Hashing in MySQL”.)
- As of MySQL 5.7.2, the server requires the `plugin` column to be nonempty and disables accounts that have an empty `plugin` value.

Pre-4.1 password hashes and the `mysql_old_password` plugin are deprecated as of MySQL 5.6.5 and support for them is removed in MySQL 5.7.5. They provide a level of security inferior to that offered by 4.1 password hashing and the `mysql_native_password` plugin.

Given the requirement in MySQL 5.7.2 that the `plugin` column must be nonempty, coupled with removal of `mysql_old_password` support in 5.7.5, DBAs are advised to upgrade accounts as follows:

- Upgrade accounts that use `mysql_native_password` implicitly to use it explicitly
- Upgrade accounts that use `mysql_old_password` (either implicitly or explicitly) to use `mysql_native_password` explicitly

The instructions in this section describe how to perform those upgrades. The result is that no account has an empty `plugin` value and no account uses pre-4.1 password hashing or the `mysql_old_password` plugin.

As a variant on these instructions, DBAs might offer users the choice to upgrade to the `sha256_password` plugin, which authenticates using SHA-256 password hashes. For information about this plugin, see Section 7.1.4, “The SHA-256 Authentication Plugin”.

The following table lists the types of `mysql.user` accounts considered in this discussion.

`plugin` Column	**`Password` Column**	**Authentication Result**	**Upgrade Action**
Empty	Empty	Implicitly uses `mysql_native_password`	Assign plugin
Empty	4.1 hash	Implicitly uses `mysql_native_password`	Assign plugin
Empty	Pre-4.1 hash	Implicitly uses `mysql_old_password`	Assign plugin, rehash password
`mysql_native_password`	Empty	Explicitly uses `mysql_native_password`	None
`mysql_native_password`	4.1 hash	Explicitly uses `mysql_native_password`	None
`mysql_old_password`	Empty	Explicitly uses `mysql_old_password`	Upgrade plugin
`mysql_old_password`	Pre-4.1 hash	Explicitly uses `mysql_old_password`	Upgrade plugin, rehash password

Accounts corresponding to lines for the `mysql_native_password` plugin require no upgrade action (because no change of plugin or hash format is required). For accounts corresponding to lines for which the password is empty, consider asking the account owners to choose a password (or require it by using `ALTER USER` to expire empty account passwords).

Upgrading Accounts from Implicit to Explicit mysql_native_password Use

Accounts that have an empty plugin and a 4.1 password hash use `mysql_native_password` implicitly. To upgrade these accounts to use `mysql_native_password` explicitly, execute these statements:

```
UPDATE mysql.user SET plugin = 'mysql_native_password'
WHERE plugin = '' AND (Password = '' OR LENGTH(Password) = 41);
FLUSH PRIVILEGES;
```

Before MySQL 5.7.2, you can execute those statements to uprade accounts proactively. As of MySQL 5.7.2, you can run `mysql_upgrade`, which performs the same operation among its upgrade actions.

Notes:

- The upgrade operation just described is safe to execute at any time because it makes the `mysql_native_password` plugin explicit only for accounts that already use it implicitly.
- This operation requires no password changes, so it can be performed without affecting users or requiring their involvement in the upgrade process.

Upgrading Accounts from mysql_old_password to mysql_native_password

Accounts that use `mysql_old_password` (either implicitly or explicitly) should be upgraded to use `mysql_native_password` explicitly. This requires changing the plugin *and* changing the password from pre-4.1 to 4.1 hash format.

For the accounts covered in this step that must be upgraded, one of these conditions is true:

- The account uses `mysql_old_password` implicitly because the `plugin` column is empty and the password has the pre-4.1 hash format (16 characters).
- The account uses `mysql_old_password` explicitly.

To identify such accounts, use this query:

```
SELECT User, Host, Password FROM mysql.user
WHERE (plugin = '' AND LENGTH(Password) = 16)
OR plugin = 'mysql_old_password';
```

The following discussion provides two methods for updating that set of accounts. They have differing characteristics, so read both and decide which is most suitable for a given MySQL installation.

Method 1.

Characteristics of this method:

- It requires that server and clients be run with `secure_auth=0` until all users have been upgraded to `mysql_native_password`. (Otherwise, users cannot connect to the server using their old-format password hashes for the purpose of upgrading to a new-format hash.)
- It works for MySQL 5.5 through 5.7.1. As of 5.7.2, it does not work because the server requires accounts to have a nonempty plugin and disables them otherwise. Therefore, if you have already upgraded to 5.7.2 or later, choose Method 2, described later.

You should ensure that the server is running with `secure_auth=0`.

For all accounts that use `mysql_old_password` explicitly, set them to the empty plugin:

```
UPDATE mysql.user SET plugin = ''
WHERE plugin = 'mysql_old_password';
FLUSH PRIVILEGES;
```

To also expire the password for affected accounts, use these statements instead:

```
UPDATE mysql.user SET plugin = '', password_expired = 'Y'
WHERE plugin = 'mysql_old_password';
FLUSH PRIVILEGES;
```

Now affected users can reset their password to use 4.1 hashing. Ask each user who now has an empty plugin to connect to the server and execute these statements:

```
SET old_passwords = 0;
SET PASSWORD = PASSWORD('user-chosen-password');
```

> **Note**
>
> The client-side `--secure-auth` option is enabled by default, so remind users to disable it or they will be unable to connect:
>
> ```
> shell> mysql -u user_name -p --secure-auth=0
> ```

After an affected user has executed those statements, you can set the corresponding account plugin to `mysql_native_password` to make the plugin explicit. Or you can periodically run these statements to find and fix any accounts for which affected users have reset their password:

```
UPDATE mysql.user SET plugin = 'mysql_native_password'
WHERE plugin = '' AND (Password = '' OR LENGTH(Password) = 41);
FLUSH PRIVILEGES;
```

When there are no more accounts with an empty plugin, this query returns an empty result:

```
SELECT User, Host, Password FROM mysql.user
WHERE (plugin = '' AND LENGTH(Password) = 16);
```

At that point, all accounts have been migrated away from pre-4.1 password hashing and the server no longer need be run with `secure_auth=0`.

Method 2.

Characteristics of this method:

- It assigns each affected account a new password, so you must tell each such user the new password and ask the user to choose a new one. Communication of passwords to users is outside the scope of MySQL, but should be done carefully.
- It does not require server or clients to be run with `secure_auth=0`.
- It works for any version of MySQL 5.5 or later (and for 5.7.6 or later has an easier variant).

With this method, you update each account separately due to the need to set passwords individually. *Choose a different password for each account.*

Suppose that `'user1'@'localhost'` is one of the accounts to be upgraded. Modify it as follows:

- In MySQL 5.7.6 and higher, `ALTER USER` provides the capability of modifying both the account password and its authentication plugin, so you need not modify the `mysql.user` table directly:

  ```
  ALTER USER 'user1'@'localhost'
  IDENTIFIED WITH mysql_native_password BY 'DBA-chosen-password';
  ```

  To also expire the account password, use this statement instead:

  ```
  ```

```
ALTER USER 'user1'@'localhost'
IDENTIFIED WITH mysql_native_password BY 'DBA-chosen-password'
PASSWORD EXPIRE;
```

Then tell the user the new password and ask the user to connect to the server with that password and execute this statement to choose a new password:

```
ALTER USER USER() IDENTIFIED BY 'user-chosen-password';
```

- Before MySQL 5.7.6, you must modify the `mysql.user` table directly using these statements:

```
SET old_passwords = 0;
UPDATE mysql.user SET plugin = 'mysql_native_password',
Password = PASSWORD('DBA-chosen-password')
WHERE (User, Host) = ('user1', 'localhost');
FLUSH PRIVILEGES;
```

To also expire the account password, use these statements instead:

```
SET old_passwords = 0;
UPDATE mysql.user SET plugin = 'mysql_native_password',
Password = PASSWORD('DBA-chosen-password'), password_expired = 'Y'
WHERE (User, Host) = ('user1', 'localhost');
FLUSH PRIVILEGES;
```

Then tell the user the new password and ask the user to connect to the server with that password and execute these statements to choose a new password:

```
SET old_passwords = 0;
SET PASSWORD = PASSWORD('user-chosen-password');
```

Repeat for each account to be upgraded.

7.1.4 The SHA-256 Authentication Plugin

MySQL provides an authentication plugin that implements SHA-256 hashing for user account passwords.

> **Important**
>
> To connect to the server using an account that authenticates with the `sha256_password` plugin, you must use either an SSL connection or an unencrypted connection that encrypts the password using RSA, as described later in this section. Either way, use of the `sha256_password` plugin requires that MySQL be built with SSL capabilities. See Chapter 6, *Using Secure Connections*.

The following table shows the plugin names on the server and client sides.

Table 7.3 MySQL SHA-256 Authentication Plugin

Server-side plugin name	`sha256_password`
Client-side plugin name	`sha256_password`
Library file name	None (plugins are built in)

The server-side `sha256_password` plugin is built into the server, need not be loaded explicitly, and cannot be disabled by unloading it. Similarly, clients need not specify the location of the client-side plugin.

To set up an account that uses the `sha256_password` plugin for SHA-256 password hashing, use the following statement for MySQL 5.7.6 and up:

```
CREATE USER 'sha256user'@'localhost'
IDENTIFIED WITH sha256_password BY 'Sh@256Pa33';
```

Before MySQL 5.7.6, use this procedure:

1. Create the account and specify that it authenticates using the `sha256_password` plugin:

   ```
   CREATE USER 'sha256user'@'localhost' IDENTIFIED WITH sha256_password;
   ```

2. Set the `old_passwords` system variable to 2 to cause the `PASSWORD()` function to use SHA-256 hashing of password strings, then set the account password:

   ```
   SET old_passwords = 2;
   SET PASSWORD FOR 'sha256user'@'localhost' = PASSWORD('Sh@256Pa33');
   ```

Alternatively, start the server with the default authentication plugin set to `sha256_password`. For example, put these lines in the server option file:

```
[mysqld]
default_authentication_plugin=sha256_password
```

That causes the `sha256_password` plugin to be used by default for new accounts. As a result, it is possible to create the account and set its password without naming the plugin explicitly using this `CREATE USER` syntax:

```
CREATE USER 'sha256user'@'localhost' IDENTIFIED BY 'Sh@256Pa33';
```

In this case, the server assigns the `sha256_password` plugin to the account and encrypts the password using SHA-256.

Accounts in the `mysql.user` table that use SHA-256 passwords can be identified as rows with `'sha256_password'` in the `plugin` column and a SHA-256 password hash in the `authentication_string` column.

Another consequence of using `sha256_password` as the default authentication plugin is that to create an account that uses a different plugin, you must specify the plugin using an `IDENTIFIED WITH` clause in the `CREATE USER` statement. For example, to use the `mysql_native_password` plugin, use this statement for MySQL 5.7.6 and up:

```
CREATE USER 'nativeuser'@'localhost'
IDENTIFIED WITH mysql_native_password BY 'N@tivePa33';
```

Before MySQL 5.7.6, create the account, then set `old_passwords` appropriately for the plugin before using `SET PASSWORD` to set the account password.

```
CREATE USER 'nativeuser'@'localhost' IDENTIFIED WITH mysql_native_password;
SET old_passwords = 0;
SET PASSWORD FOR 'nativeuser'@'localhost' = PASSWORD('N@tivePa33');
```

Before MySQL 5.7.6, to set or change the password for an account that authenticates using the `sha256_password` plugin, be sure that the value of `old_passwords` is 2 before using `SET PASSWORD`. If `old_passwords` has a value other than 2, an error occurs for attempts to set the password:

```
mysql> SET old_passwords = 0;
mysql> SET PASSWORD FOR 'sha256user'@'localhost' = PASSWORD('NewSh@256Pa33');
ERROR 1827 (HY000): The password hash doesn't have the expected format.
Check if the correct password algorithm is being used with the
```

```
PASSWORD() function.
```

For more information about `old_passwords` and `PASSWORD()`, see Server System Variables, and Encryption and Compression Functions.

MySQL can be compiled using either OpenSSL or yaSSL (see Section 6.1, “OpenSSL Versus yaSSL”). The `sha256_password` plugin works with distributions compiled using either package, but if MySQL is compiled using OpenSSL, RSA encryption is available and `sha256_password` implements the following additional capabilities. (To enable these capabilities, you must also follow the RSA configuration procedure given later in this section.)

- It is possible for the client to transmit passwords to the server using RSA encryption during the client connection process, as described later.
- The server exposes two additional system variables, `sha256_password_private_key_path` and `sha256_password_public_key_path`. It is intended that the database administrator will set these to the names of the RSA private and public key-pair files at server startup if the key files have names that differ from the system variable default values.
- The server exposes a status variable, `Rsa_public_key`, that displays the RSA public key value.
- The `mysql` and `mysqltest` client programs support a `--server-public-key-path` option for specifying an RSA public key file explicitly.

For clients that use the `sha256_password` plugin, passwords are never exposed as cleartext when connecting to the server. How password transmission occurs depends on whether an SSL connection is used and whether RSA encryption is available:

- If an SSL connection is used, the password is sent as cleartext but cannot be snooped because the connection is encrypted using SSL.
- If an SSL connection is not used but RSA encryption is available, the password is sent within an unencrypted connection, but the password is RSA-encrypted to prevent snooping. When the server receives the password, it decrypts it. A scramble is used in the encryption to prevent repeat attacks.
- If an SSL connection is not used and RSA encryption is not available, the `sha256_password` plugin causes the connection attempt to fail because the password cannot be sent without being exposed as cleartext.

As mentioned previously, RSA password encryption is available only if MySQL was compiled using OpenSSL. The implication for MySQL distributions compiled using yaSSL is that SHA-256 passwords can be used only when clients use SSL to access the server. See Section 6.4, “Configuring MySQL to Use Secure Connections”.

Assuming that MySQL has been compiled using OpenSSL, the following procedure describes how to enable RSA encryption of passwords during the client connection process:

1. Create the RSA private and public key-pair files using the instructions in Section 6.6, “Creating SSL and RSA Certificates and Keys”.
2. If the private and public key files are located in the data directory and are named `private_key.pem` and `public_key.pem` (the default values of the `sha256_password_private_key_path` and `sha256_password_public_key_path` system variables), the server will use them automatically at startup.

   Otherwise, in the server option file, set the system variables to the key file names. If the files are located in the server data directory, you need not specify their full path names:

   ```
   [mysqld]
   sha256_password_private_key_path=myprivkey.pem
   sha256_password_public_key_path=mypubkey.pem
   ```

If the key files are not located in the data directory, or to make their locations explicit in the system variable values, use full path names:

```
[mysqld]
sha256_password_private_key_path=/usr/local/mysql/myprivkey.pem
sha256_password_public_key_path=/usr/local/mysql/mypubkey.pem
```

3. Restart the server, then connect to it and check the `Rsa_public_key` status variable value. The value will differ from that shown here, but should be nonempty:

```
mysql> SHOW STATUS LIKE 'Rsa_public_key'\G
*************************** 1. row ***************************
Variable_name: Rsa_public_key
        Value: -----BEGIN PUBLIC KEY-----
MIGfMA0GCSqGSIb3DQEBAQUAA4GNADCBiQKBgQDO9nRUDd+KvSZgY7cNBZMNpwX6
MvE1PbJFXO7u18nJ9lwc99Du/E7lw6CVXw7VKrXPeHbVQUzGyUNkf45Nz/ckaaJa
aLgJOBCIDmNVnyU54OT/1lcs2xiyfaDMe8fCJ64ZwTnKbY2gkt1IMjUAB5Ogd5kJ
g8aV7EtKwyhHb0c30QIDAQAB
-----END PUBLIC KEY-----
```

   If the value is empty, the server found some problem with the key files. Check the error log for diagnostic information.

After the server has been configured with the RSA key files, clients have the option of using them to connect to the server using accounts that authenticate with the `sha256_password` plugin. As mentioned previously, such accounts can use either an SSL connection (in which case RSA is not used) or an unencrypted connection that encrypts the password using RSA. Assume for the following discussion that SSL is not used. Connecting to the server involves no special preparation on the client side. For example:

```
shell> mysql --ssl-mode=DISABLED -u sha256user -p
Enter password: Sh@256Pa33
```

For connection attempts by `sha256user`, the server determines that `sha256_password` is the appropriate authentication plugin and invokes it. The plugin finds that the connection does not use SSL and thus requires the password to be transmitted using RSA encryption. In this case, the plugin sends the RSA public key to the client, which uses it to encrypt the password and returns the result to the server. The plugin uses the RSA key on the server side to decrypt the password and accepts or rejects the connection based on whether the password is correct.

The server sends the public key to the client as needed, but if a copy of the RSA public key is available on the client host, the client can use it to save a round trip in the client/server protocol:

```
shell> mysql --ssl-mode=DISABLED -u sha256user -p --server-public-key-path=file_name
```

The public key value in the file named by the `--server-public-key-path` option should be the same as the key value in the server-side file named by the `sha256_password_public_key_path` system variable. If the key file contains a valid public key value but the value is incorrect, an access-denied error occurs. If the key file does not contain a valid public key, the client program cannot use it. In this case, the `sha256_password` plugin sends the public key to the client as if no `--server-public-key-path` option had been specified.

Client users can get the RSA public key two ways:

- The database administrator can provide a copy of the public key file.
- A client user who can connect to the server some other way can use a `SHOW STATUS LIKE 'Rsa_public_key'` statement and save the returned key value in a file.

7.1.5 The PAM Authentication Plugin

> **Note**
>
> The PAM authentication plugin is an extension included in MySQL Enterprise Edition, a commercial product. To learn more about commercial products, see http://www.mysql.com/products/.

As of MySQL 5.7.9, MySQL Enterprise Edition includes an authentication plugin that enables MySQL Server to use PAM (Pluggable Authentication Modules) to authenticate MySQL users. PAM enables a system to use a standard interface to access various kinds of authentication methods, such as Unix passwords or an LDAP directory.

The PAM authentication plugin provides these capabilities:

- External authentication: The plugin enables MySQL Server to accept connections from users defined outside the MySQL grant tables and that authenticate using methods supported by PAM.
- Proxy user support: The plugin can return to MySQL a user name different from the login user, based on the groups the external user is in and the authentication string provided. This means that the plugin can return the MySQL user that defines the privileges the external PAM-authenticated user should have. For example, a PAM user named `joe` can connect and have the privileges of the MySQL user named `developer`.

The PAM authentication plugin has been tested on Linux and Mac OS X.

The PAM plugin uses the information passed to it by MySQL Server (such as user name, host name, password, and authentication string), plus whatever method is available for PAM lookup. The plugin checks the user credentials against PAM and returns `'Authentication succeeded, Username is user_name'` or `'Authentication failed'`.

The following table shows the plugin and library file names. The file name suffix might be different on your system. The file location must be the directory named by the `plugin_dir` system variable. For installation information, see Section 7.1.5.1, “Installing the PAM Authentication Plugin”.

Table 7.4 MySQL PAM Authentication Plugin

Server-side plugin name	`authentication_pam`
Client-side plugin name	`mysql_clear_password`
Library file name	`authentication_pam.so`

The library file includes only the server-side plugin. The client-side plugin is built into the `libmysqlclient` client library. See Section 7.1.8, “The Cleartext Client-Side Authentication Plugin”.

The server-side PAM authentication plugin is included only in MySQL Enterprise Edition. It is not included in MySQL community distributions. The client-side clear-text plugin that communicates with the server-side plugin is built into the MySQL client library and is included in all distributions, including community distributions. This permits clients from any MySQL distribution to connect to a server that has the server-side plugin loaded.

For general information about pluggable authentication in MySQL, see Section 5.8, “Pluggable Authentication”. For proxy user information, see Section 5.9, “Proxy Users”.

7.1.5.1 Installing the PAM Authentication Plugin

The PAM authentication plugin must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, set the value of `plugin_dir` at server startup to tell the server the plugin directory location.

To enable the plugin, start the server with the `--plugin-load` option. For example, put the following lines in your `my.cnf` file. If library files have a suffix different from `.so` on your system, substitute the correct suffix.

```
[mysqld]
plugin-load=authentication_pam.so
```

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Obtaining Server Plugin Information). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS FROM INFORMATION_SCHEMA.PLUGINS
    -> WHERE PLUGIN_NAME LIKE 'authentication%';
+-------------------+---------------+
| PLUGIN_NAME       | PLUGIN_STATUS |
+-------------------+---------------+
| authentication_pam | ACTIVE        |
+-------------------+---------------+
```

To associate a MySQL account with the PAM plugin, use the plugin name `authentication_pam` in the `IDENTIFIED WITH` clause of `CREATE USER` or `GRANT` statement that creates the account.

7.1.5.2 Using the PAM Authentication Plugin

This section describes how to use the PAM authentication plugin to connect from MySQL client programs to the server. It is assumed that the server-side plugin is enabled, as described previously.

> **Note**
>
> The client-side plugin with which the PAM plugin communicates simply sends the password to the server in clear text so it can be passed to PAM. This may be a security problem in some configurations, but is necessary to use the server-side PAM library. To avoid problems if there is any possibility that the password would be intercepted, clients should connect to MySQL Server using a secure connection. See Section 7.1.8, “The Cleartext Client-Side Authentication Plugin”.

To refer to the PAM authentication plugin in the `IDENTIFIED WITH` clause of a `CREATE USER` or `GRANT` statement, use the name `authentication_pam`. For example:

```
CREATE USER user
  IDENTIFIED WITH authentication_pam
  AS 'authentication_string';
```

The authentication string specifies the following types of information:

- PAM supports the notion of “service name,” which is a name that the system administrator can use to configure the authentication method for a particular application. There can be several such “applications” associated with a single database server instance, so the choice of service name is left to the SQL application developer. When you define an account that should authenticate using PAM, specify the service name in the authentication string.
- PAM provides a way for a PAM module to return to the server a MySQL user name other than the login name supplied at login time. Use the authentication string to control the mapping between login name and MySQL user name. If you want to take advantage of proxy user capabilities, the authentication string must include this kind of mapping.

For example, if the service name is `mysql` and users in the `root` and `users` PAM groups should be mapped to the `developer` and `data_entry` MySQL users, respectively, use a statement like this:

```
CREATE USER user
  IDENTIFIED WITH authentication_pam
  AS 'mysql, root=developer, users=data_entry';
```

Authentication string syntax for the PAM authentication plugin follows these rules:

- The string consists of a PAM service name, optionally followed by a group mapping list consisting of one or more keyword/value pairs each specifying a group name and a MySQL user name:

  ```
  pam_service_name[,group_name=mysql_user_name]...
  ```

  The plugin parses the authentication string on each login check. To minimize overhead, keep the string as short as possible.

- Each *`group_name=mysql_user_name`* pair must be preceded by a comma.
- Leading and trailing spaces not inside double quotation marks are ignored.
- Unquoted *`pam_service_name`*, *`group_name`*, and *`mysql_user_name`* values can contain anything except equal sign, comma, or space.
- If a *`pam_service_name`*, *`group_name`*, or *`mysql_user_name`* value is quoted with double quotation marks, everything between the quotation marks is part of the value. This is necessary, for example, if the value contains space characters. All characters are legal except double quotation mark and backslash (`\`). To include either character, escape it with a backslash.

If the plugin successfully authenticates a login name, it looks for a group mapping list in the authentication string and, if present, uses it to return a different user name to the MySQL server based on the groups the external user is a member of:

- If the authentication string contains no group mapping list, the plugin returns the login name.
- If the authentication string does contain a group mapping list, the plugin examines each *`group_name=mysql_user_name`* pair in the list from left to right and tries to find a match for the *`group_name`* value in a non-MySQL directory of the groups assigned to the authenticated user and returns *`mysql_user_name`* for the first match it finds. If the plugin finds no match for any group, it returns the login name. If the plugin is not capable of looking up a group in a directory, it ignores the group mapping list and returns the login name.

The following sections describe how to set up several authentication scenarios that use the PAM authentication plugin:

- No proxy users. This uses PAM only to check login names and passwords. Every external user permitted to connect to MySQL Server should have a matching MySQL account that is defined to use external PAM authentication. (For a MySQL account of *`user_name@host_name`* to match the external user, *`user_name`* must be the login name and *`host_name`* must match the host from which the client connects.) Authentication can be performed by various PAM-supported methods. The discussion shows how to use traditional Unix passwords and LDAP.

  PAM authentication, when not done through proxy users or groups, requires the MySQL account to have the same user name as the Unix account. Because MySQL user names are limited to 32 characters (16 before MySQL 5.7.8; see Section 4.2, “Grant Tables”), this limits PAM nonproxy authentication to Unix accounts with names of at most 16 characters.

- Proxy login only and group mapping. For this scenario, create one or a few MySQL accounts that define different sets of privileges. (Ideally, nobody should connect using those accounts directly.) Then define a default user authenticating through PAM that uses some mapping scheme (usually by the external groups the users are in) to map all the external logins to the few MySQL accounts holding the privilege sets. Any user that logs in is mapped to one of the MySQL accounts and uses its privileges. The discussion shows how to set this up using Unix passwords, but other PAM methods such as LDAP could be used instead.

Variations on these scenarios are possible. For example, you can permit some users to log in directly (without proxying) but require others to connect through proxy users.

The examples make the following assumptions. You might need to make some adjustments if your system is set up differently.

- The PAM configuration directory is `/etc/pam.d`.
- The PAM service name is `mysql`, which means that you must set up a PAM file named `mysql` in the PAM configuration directory (creating the file if it does not exist). If you use a service name different from `mysql`, the file name will be different and you must use a different name in the `AS 'auth_string'` clause of `CREATE USER` and `GRANT` statements.
- The examples use a login name of `antonio` and password of `verysecret`. Change these to correspond to the users you want to authenticate.

The PAM authentication plugin checks at initialization time whether the `AUTHENTICATION_PAM_LOG` environment value is set in the server's startup environment. If so, the plugin enables logging of diagnostic messages to the standard output. Depending on how your server is started, the message might appear on the console or in the error log. These messages can be helpful for debugging PAM-related problems that occur when the plugin performs authentication. For more information, see Section 7.1.5.6, “PAM Authentication Plugin Debugging”.

7.1.5.3 Unix Password Authentication without Proxy Users

This authentication scenario uses PAM only to check Unix user login names and passwords. Every external user permitted to connect to MySQL Server should have a matching MySQL account that is defined to use external PAM authentication.

1. Verify that Unix authentication in PAM permits you to log in as `antonio` with password `verysecret`.
2. Set up PAM to authenticate the `mysql` service by creating a file named `/etc/pam.d/mysql`. The file contents are system dependent, so check existing login-related files in the `/etc/pam.d` directory to see what they look like. On Linux, the `mysql` file might look like this:

   ```
   #%PAM-1.0
   auth            include         password-auth
   account         include         password-auth
   ```

   For Gentoo Linux, use `system-login` rather than `password-auth`. For OS X, use `login` rather than `password-auth`.

   On Ubuntu and other Debian-based systems, use these file contents instead:

   ```
   @include common-auth
   @include common-account
   @include common-session-noninteractive
   ```

3. Create a MySQL account with the same user name as the Unix login name and define it to authenticate using the PAM plugin:

   ```
   CREATE USER 'antonio'@'localhost'
     IDENTIFIED WITH authentication_pam AS 'mysql';
   GRANT ALL PRIVILEGES ON mydb.* TO 'antonio'@'localhost';
   ```

4. Connect to the MySQL server using the `mysql` command-line client. For example:

   ```
   mysql --user=antonio --password=verysecret --enable-cleartext-plugin mydb
   ```

   The server should permit the connection and the following query should return output as shown:

   ```
   mysql> SELECT USER(), CURRENT_USER(), @@proxy_user;
   +------------------+------------------+--------------+
   | USER()           | CURRENT_USER()   | @@proxy_user |
   +------------------+------------------+--------------+
   ```

```
| antonio@localhost | antonio@localhost | NULL         |
+-------------------+-------------------+--------------+
```

This demonstrates that `antonio` uses the privileges granted to the `antonio` MySQL account, and that no proxying has occurred.

7.1.5.4 LDAP Authentication without Proxy Users

This authentication scenario uses PAM only to check LDAP user login names and passwords. Every external user permitted to connect to MySQL Server should have a matching MySQL account that is defined to use external PAM authentication.

1. Verify that LDAP authentication in PAM permits you to log in as `antonio` with password `verysecret`.

2. Set up PAM to authenticate the `mysql` service through LDAP by creating a file named `/etc/pam.d/mysql`. The file contents are system dependent, so check existing login-related files in the `/etc/pam.d` directory to see what they look like. On Linux, the `mysql` file might look like this:

   ```
   #%PAM-1.0
   auth        required    pam_ldap.so
   account     required    pam_ldap.so
   ```

   If PAM object files have a suffix different from `.so` on your system, substitute the correct suffix.

   The PAM file might have a different format on some systems.

3. MySQL account creation and connecting to the server is the same as previously described in Section 7.1.5.3, “Unix Password Authentication without Proxy Users”.

7.1.5.5 Unix Password Authentication with Proxy Users and Group Mapping

This authentication scheme uses proxying and group mapping to map users who connect to the MySQL server through PAM onto MySQL accounts that define different sets of privileges. Users do not connect directly through the accounts that define the privileges. Instead, they connect through a default proxy user authenticating through PAM that uses a mapping scheme to map all the external logins to the few MySQL accounts holding the privileges. Any user who connects is mapped to one of the MySQL accounts and uses its privileges.

The procedure shown here uses Unix password authentication. To use LDAP instead, see the early steps of Section 7.1.5.4, “LDAP Authentication without Proxy Users”.

1. Verify that Unix authentication in PAM permits you to log in as `antonio` with password `verysecret` and that `antonio` is a member of the `root` or `users` group.

2. Set up PAM to authenticate the `mysql` service. Put the following in `/etc/pam.d/mysql`:

   ```
   #%PAM-1.0
   auth            include         password-auth
   account         include         password-auth
   ```

   use `system-login` rather than `password-auth`. For OS X, use `login` rather than `password-auth`.

   The PAM file might have a different format on some systems. For example, on Ubuntu and other Debian-based systems, use these file contents instead:

   ```
   @include common-auth
   @include common-account
   @include common-session-noninteractive
   ```

3. Create a default proxy user (`''@''`) that maps the external PAM users to the proxied accounts. It maps external users from the `root` PAM group to the `developer` MySQL account and the external users from the `users` PAM group to the `data_entry` MySQL account:

```
CREATE USER ''@''
  IDENTIFIED WITH authentication_pam
  AS 'mysql, root=developer, users=data_entry';
```

   The mapping list following the service name is required when you set up proxy users. Otherwise, the plugin cannot tell how to map the name of PAM groups to the proper proxied user name.

   If your MySQL installation has anonymous users, they might conflict with the default proxy user. For more information about this problem, and ways of dealing with it, see Default Proxy User and Anonymous User Conflicts.

4. Create the proxied accounts that will be used to access the databases:

```
CREATE USER 'developer'@'localhost' IDENTIFIED BY 'very secret password';
GRANT ALL PRIVILEGES ON mydevdb.* TO 'developer'@'localhost';
CREATE USER 'data_entry'@'localhost' IDENTIFIED BY 'very secret password';
GRANT ALL PRIVILEGES ON mydb.* TO 'data_entry'@'localhost';
```

   If you do not let anyone know the passwords for these accounts, other users cannot use them to connect directly to the MySQL server. Instead, it is expected that users will authenticate using PAM and that they will use the `developer` or `data_entry` account by proxy based on their PAM group.

5. Grant the `PROXY` privilege to the proxy account for the proxied accounts:

```
GRANT PROXY ON 'developer'@'localhost' TO ''@'';
GRANT PROXY ON 'data_entry'@'localhost' TO ''@'';
```

6. Connect to the MySQL server using the `mysql` command-line client. For example:

```
mysql --user=antonio --password=verysecret --enable-cleartext-plugin mydb
```

   The server authenticates the connection using the `''@''` account. The privileges `antonio` will have depends on what PAM groups he is a member of. If `antonio` is a member of the `root` PAM group, the PAM plugin maps `root` to the `developer` MySQL user name and returns that name to the server. The server verifies that `''@''` has the `PROXY` privilege for `developer` and permits the connection. the following query should return output as shown:

```
mysql> SELECT USER(), CURRENT_USER(), @@proxy_user;
+-------------------+--------------------+--------------+
| USER()            | CURRENT_USER()     | @@proxy_user |
+-------------------+--------------------+--------------+
| antonio@localhost | developer@localhost | ''@''        |
+-------------------+--------------------+--------------+
```

   This demonstrates that `antonio` uses the privileges granted to the `developer` MySQL account, and that proxying occurred through the default proxy user account.

   If `antonio` is not a member of the `root` PAM group but is a member of the `users` group, a similar process occurs, but the plugin maps `user` group membership to the `data_entry` MySQL user name and returns that name to the server. In this case, `antonio` uses the privileges of the `data_entry` MySQL account:

```
mysql> SELECT USER(), CURRENT_USER(), @@proxy_user;
+-------------------+--------------------+--------------+
| USER()            | CURRENT_USER()     | @@proxy_user |
```

```
+------------------+---------------------+-------------+
| antonio@localhost | data_entry@localhost | ''@''       |
+------------------+---------------------+-------------+
```

7.1.5.6 PAM Authentication Plugin Debugging

The PAM authentication plugin checks at initialization time whether the `AUTHENTICATION_PAM_LOG` environment value is set (the value does not matter). If so, the plugin enables logging of diagnostic messages to the standard output. These messages may be helpful for debugging PAM-related problems that occur when the plugin performs authentication.

Some messages include reference to PAM plugin source files and line numbers, which enables plugin actions to be tied more closely to the location in the code where they occur.

The following transcript demonstrates the kind of information produced by enabling logging. It resulted from a successful proxy authentication attempt.

```
entering auth_pam_server
entering auth_pam_next_token
auth_pam_next_token:reading at [cups,admin=writer,everyone=reader], sep=[,]
auth_pam_next_token:state=PRESPACE, ptr=[cups,admin=writer,everyone=reader],
out=[]
auth_pam_next_token:state=IDENT, ptr=[cups,admin=writer,everyone=reader],
out=[]
auth_pam_next_token:state=AFTERSPACE, ptr=[,admin=writer,everyone=reader],
out=[cups]
auth_pam_next_token:state=DELIMITER, ptr=[,admin=writer,everyone=reader],
out=[cups]
auth_pam_next_token:state=DONE, ptr=[,admin=writer,everyone=reader],
out=[cups]
leaving auth_pam_next_token on
/Users/gkodinov/mysql/work/x-5.5.16-release-basket/release/plugin/pam-authentication-plugin/src/parser.
auth_pam_server:password 12345qq received
auth_pam_server:pam_start rc=0
auth_pam_server:pam_set_item(PAM_RUSER,gkodinov) rc=0
auth_pam_server:pam_set_item(PAM_RHOST,localhost) rc=0
entering auth_pam_server_conv
auth_pam_server_conv:PAM_PROMPT_ECHO_OFF [Password:] received
leaving auth_pam_server_conv on
/Users/gkodinov/mysql/work/x-5.5.16-release-basket/release/plugin/pam-authentication-plugin/src/authent
auth_pam_server:pam_authenticate rc=0
auth_pam_server:pam_acct_mgmt rc=0
auth_pam_server:pam_setcred(PAM_ESTABLISH_CRED) rc=0
auth_pam_server:pam_get_item rc=0
auth_pam_server:pam_setcred(PAM_DELETE_CRED) rc=0
entering auth_pam_map_groups
entering auth_pam_walk_namevalue_list
auth_pam_walk_namevalue_list:reading at: [admin=writer,everyone=reader]
entering auth_pam_next_token
auth_pam_next_token:reading at [admin=writer,everyone=reader], sep=[=]
auth_pam_next_token:state=PRESPACE, ptr=[admin=writer,everyone=reader], out=[]
auth_pam_next_token:state=IDENT, ptr=[admin=writer,everyone=reader], out=[]
auth_pam_next_token:state=AFTERSPACE, ptr=[=writer,everyone=reader],
out=[admin]
auth_pam_next_token:state=DELIMITER, ptr=[=writer,everyone=reader],
out=[admin]
auth_pam_next_token:state=DONE, ptr=[=writer,everyone=reader], out=[admin]
leaving auth_pam_next_token on
/Users/gkodinov/mysql/work/x-5.5.16-release-basket/release/plugin/pam-authentication-plugin/src/parser.
auth_pam_walk_namevalue_list:name=[admin]
entering auth_pam_next_token
auth_pam_next_token:reading at [writer,everyone=reader], sep=[,]
auth_pam_next_token:state=PRESPACE, ptr=[writer,everyone=reader], out=[]
auth_pam_next_token:state=IDENT, ptr=[writer,everyone=reader], out=[]
auth_pam_next_token:state=AFTERSPACE, ptr=[,everyone=reader], out=[writer]
auth_pam_next_token:state=DELIMITER, ptr=[,everyone=reader], out=[writer]
auth_pam_next_token:state=DONE, ptr=[,everyone=reader], out=[writer]
leaving auth_pam_next_token on
/Users/gkodinov/mysql/work/x-5.5.16-release-basket/release/plugin/pam-authentication-plugin/src/parser.
```

```
walk, &error_namevalue_list:value=[writer]
entering auth_pam_map_group_to_user
auth_pam_map_group_to_user:pam_user=gkodinov, name=admin, value=writer
examining member root
examining member gkodinov
substitution was made to mysql user writer
leaving auth_pam_map_group_to_user on
/Users/gkodinov/mysql/work/x-5.5.16-release-basket/release/plugin/pam-authentication-plugin/src/authenticat
auth_pam_walk_namevalue_list:found mapping
leaving auth_pam_walk_namevalue_list on
/Users/gkodinov/mysql/work/x-5.5.16-release-basket/release/plugin/pam-authentication-plugin/src/parser.c:27
auth_pam_walk_namevalue_list returned 0
leaving auth_pam_map_groups on
/Users/gkodinov/mysql/work/x-5.5.16-release-basket/release/plugin/pam-authentication-plugin/src/authenticat
auth_pam_server:authenticated_as=writer
auth_pam_server: rc=0
leaving auth_pam_server on
/Users/gkodinov/mysql/work/x-5.5.16-release-basket/release/plugin/pam-authentication-plugin/src/authenticat
```

7.1.6 The Windows Native Authentication Plugin

> **Note**
>
> The Windows authentication plugin is an extension included in MySQL Enterprise Edition, a commercial product. To learn more about commercial products, see http://www.mysql.com/products/.

As of MySQL 5.7.9, MySQL Enterprise Edition for Windows includes an authentication plugin that performs external authentication on Windows, enabling MySQL Server to use native Windows services to authenticate client connections. Users who have logged in to Windows can connect from MySQL client programs to the server based on the information in their environment without specifying an additional password.

The client and server exchange data packets in the authentication handshake. As a result of this exchange, the server creates a security context object that represents the identity of the client in the Windows OS. This identity includes the name of the client account. The Windows authentication plugin uses the identity of the client to check whether it is a given account or a member of a group. By default, negotiation uses Kerberos to authenticate, then NTLM if Kerberos is unavailable.

The Windows authentication plugin provides these capabilities:

- External authentication: The plugin enables MySQL Server to accept connections from users defined outside the MySQL grant tables.
- Proxy user support: The plugin can return to MySQL a user name different from the client user. This means that the plugin can return the MySQL user that defines the privileges the external Windows-authenticated user should have. For example, a Windows user named `joe` can connect and have the privileges of the MySQL user named `developer`.

The following table shows the plugin and library file names. The file location must be the directory named by the `plugin_dir` system variable. For installation information, see Section 7.1.6.1, “Installing the Windows Authentication Plugin”.

Table 7.5 MySQL Windows Authentication Plugin

Server-side plugin name	`authentication_windows`
Client-side plugin name	`authentication_windows_client`
Library file name	`authentication_windows.dll`

The library file includes only the server-side plugin. The client-side plugin is built into the `libmysqlclient` client library.

The server-side Windows authentication plugin is included only in MySQL Enterprise Edition. It is not included in MySQL community distributions. The client-side plugin is included in all distributions,

including community distributions. This permits clients from any distribution to connect to a server that has the server-side plugin loaded.

The Windows authentication plugin is supported on any version of Windows supported by MySQL 5.7 (see http://www.mysql.com/support/supportedplatforms/database.html).

For general information about pluggable authentication in MySQL, see Section 5.8, “Pluggable Authentication”. For proxy user information, see Section 5.9, “Proxy Users”.

7.1.6.1 Installing the Windows Authentication Plugin

This section describes how to install the Windows authentication plugin. For general information about installing plugins, see Installing and Uninstalling Plugins.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, set the value of `plugin_dir` at server startup to tell the server the plugin directory location.

To enable the plugin, start the server with the `--plugin-load` option. For example, put these lines in your `my.ini` file:

```
[mysqld]
plugin-load=authentication_windows.dll
```

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Obtaining Server Plugin Information). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS FROM INFORMATION_SCHEMA.PLUGINS
    -> WHERE PLUGIN_NAME LIKE 'authentication%';
+-----------------------+---------------+
| PLUGIN_NAME           | PLUGIN_STATUS |
+-----------------------+---------------+
| authentication_windows | ACTIVE        |
+-----------------------+---------------+
```

To associate a MySQL account with the Windows authentication plugin, use the plugin name `authentication_windows` in the `IDENTIFIED WITH` clause of `CREATE USER` or `GRANT` statement that creates the account.

7.1.6.2 Using the Windows Authentication Plugin

The Windows authentication plugin supports the use of MySQL accounts such that users who have logged in to Windows can connect to the MySQL server without having to specify an additional password. It is assumed that the server-side plugin is enabled, as described previously. Once the DBA has enabled the server-side plugin and set up accounts to use it, clients can connect using those accounts with no other setup required on their part.

To refer to the Windows authentication plugin in the `IDENTIFIED WITH` clause of a `CREATE USER` or `GRANT` statement, use the name `authentication_windows`. Suppose that the Windows users `Rafal` and `Tasha` should be permitted to connect to MySQL, as well as any users in the `Administrators` or `Power Users` group. To set this up, create a MySQL account named `sql_admin` that uses the Windows plugin for authentication:

```
CREATE USER sql_admin
  IDENTIFIED WITH authentication_windows
  AS 'Rafal, Tasha, Administrators, "Power Users"';
```

The plugin name is `authentication_windows`. The string following the `AS` keyword is the authentication string. It specifies that the Windows users named `Rafal` or `Tasha` are permitted to authenticate to the server as the MySQL user `sql_admin`, as are any Windows users in the `Administrators` or `Power Users` group. The latter group name contains a space, so it must be quoted with double quote characters.

After you create the `sql_admin` account, a user who has logged in to Windows can attempt to connect to the server using that account:

```
C:\> mysql --user=sql_admin
```

No password is required here. The `authentication_windows` plugin uses the Windows security API to check which Windows user is connecting. If that user is named `Rafal` or `Tasha`, or is in the `Administrators` or `Power Users` group, the server grants access and the client is authenticated as `sql_admin` and has whatever privileges are granted to the `sql_admin` account. Otherwise, the server denies access.

Authentication string syntax for the Windows authentication plugin follows these rules:

- The string consists of one or more user mappings separated by commas.
- Each user mapping associates a Windows user or group name with a MySQL user name:

  ```
  win_user_or_group_name=mysql_user_name
  win_user_or_group_name
  ```

  For the latter syntax, with no *`mysql_user_name`* value given, the implicit value is the MySQL user created by the `CREATE USER` statement. Thus, these statements are equivalent:

  ```
  CREATE USER sql_admin
    IDENTIFIED WITH authentication_windows
    AS 'Rafal, Tasha, Administrators, "Power Users"';
  CREATE USER sql_admin
    IDENTIFIED WITH authentication_windows
    AS 'Rafal=sql_admin, Tasha=sql_admin, Administrators=sql_admin,
        "Power Users"=sql_admin';
  ```

- Each backslash (`'\'`) in a value must be doubled because backslash is the escape character in MySQL strings.
- Leading and trailing spaces not inside double quotation marks are ignored.
- Unquoted *`win_user_or_group_name`* and *`mysql_user_name`* values can contain anything except equal sign, comma, or space.
- If a *`win_user_or_group_name`* and or *`mysql_user_name`* value is quoted with double quotation marks, everything between the quotation marks is part of the value. This is necessary, for example, if the name contains space characters. All characters within double quotes are legal except double quotation mark and backslash. To include either character, escape it with a backslash.
- *`win_user_or_group_name`* values use conventional syntax for Windows principals, either local or in a domain. Examples (note the doubling of backslashes):

  ```
  domain\\user
  .\\user
  domain\\group
  .\\group
  BUILTIN\\WellKnownGroup
  ```

When invoked by the server to authenticate a client, the plugin scans the authentication string left to right for a user or group match to the Windows user. If there is a match, the plugin returns the corresponding *`mysql_user_name`* to the MySQL server. If there is no match, authentication fails.

A user name match takes preference over a group name match. Suppose that the Windows user named `win_user` is a member of `win_group` and the authentication string looks like this:

```
'win_group = sql_user1, win_user = sql_user2'
```

When `win_user` connects to the MySQL server, there is a match both to `win_group` and to `win_user`. The plugin authenticates the user as `sql_user2` because the more-specific user match takes precedence over the group match, even though the group is listed first in the authentication string.

Windows authentication always works for connections from the same computer on which the server is running. For cross-computer connections, both computers must be registered with Windows Active Directory. If they are in the same Windows domain, it is unnecessary to specify a domain name. It is also possible to permit connections from a different domain, as in this example:

```
CREATE USER sql_accounting
  IDENTIFIED WITH authentication_windows
  AS 'SomeDomain\\Accounting';
```

Here `SomeDomain` is the name of the other domain. The backslash character is doubled because it is the MySQL escape character within strings.

MySQL supports the concept of proxy users whereby a client can connect and authenticate to the MySQL server using one account but while connected has the privileges of another account (see Section 5.9, “Proxy Users”). Suppose that you want Windows users to connect using a single user name but be mapped based on their Windows user and group names onto specific MySQL accounts as follows:

- The `local_user` and `MyDomain\domain_user` local and domain Windows users should map to the `local_wlad` MySQL account.
- Users in the `MyDomain\Developers` domain group should map to the `local_dev` MySQL account.
- Local machine administrators should map to the `local_admin` MySQL account.

To set this up, create a proxy account for Windows users to connect to, and configure this account so that users and groups map to the appropriate MySQL accounts (`local_wlad`, `local_dev`, `local_admin`). In addition, grant the MySQL accounts the privileges appropriate to the operations they need to perform. The following instructions use `win_proxy` as the proxy account, and `local_wlad`, `local_dev`, and `local_admin` as the proxied accounts.

1. Create the proxy MySQL account:

   ```
   CREATE USER win_proxy
     IDENTIFIED WITH  authentication_windows
     AS 'local_user = local_wlad,
         MyDomain\\domain_user = local_wlad,
         MyDomain\\Developers = local_dev,
         BUILTIN\\Administrators = local_admin';
   ```

2. For proxying to work, the proxied accounts must exist, so create them:

   ```
   CREATE USER local_wlad IDENTIFIED BY 'wlad_pass';
   CREATE USER local_dev IDENTIFIED BY 'dev_pass';
   CREATE USER local_admin IDENTIFIED BY  'admin_pass';
   ```

   If you do not let anyone know the passwords for these accounts, other users cannot use them to connect directly to the MySQL server.

   You should also issue `GRANT` statements (not shown) that grant each proxied account the privileges it needs.

3. The proxy account must have the `PROXY` privilege for each of the proxied accounts:

   ```
   GRANT PROXY ON local_wlad TO win_proxy;
   ```

```
GRANT PROXY ON local_dev TO win_proxy;
GRANT PROXY ON local_admin TO win_proxy;
```

Now the Windows users `local_user` and `MyDomain\domain_user` can connect to the MySQL server as `win_proxy` and when authenticated have the privileges of the account given in the authentication string—in this case, `local_wlad`. A user in the `MyDomain\Developers` group who connects as `win_proxy` has the privileges of the `local_dev` account. A user in the `BUILTIN\Administrators` group has the privileges of the `local_admin` account.

To configure authentication so that all Windows users who do not have their own MySQL account go through a proxy account, substitute the default proxy user (`''@''`) for `win_proxy` in the preceding instructions. For information about the default proxy user, see Section 5.9, “Proxy Users”.

If your MySQL installation has anonymous users, they might conflict with the default proxy user. For more information about this problem, and ways of dealing with it, see Default Proxy User and Anonymous User Conflicts.

To use the Windows authentication plugin with Connector/Net connection strings in Connection/Net 6.4.4 and higher, see Using the Windows Native Authentication Plugin.

Additional control over the Windows authentication plugin is provided by the `authentication_windows_use_principal_name` and `authentication_windows_log_level` system variables. See Server System Variables.

7.1.7 The No-Login Authentication Plugin

The `mysql_no_login` server-side authentication plugin prevents all client connections to any account that uses it. Use cases for such a plugin includes accounts that must be able to execute stored programs and views with elevated privileges without exposing those privileges to ordinary users, and proxy accounts that should never permit direct login.

The following table shows the plugin and library file names. The file name suffix might differ on your system. The file location is the directory named by the `plugin_dir` system variable. For installation information, see Section 5.8, “Pluggable Authentication”.

Table 7.6 MySQL “No Login” Authentication Plugin

Server-side plugin name	`mysql_no_login`
Client-side plugin name	None
Library file name	`mysql_no_login.so`

An account that authenticates using `mysql_no_login` may be used as the `DEFINER` for stored program and view objects. If such an object definition also includes `SQL SECURITY DEFINER`, it executes with that account's privileges. DBAs can use this behavior to provide access to confidential or sensitive data that is exposed only through well-controlled interfaces.

The following example provides a simple illustration of these principles. It defines an account that does not permit client connections, and associates with it a view that exposes only certain columns of the `mysql.user` table:

```
CREATE DATABASE nologindb;
CREATE USER 'nologin'@'localhost' IDENTIFIED WITH mysql_no_login;
GRANT ALL ON nologindb.* TO 'nologin'@'localhost';
GRANT SELECT ON mysql.user TO 'nologin'@'localhost';
CREATE DEFINER = 'nologin'@'localhost' SQL SECURITY DEFINER
VIEW nologindb.myview AS SELECT User, Host FROM mysql.user;
```

To provide protected access to the view to ordinary users, do this:

```
GRANT SELECT ON nologindb.myview TO 'ordinaryuser'@'localhost';
```

Now the ordinary user can use the view to access the limited information it presents:

```
SELECT * FROM nologindb.myview;
```

Attempts by the user to access columns other than those exposed by the view result in an error.

> **Note**
>
> Because the `nologin` account cannot be used directly, the operations required to set up objects that it uses must be performed by `root` or similar account with the privileges required to create the objects and set `DEFINER` values.

An account that authenticates using `mysql_no_login` may be used as a base user for proxy accounts:

```
CREATE USER 'proxy_base'@'localhost' IDENTIFIED WITH mysql_no_login;
... grant to 'proxy_base'@'localhost' any privileges it requires ...
GRANT PROXY ON 'proxy_base'@'localhost' TO 'real_user'@'localhost';
```

This enables clients to access MySQL through the proxy account but not to bypass the proxy mechanism by connecting directly as the proxy user.

For general information about pluggable authentication in MySQL, see Section 5.8, “Pluggable Authentication”.

7.1.8 The Cleartext Client-Side Authentication Plugin

A client-side authentication plugin is available that sends the password to the server without hashing or encryption. This plugin is built into the MySQL client library.

The following table shows the plugin name.

Table 7.7 MySQL Cleartext Authentication Plugin

Server-side plugin name	None, see discussion
Client-side plugin name	`mysql_clear_password`
Library file name	None (plugin is built in)

With native MySQL authentication, the client performs one-way hashing on the password before sending it to the server. This enables the client to avoid sending the password in clear text. See Section 2.2.4, “Password Hashing in MySQL”. However, because the hash algorithm is one way, the original password cannot be recovered on the server side.

One-way hashing cannot be done for authentication schemes that require the server to receive the password as entered on the client side. In such cases, the `mysql_clear_password` client-side plugin can be used to send the password to the server in clear text. There is no corresponding server-side plugin. Rather, the client-side plugin can be used by any server-side plugin that needs a clear text password. (The PAM authentication plugin is one such; see Section 7.1.5, “The PAM Authentication Plugin”.)

For general information about pluggable authentication in MySQL, see Section 5.8, “Pluggable Authentication”.

> **Note**
>
> Sending passwords in clear text may be a security problem in some configurations. To avoid problems if there is any possibility that the password would be intercepted, clients should connect to MySQL Server using a method that protects the password. Possibilities include SSL (see Chapter 6, *Using Secure Connections*), IPsec, or a private network.

To make inadvertent use of this plugin less likely, it is required that clients explicitly enable it. This can be done several ways:

- Set the `LIBMYSQL_ENABLE_CLEARTEXT_PLUGIN` environment variable to a value that begins with `1`, `Y`, or `y`. This enables the plugin for all client connections.
- The `mysql`, `mysqladmin`, and `mysqlslap` client programs support an `--enable-cleartext-plugin` option that enables the plugin on a per-invocation basis.
- The `mysql_options()` C API function supports a `MYSQL_ENABLE_CLEARTEXT_PLUGIN` option that enables the plugin on a per-connection basis. Also, any program that uses `libmysqlclient` and reads option files can enable the plugin by including an `enable-cleartext-plugin` option in an option group read by the client library.

7.1.9 The Socket Peer-Credential Authentication Plugin

A server-side authentication plugin is available that authenticates clients that connect from the local host through the Unix socket file.

The source code for this plugin can be examined as a relatively simple example demonstrating how to write a loadable authentication plugin.

The following table shows the plugin and library file names. The file name suffix might differ on your system. The file location is the directory named by the `plugin_dir` system variable. For installation information, see Section 5.8, “Pluggable Authentication”.

Table 7.8 MySQL Socket Peer-Credential Authentication Plugin

Server-side plugin name	`auth_socket`
Client-side plugin name	None, see discussion
Library file name	`auth_socket.so`

The `auth_socket` authentication plugin authenticates clients that connect from the local host through the Unix socket file. The plugin uses the `SO_PEERCRED` socket option to obtain information about the user running the client program. Thus, the plugin can be built only on systems that support the `SO_PEERCRED` option, such as Linux.

The plugin checks whether the socket user name matches the MySQL user name specified by the client program to the server. As of MySQL 5.7.6, if the names do not match, the plugin also checks whether the socket user name matches the name specified in the `authentication_string` column of the `mysql.user` table row. If a match is found, the plugin permits the connection.

Suppose that a MySQL account is created for a user named `valerie` who is to be authenticated by the `auth_socket` plugin for connections from the local host through the socket file:

```
CREATE USER 'valerie'@'localhost' IDENTIFIED WITH auth_socket;
```

If a user on the local host with a login name of `stefanie` invokes `mysql` with the option `--user=valerie` to connect through the socket file, the server uses `auth_socket` to authenticate the client. The plugin determines that the `--user` option value (`valerie`) differs from the client user's name (`stephanie`) and refuses the connection. If a user named `valerie` tries the same thing, the plugin finds that the user name and the MySQL user name are both `valerie` and permits the connection. However, the plugin refuses the connection even for `valerie` if the connection is made using a different protocol, such as TCP/IP.

For general information about pluggable authentication in MySQL, see Section 5.8, “Pluggable Authentication”.

7.1.10 The Test Authentication Plugin

MySQL includes a test plugin that authenticates using MySQL native authentication, but is a loadable plugin (not built in) and must be installed prior to use. It can authenticate against either normal or older (shorter) password hash values.

This plugin is intended for testing and development purposes, and not for use in production environments. The test plugin source code is separate from the server source, unlike the built-in native plugin, so it can be examined as a relatively simple example demonstrating how to write a loadable authentication plugin.

The following table shows the plugin and library file names. The file name suffix might differ on your system. The file location is the directory named by the `plugin_dir` system variable. For installation information, see Section 5.8, “Pluggable Authentication”.

Table 7.9 MySQL Test Authentication Plugin

Server-side plugin name	`test_plugin_server`
Client-side plugin name	`auth_test_plugin`
Library file name	`auth_test_plugin.so`

Because the test plugin authenticates the same way as native MySQL authentication, provide the usual `--user` and `--password` options that you normally use for accounts that use native authentication when you connect to the server. For example:

```
shell> mysql --user=your_name --password=your_pass
```

For general information about pluggable authentication in MySQL, see Section 5.8, “Pluggable Authentication”.

7.2 The Password Validation Plugin

The `validate_password` plugin serves to test passwords and improve security. The plugin exposes a set of system variables that enable you to define password policy.

This plugin implements two capabilities:

- In statements that assign a password supplied as a cleartext value, the plugin checks the password against the current password policy and rejects it if it is weak (the statement returns an `ER_NOT_VALID_PASSWORD` error). This affects the `ALTER USER`, `CREATE USER`, `GRANT`, and `SET PASSWORD` statements. Passwords given as arguments to the `PASSWORD()` and `OLD_PASSWORD()` functions are checked as well.
- The `VALIDATE_PASSWORD_STRENGTH()` SQL function assesses the strength of potential passwords. The function takes a password argument and returns an integer from 0 (weak) to 100 (strong).

For example, the cleartext password in the following statement is checked. Under the default password policy, which requires passwords to be at least 8 characters long, the password is weak and the statement produces an error:

```
mysql> ALTER USER USER() IDENTIFIED BY 'abc';
ERROR 1819 (HY000): Your password does not satisfy the current
policy requirements
```

Passwords specified as hashed values are not checked because the original password value is not available:

```
mysql> ALTER USER 'jeffrey'@'localhost'
    -> IDENTIFIED WITH mysql_native_password
    -> AS '*0D3CED9BEC10A777AEC23CCC353A8C08A633045E';
Query OK, 0 rows affected (0.01 sec)
```

System variables having names of the form `validate_password_xxx` represent the parameters that control password policy. To configure password checking, modify these variables; see Section 7.2.2, "Password Validation Plugin Options and Variables".

If the `validate_password` plugin is not installed, the `validate_password_xxx` system variables are not available, passwords in statements are not checked, and the `VALIDATE_PASSWORD_STRENGTH()` function always returns 0. For example, without the plugin installed, accounts can be assigned passwords shorter than 8 characters.

Assuming that the `validate_password` plugin is installed, it implements three levels of password checking: `LOW`, `MEDIUM`, and `STRONG`. The default is `MEDIUM`; to change this, modify the value of `validate_password_policy`. The policies implement increasingly strict password tests. The following descriptions refer to default parameter values, which can be modified by changing the appropriate system variables.

- `LOW` policy tests password length only. Passwords must be at least 8 characters long.
- `MEDIUM` policy adds the conditions that passwords must contain at least 1 numeric character, 1 lowercase character, 1 uppercase character, and 1 special (nonalphanumeric) character.
- `STRONG` policy adds the condition that password substrings of length 4 or longer must not match words in the dictionary file, if one has been specified.

In addition, as of MySQL 5.7.15, the `validate_password` plugin supports the capability of rejecting passwords that match the user name part of the effective user account for the current session, either forward or in reverse. To enable control over this capability, the plugin exposes a `validate_password_check_user_name` system variable. By default, this variable is disabled.

7.2.1 Password Validation Plugin Installation

This section describes how to install the `validate_password` password-validation plugin. For general information about installing plugins, see Installing and Uninstalling Plugins.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, set the value of `plugin_dir` at server startup to tell the server the plugin directory location.

The plugin library file base name is `validate_password`. The file name suffix differs per platform (for example, `.so` for Unix and Unix-like systems, `.dll` for Windows).

To load the plugin at server startup, use the `--plugin-load` option to name the library file that contains the plugin. With this plugin-loading method, the option must be given each time the server starts. For example, put these lines in your `my.cnf` file (adjust the `.so` suffix for your platform as necessary):

```
[mysqld]
plugin-load=validate_password.so
```

Alternatively, to register the plugin at runtime, use this statement (adjust the extension as necessary):

```
INSTALL PLUGIN validate_password SONAME 'validate_password.so';
```

`INSTALL PLUGIN` loads the plugin, and also registers it in the `mysql.plugins` table to cause the plugin to be loaded for each subsequent normal server startup.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Obtaining Server Plugin Information). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS FROM INFORMATION_SCHEMA.PLUGINS
    -> WHERE PLUGIN_NAME LIKE 'validate%';
+-------------------+---------------+
```

```
| PLUGIN_NAME       | PLUGIN_STATUS |
+-------------------+---------------+
| validate_password | ACTIVE        |
+-------------------+---------------+
```

If the plugin has been previously registered with `INSTALL PLUGIN` or is loaded with `--plugin-load`, you can use the `--validate-password` option at server startup to control plugin activation. For example, to load the plugin at startup and prevent it from being removed at runtime, use these options:

```
[mysqld]
plugin-load=validate_password.so
validate-password=FORCE_PLUS_PERMANENT
```

If it is desired to prevent the server from running without the password-validation plugin, use `--validate-password` with a value of `FORCE` or `FORCE_PLUS_PERMANENT` to force server startup to fail if the plugin does not initialize successfully.

7.2.2 Password Validation Plugin Options and Variables

To control the activation of the `validate_password` plugin, use this option:

- `--validate-password[=value]`

Command-Line Format	`--validate-password[=value]`	
Permitted Values	**Type**	enumeration
	Default	`ON`
	Valid Values	`ON`
		`OFF`
		`FORCE`
		`FORCE_PLUS_PERMANENT`

This option controls how the server loads the `validate_password` plugin at startup. The value should be one of those available for plugin-loading options, as described in Installing and Uninstalling Plugins. For example, `--validate-password=FORCE_PLUS_PERMANENT` tells the server to load the plugin at startup and prevents it from being removed while the server is running.

This option is available only if the `validate_password` plugin has been previously registered with `INSTALL PLUGIN` or is loaded with `--plugin-load`. See Section 7.2.1, “Password Validation Plugin Installation”.

If the `validate_password` plugin is enabled, it exposes several system variables representing the parameters that control password checking:

```
mysql> SHOW VARIABLES LIKE 'validate_password%';
+--------------------------------------+--------+
| Variable_name                        | Value  |
+--------------------------------------+--------+
| validate_password_check_user_name    | OFF    |
| validate_password_dictionary_file    |        |
| validate_password_length             | 8      |
| validate_password_mixed_case_count   | 1      |
| validate_password_number_count       | 1      |
| validate_password_policy             | MEDIUM |
| validate_password_special_char_count | 1      |
+--------------------------------------+--------+
```

To change how passwords are checked, you can set these system variables at server startup or at runtime. The following list describes the meaning of each variable.

- `validate_password_check_user_name`

Introduced	5.7.15	
Command-Line Format	`--validate_password_check_user_name`	
System Variable	**Name**	`validate_password_check_user_name`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	boolean
	Default	`OFF`

Whether passwords are compared to the user name part of the effective user account for the current session and rejected if they match. By default, `validate_password_check_user_name` is disabled. This variable controls user name matching independent of the value of `validate_password_policy`.

When `validate_password_check_user_name` is enabled, it has these effects:

- Checking occurs in all contexts for which the `validate_password` plugin is invoked, which includes statements such as `ALTER USER` and `SET PASSWORD`, and invocation of functions such as `PASSWORD()` and `VALIDATE_PASSWORD_STRENGTH()`.
- If a password is the same as the user name or its reverse, a match occurs and the password is rejected.
- If a password matches the user name, `VALIDATE_PASSWORD_STRENGTH()` returns 0 regardless of how other `validate_password` system variables are set.
- The user names used for comparison are taken from the values of the `USER()` and `CURRENT_USER()` functions for the current session. (An implication is that a user who has the `SUPER` privilege can execute a statement to set another user's password to that user name, and cannot set that user's password to the name of the user executing the statement.)
- Only the user name part of the `USER()` and `CURRENT_USER()` function values is used, not the host name part. If a user name is empty, no comparison is done.
- User name matching is case sensitive. The password and user name values are compared as binary strings on a byte-by-byte basis.

- `validate_password_dictionary_file`

System Variable (<= 5.7.7)	**Name**	`validate_password_dictionary_file`
	Variable Scope	Global
	Dynamic Variable	No
System Variable (>= 5.7.8)	**Name**	`validate_password_dictionary_file`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	file name

The path name of the dictionary file used by the `validate_password` plugin for checking passwords. This variable is unavailable unless that plugin is installed.

By default, this variable has an empty value and dictionary checks are not performed. To enable dictionary checks, you must set this variable to a nonempty value. If the file is named as a relative path, it is interpreted relative to the server data directory. Its contents should be lowercase, one word per line. Contents are treated as having a character set of `utf8`. The maximum permitted file size is 1MB.

For the dictionary file to be used during password checking, the password policy must be set to 2 (`STRONG`); see the description of the `validate_password_policy` system variable. Assuming that is true, each substring of the password of length 4 up to 100 is compared to the words in the dictionary file. Any match causes the password to be rejected. Comparisons are not case sensitive.

For `VALIDATE_PASSWORD_STRENGTH()`, the password is checked against all policies, including `STRONG`, so the strength assessment includes the dictionary check regardless of the `validate_password_policy` value.

Before MySQL 5.7.8, changes to the dictionary file while the server is running require a restart for the server to recognize the changes. As of MySQL 5.7.8, `validate_password_dictionary_file` can be set at runtime and assigning a value causes the named file to be read without a restart.

- `validate_password_length`

System Variable	Name	validate_password_length
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	integer
	Default	8
	Min Value	0

The minimum number of characters that passwords checked by the `validate_password` plugin must have. This variable is unavailable unless that plugin is installed.

The `validate_password_length` minimum value is a function of several other related system variables. The server will not set the value less than the value of this expression:

```
validate_password_number_count
+ validate_password_special_char_count
+ (2 * validate_password_mixed_case_count)
```

If the `validate_password` plugin adjusts the value of `validate_password_length` due to the preceding constraint, it writes a message to the error log.

- `validate_password_mixed_case_count`

System Variable	Name	validate_password_mixed_case_count
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	integer
	Default	1

	Min Value	`0`

The minimum number of lowercase and uppercase characters that passwords checked by the `validate_password` plugin must have if the password policy is `MEDIUM` or stronger. For a given value, the password must have that many lowercase characters, and that many uppercase characters. This variable is unavailable unless that plugin is installed.

- `validate_password_number_count`

System Variable	**Name**	`validate_password_number_count`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	integer
	Default	`1`
	Min Value	`0`

The minimum number of numeric (digit) characters that passwords checked by the `validate_password` plugin must have if the password policy is `MEDIUM` or stronger. This variable is unavailable unless that plugin is installed.

- `validate_password_policy`

System Variable	**Name**	`validate_password_policy`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	enumeration
	Default	`1`
	Valid Values	`0`
		`1`
		`2`

The password policy enforced by the `validate_password` plugin. This variable is unavailable unless that plugin is installed.

`validate_password_policy` affects how the plugin uses its other policy-setting system variables, except for checking passwords against user names, which is controlled independently by `validate_password_check_user_name`.

The `validate_password_policy` value can be specified using numeric values 0, 1, 2, or the corresponding symbolic values `LOW`, `MEDIUM`, `STRONG`. The following table describes the tests performed for each policy. For the length test, the required length is the value of the `validate_password_length` system variable. Similarly, the required values for the other tests are given by other `validate_password_xxx` variables.

Policy	Tests Performed
`0` or `LOW`	Length
`1` or `MEDIUM`	Length; numeric, lowercase/uppercase, and special characters

Policy	Tests Performed
2 or STRONG	Length; numeric, lowercase/uppercase, and special characters; dictionary file

- validate_password_special_char_count

System Variable	Name	validate_password_special_char_count
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	integer
	Default	1
	Min Value	0

The minimum number of nonalphanumeric characters that passwords checked by the validate_password plugin must have if the password policy is MEDIUM or stronger. This variable is unavailable unless that plugin is installed.

If the validate_password plugin is enabled, it exposes status variables that provide operational information:

```
mysql> SHOW STATUS LIKE 'validate_password%';
+----------------------------------------------+---------------------+
| Variable_name                                | Value               |
+----------------------------------------------+---------------------+
| validate_password_dictionary_file_last_parsed | 2015-06-29 11:08:51 |
| validate_password_dictionary_file_words_count | 1902                |
+----------------------------------------------+---------------------+
```

The following list describes the meaning of each status variable.

- validate_password_dictionary_file_last_parsed

  When the dictionary file was last parsed.

  This variable was added in MySQL 5.7.8.

- validate_password_dictionary_file_words_count

  The number of words read from the dictionary file.

  This variable was added in MySQL 5.7.8.

7.3 The MySQL Keyring

MySQL Server supports a keyring service that enables internal server components and plugins to securely store sensitive information for later retrieval. The implementation is plugin-based:

- MySQL 5.7.11 and higher includes the initial keyring plugin, keyring_file, which stores keyring data in a file local to the server host. This plugin is available in all MySQL distributions, Community Edition and Enterprise Edition included.

  > **Warning**
  >
  > The keyring_file plugin for encryption key management is not intended as a regulatory compliance solution. Security standards such as PCI, FIPS, and others require use of key management systems to secure, manage, and protect encryption keys in key vaults or hardware security modules (HSMs).

- MySQL 5.7.12 and higher includes `keyring_okv`, a plugin that uses Oracle Key Vault for keyring backend storage. This plugin is available in MySQL Enterprise Edition distributions.
- MySQL 5.7.13 and higher includes an SQL interface for keyring key management, implemented as a set of user-defined functions (UDFs).

The `InnoDB` storage engine uses the keyring to store its key for tablespace encryption. `InnoDB` can use either the `keyring_file` or `keyring_okv` plugin.

For keyring installation instructions, see Section 7.3.1, “Keyring Plugin Installation”.

For information about using the keyring UDFs, see Section 7.3.4, “Keyring Key Management Functions”.

Keyring plugins and UDFs access a keyring service that provides the interface for server components to the keyring. For information about writing keyring plugins or accessing the keyring plugin service, see Writing Keyring Plugins, and The Keyring Service.

7.3.1 Keyring Plugin Installation

Keyring service consumers require a keyring plugin to be installed. MySQL provides these plugin choices:

- `keyring_file`: A plugin that stores keyring data in a file local to the server host. Available in all MySQL distributions as of MySQL 5.7.11.
- `keyring_okv`: A plugin that uses Oracle Key Vault for keyring backend storage. Available in MySQL Enterprise Edition distributions as of MySQL 5.7.12.

This section describes how to install the keyring plugin of your choosing. For general information about installing plugins, see Installing and Uninstalling Plugins.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, set the value of `plugin_dir` at server startup to tell the server the plugin directory location.

Installation for each keyring plugin is similar. The following instructions use `keyring_file`, but Enterprise Edition customers can use the Oracle Key Vault plugin by substituting `keyring_okv` for `keyring_file`.

> **Note**
>
> Only one keyring plugin should be enabled at a time. Enabling multiple keyring plugins is unsupported and results may not be as anticipated.

The keyring plugin must be loaded early during the server startup sequence so that server components can access it as necessary during their own initialization. For example, the `InnoDB` storage engine uses the keyring for tablespace encryption, so the keyring plugin must be loaded and available prior to `InnoDB` initialization.

The `keyring_file` plugin library file base name is `keyring_file`. The file name suffix differs per platform (for example, `.so` for Unix and Unix-like systems, `.dll` for Windows).

To load the plugin, use the `--early-plugin-load` option to name the plugin library file. For example, on platforms where the plugin library file suffix is `.so`, use these lines in the server `my.cnf` file (adjust the `.so` suffix for your platform as necessary):

```
[mysqld]
early-plugin-load=keyring_file.so
```

As of MySQL 5.7.12, the default `--early-plugin-load` value is empty. To load a keyring plugin, you must use an explicit `--early-plugin-load` option with a nonempty value.

> **Important**
>
> In MySQL 5.7.11, the default `--early-plugin-load` value was the name of the `keyring_file` plugin library file, so that plugin was loaded by default. `InnoDB` tablespace encryption requires the `keyring_file` plugin to be loaded prior to `InnoDB` initialization, so this change of default `--early-plugin-load` value introduces an incompatibility for upgrades from 5.7.11 to 5.7.12 or higher. Administrators who have encrypted `InnoDB` tablespaces must take explicit action to ensure continued loading of the `keyring_file` plugin: Start the server with an `--early-plugin-load` option that names the plugin library file.

Before starting the server, check the notes for your chosen keyring plugin to see whether it permits or requires additional configuration:

- For `keyring_file`: Section 7.3.2, “Configuring the keyring_file File-Based Plugin”.
- For `keyring_okv`: Section 7.3.3, “Configuring the keyring_okv Oracle Key Vault Plugin”.

After performing any plugin-specific configuration, start the server. To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Obtaining Server Plugin Information). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS FROM INFORMATION_SCHEMA.PLUGINS
    -> WHERE PLUGIN_NAME LIKE 'keyring%';
+--------------+---------------+
| PLUGIN_NAME  | PLUGIN_STATUS |
+--------------+---------------+
| keyring_file | ACTIVE        |
+--------------+---------------+
```

If no keyring plugin is available when a server component tries to access the keyring service, the service cannot be used by that component. As a result, the component may fail to initialize or may initialize with limited functionality. For example, if `InnoDB` finds that there are encrypted tablespaces when it initializes, it attempts to access the keyring. If the keyring is unavailable, `InnoDB` can access only unencrypted tablespaces. To ensure that `InnoDB` can access encrypted tablespaces as well, use `--early-plugin-load` to load the keyring plugin.

Plugins can be loaded by other methods, such as the `--plugin-load` or `--plugin-load-add` option or the `INSTALL PLUGIN` statement. However, keyring plugins loaded using those methods may be available too late in the server startup sequence for certain server components, such as `InnoDB`:

- Plugin loading using `--plugin-load` or `--plugin-load-add` occurs after `InnoDB` initialization.
- Plugins installed using `INSTALL PLUGIN` are registered in the `mysql.plugin` system table and loaded automatically for subsequent server restarts. However, because `mysql.plugin` is an `InnoDB` table, any plugins named in it can be loaded during startup only after `InnoDB` initialization.

7.3.2 Configuring the keyring_file File-Based Plugin

The `keyring_file` plugin is a keyring plugin that stores keyring data in a file local to the server host.

> **Warning**
>
> The `keyring_file` plugin for encryption key management is not intended as a regulatory compliance solution. Security standards such as PCI, FIPS, and others require use of key management systems to secure, manage, and protect encryption keys in key vaults or hardware security modules (HSMs).

To use the `keyring_file` plugin, use the general installation instructions found in Section 7.3.1, “Keyring Plugin Installation”, together with the plugin-specific configuration information found here.

The `keyring_file_data` system variable configures the location of the file used by the `keyring_file` plugin for data storage. The default value is platform specific. To configure the location explicitly, set the variable value at startup. For example:

```
[mysqld]
early-plugin-load=keyring_file.so
keyring_file_data=/usr/local/mysql/mysql-keyring/keyring
```

Keyring operations are transactional: The `keyring_file` plugin uses a backup file during write operations to ensure that it can roll back to the original file if an operation fails. The backup file has the same name as the value of the `keyring_file_data` system variable with an extension of `.backup`.

For additional information about `keyring_file_data`, see Server System Variables.

7.3.3 Configuring the keyring_okv Oracle Key Vault Plugin

> **Note**
>
> The `keyring_okv` plugin is an extension included in MySQL Enterprise Edition, a commercial product. To learn more about commercial products, see http://www.mysql.com/products/.

The `keyring_okv` plugin is a keyring plugin that uses Oracle Key Vault for keyring backend storage. `keyring_okv` communicates securely with Oracle Key Vault. All keyring material is generated exclusively by the Oracle Key Vault server, not by `keyring_okv`.

To use the `keyring_okv` plugin, use the general installation instructions found in Section 7.3.1, “Keyring Plugin Installation”, together with the plugin-specific configuration information found here.

In Oracle Key Vault terminology, clients that use Oracle Key Vault to store and retrieve security objects are called endpoints. To communicate with Oracle Key Vault, it is necessary to register as an endpoint and enroll by downloading and installing endpoint support files.

The `keyring_okv_conf_dir` system variable configures the location of the directory used by `keyring_okv` for Oracle Key Vault support files. The default value is empty, so you must set it before the plugin can communicate with Oracle Key Vault. The following procedure briefly summarizes the process of configuring this directory:

1. Register an endpoint with Oracle Key Vault to obtain an enrollment token.
2. Use the enrollment token to obtain the `okvclient.jar` client software download.
3. Install the client software to populate a directory for use by `keyring_okv` that contains Oracle Key Vault support files.
4. Set the `keyring_okv_conf_dir` system variable to the directory containing the support files.

Unless you set `keyring_okv_conf_dir` to a properly configured directory, `keyring_okv` writes a message to the error log that it cannot communicate with Oracle Key Vault:

```
[Warning] Plugin keyring_okv reported: 'For keyring_okv to be
initialized, please point the keyring_okv_conf_dir variable to a directory
containing Oracle Key Vault configuration file and ssl materials'
```

Use the following procedure to register with Oracle Key Vault as an endpoint and install the required software. This procedure summarizes only briefly how to interact with Oracle Key Vault. For details, visit the Oracle Key Vault site and consult the Oracle Key Vault Administrator's Guide.

1. Log in to the Oracle Key Vault management console as a user who has the System Administrator role.
2. Select the Endpoints tab to arrive at the Endpoints page, then click Add on the Endpoints page.

3. Provide the required endpoint information and click Register. The endpoint type should be Other. Successful registration results in an enrollment token.

4. Log out from the Oracle Key Vault server.

5. Connect again to the Oracle Key Vault server, this time without logging in. Use the endpoint enrollment token to enroll and request the `okvclient.jar` software download. Save this file to your system.

6. Install the `okvclient.jar` using following command (you must have JDK 1.4 or higher):

   ```
   java -jar okvclient.jar -d dir_name [-v]
   ```

   The directory name following the `-d` option is the location in which to install extracted files. The `-v`, if given, causes log information to be produced that may be useful if the command fails.

   When the command asks for an Oracle Key Vault endpoint password, do not provide one. Instead, press Enter. (The result is that no password will be required when the endpoint connects to Oracle Key Vault.)

7. The preceding command produces an `okvclient.ora` file, which should be in this location under the directory named by the `-d` option in the preceding `java -jar` command:

   ```
   install_dir/conf/okvclient.ora
   ```

   The `okvclient.ora` file should contain settings for `SERVER` and `STANDBY_SERVER` variables. The `keyring_okv` plugin will attempt to communicate with `SERVER` and fall back to `STANDBY_SERVER` if that fails.

8. Go to the Oracle Key Vault installer directory and test the setup by running this command:

   ```
   okvutil/bin/okvutil list
   ```

   The output should look something like this:

   ```
   Unique ID                            Type            Identifier
   255AB8DE-C97F-482C-E053-0100007F28B9 Symmetric Key -
   264BF6E0-A20E-7C42-E053-0100007FB29C Symmetric Key -
   ```

9. Use this command to extract the `ssl` directory containing SSL materials from the `okvclient.jar` file:

   ```
   jar xf okvclient.jar ssl
   ```

Create a directory to be used by `keyring_okv` as the location for its support files. Into that directory, copy the `okvclient.ora` file and the `ssl` directory extracted using the preceding procedure. The directory for `keyring_okv` should have a restrictive mode and be accessible only to the account used to run the server. For example, on Unix and Unix-like systems, to use `/usr/local/mysql/mysql-keyring-okv`, the following commands (executed as `root`) create the directory and set its mode and ownership:

```
shell> cd /usr/local/mysql
shell> mkdir mysql-keyring-okv
shell> chmod 750 mysql-keyring-okv
shell> chown mysql mysql-keyring-okv
shell> chgrp mysql mysql-keyring-okv
```

After installing the Oracle Key Vault support files, tell `keyring_okv` where to find them by setting the `keyring_okv_conf_dir` system variable. For example:

```
[mysqld]
early-plugin-load=keyring_okv.so
keyring_okv_conf_dir=/usr/local/mysql/mysql-keyring-okv
```

For additional information about `keyring_okv_conf_dir`, see Server System Variables.

7.3.4 Keyring Key Management Functions

MySQL Server supports a keyring service that enables internal server components and plugins to securely store sensitive information for later retrieval.

As of MySQL 5.7.13, MySQL Server includes an SQL interface for keyring key management, implemented as a set of user-defined functions (UDFs) that access the functions provided by the internal keyring service. The keyring UDFs are contained in a plugin library file, which also contains a `keyring_udf` plugin that must be enabled prior to UDF invocation. In addition, a keyring plugin such as `keyring_file` or `keyring_okv` must be enabled.

The following sections provide installation instructions for the keyring UDFs and demonstrate how to use them. For information about the keyring service functions invoked by the UDFs, see The Keyring Service. For general keyring information, see Section 7.3, “The MySQL Keyring”.

7.3.4.1 Installing or Uninstalling Keyring Functions

This section describes how to install or uninstall the keyring user-defined functions (UDFs), which are implemented in a plugin library file that also contains a `keyring_udf` plugin. For general information about installing or uninstalling plugins and UDFs, see Installing and Uninstalling Plugins, and UDF Compiling and Installing.

The keyring UDFs enable keyring key management operations, but the `keyring_udf` plugin must also be installed because the UDFs will not work correctly without it. Attempts to use the UDFs without the `keyring_udf` plugin result in an error.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, set the value of `plugin_dir` at server startup to tell the server the plugin directory location.

The plugin library file base name is `keyring_udf`. The file name suffix differs per platform (for example, `.so` for Unix and Unix-like systems, `.dll` for Windows).

To install the `keyring_udf` plugin and the UDFs, use the `INSTALL PLUGIN` and `CREATE FUNCTION` statements (adjust the `.so` suffix for your platform as necessary):

```
INSTALL PLUGIN keyring_udf SONAME 'keyring_udf.so';
CREATE FUNCTION keyring_key_generate RETURNS INTEGER SONAME 'keyring_udf.so';
CREATE FUNCTION keyring_key_fetch RETURNS STRING SONAME 'keyring_udf.so';
CREATE FUNCTION keyring_key_length_fetch RETURNS INTEGER SONAME 'keyring_udf.so';
CREATE FUNCTION keyring_key_type_fetch RETURNS STRING SONAME 'keyring_udf.so';
CREATE FUNCTION keyring_key_store RETURNS INTEGER SONAME 'keyring_udf.so';
CREATE FUNCTION keyring_key_remove RETURNS INTEGER SONAME 'keyring_udf.so';
```

If the plugin and the UDFs are used on a master replication server, install them on all slave servers as well to avoid replication problems.

Once installed as just described, the `keyring_udf` plugin and the UDFs remain installed until uninstalled. To remove them, use the `UNINSTALL PLUGIN` and `DROP FUNCTION` statements:

```
UNINSTALL PLUGIN keyring_udf;
DROP FUNCTION keyring_key_generate;
DROP FUNCTION keyring_key_fetch;
DROP FUNCTION keyring_key_length_fetch;
DROP FUNCTION keyring_key_type_fetch;
DROP FUNCTION keyring_key_store;
DROP FUNCTION keyring_key_remove;
```

7.3.4.2 Using Keyring Functions

Before using the keyring user-defined functions (UDFs), install them according to the instructions provided at Section 7.3.4.1, “Installing or Uninstalling Keyring Functions”.

The keyring UDFs are subject to these constraints:

- To use any keyring UDF, the `keyring_udf` plugin must be enabled. Otherwise, an error occurs:

  ```
  ERROR 1123 (HY000): Can't initialize function 'keyring_key_generate';
  This function requires keyring_udf plugin which is not installed.
  Please install
  ```

  To install the `keyring_udf` plugin, see Section 7.3.4.1, “Installing or Uninstalling Keyring Functions”.

- The keyring UDFs invoke keyring service functions (see The Keyring Service). The service functions in turn use whatever keyring plugin is installed (for example, `keyring_file` or `keyring_okv`). Therefore, to use any keyring UDF, some underlying keyring plugin must be enabled. Otherwise, an error occurs:

  ```
  ERROR 3188 (HY000): Function 'keyring_key_generate' failed because
  underlying keyring service returned an error. Please check if a
  keyring plugin is installed and that provided arguments are valid
  for the keyring you are using.
  ```

  To install a keyring plugin, see Section 7.3.1, “Keyring Plugin Installation”.

- To use any keyring UDF, a user must possess the `EXECUTE` privilege at the global level. Otherwise, an error occurs:

  ```
  ERROR 1123 (HY000): Can't initialize function 'keyring_key_generate';
  The user is not privileged to execute this function. User needs to
  have EXECUTE
  ```

  To grant the `EXECUTE` privilege at the global level to a user, use this statement:

  ```
  GRANT EXECUTE ON *.* TO user;
  ```

  Alternatively, should you prefer to avoid granting the global `EXECUTE` privilege while still permitting users to access specific key-management operations, “wrapper” stored programs can be defined (a technique described later in this section).

- A key stored in the keyring by a given user can be manipulated later only by the same user. That is, the value of the `CURRENT_USER()` function at the time of key manipulation must have the same value as when the key was stored in the keyring. (This constraint rules out the use of the keyring UDFs for manipulation of instance-wide keys, such as those created by `InnoDB` to support tablespace encryption.)

  To enable multiple users to perform operations on the same key, “wrapper” stored programs can be defined (a technique described later in this section).

- Keyring UDFs support the key types and lengths supported by the underlying keyring plugin, with the exception that keys cannot be longer than 2,048 bytes (16,384 bits).

To create a new random key and store it in the keyring, call `keyring_key_generate()`, passing to it an ID for the key, along with the key type (encryption method) and its length in bytes. The following call creates a 2,048-bit DSA-encrypted key named `MyKey`:

```
mysql> SELECT keyring_key_generate('MyKey', 'DSA', 256);
```

```
+----------------------------------------+
| keyring_key_generate('MyKey', 'DSA', 256) |
+----------------------------------------+
|                                      1 |
+----------------------------------------+
```

A return value of 1 indicates success. If the key cannot be created, the return value is `NULL` and an error occurs. To be able to check the return type regardless of whether an error occurs, use `SELECT ... INTO @var_name` and test the variable value:

```
mysql> SELECT keyring_key_generate('', '', -1) INTO @x;
ERROR 3188 (HY000): Function 'keyring_key_generate' failed because
underlying keyring service returned an error. Please check if a
keyring plugin is installed and that provided arguments are valid
for the keyring you are using.
mysql> SELECT @x;
+------+
| @x   |
+------+
| NULL |
+------+
mysql> SELECT keyring_key_generate('x', 'AES', 16) INTO @x;
mysql> SELECT @x;
+------+
| @x   |
+------+
|    1 |
+------+
```

This technique also applies to other keyring UDFs that return `NULL` and an error for failure.

The ID passed to `keyring_key_generate()` provides a means by which to refer to the key in subsequent UDF calls. For example, use the ID to retrieve the key type as a string or the length in bytes as an integer:

```
mysql> SELECT keyring_key_type_fetch('MyKey');
+---------------------------------+
| keyring_key_type_fetch('MyKey') |
+---------------------------------+
| DSA                             |
+---------------------------------+
mysql> SELECT keyring_key_length_fetch('MyKey');
+----------------------------------+
| keyring_key_length_fetch('MyKey') |
+----------------------------------+
|                              256 |
+----------------------------------+
```

To retrieve a key value, pass the key ID to `keyring_key_fetch()`. The following example uses `HEX()` to display the key value because it may contain nonprintable characters. The example also uses a short key for brevity, but be aware that longer keys provide better security:

```
mysql> SELECT keyring_key_generate('MyShortKey', 'DSA', 8);
+---------------------------------------------+
| keyring_key_generate('MyShortKey', 'DSA', 8) |
+---------------------------------------------+
|                                           1 |
+---------------------------------------------+
mysql> SELECT HEX(keyring_key_fetch('MyShortKey'));
+-------------------------------------+
| HEX(keyring_key_fetch('MyShortKey')) |
+-------------------------------------+
| 1DB3B0FC3328A24C                    |
+-------------------------------------+
```

Keyring UDFs treat key IDs, types, and values as binary strings, so comparisons are case sensitive. For example, IDs of `MyKey` and `mykey` refer to different keys.

To remove a key, pass the key ID to `keyring_key_remove()`:

```
mysql> SELECT keyring_key_remove('MyKey');
+----------------------------+
| keyring_key_remove('MyKey') |
+----------------------------+
|                          1 |
+----------------------------+
```

To obfuscate and store a key that you provide, pass the key ID, type, and value to `keyring_key_store()`:

```
mysql> SELECT keyring_key_store('AES_key', 'AES', 'Secret string');
+-----------------------------------------------------+
| keyring_key_store('AES_key', 'AES', 'Secret string') |
+-----------------------------------------------------+
|                                                   1 |
+-----------------------------------------------------+
```

As indicated previously, a user must have the global `EXECUTE` privilege to call keyring UDFs, and the user who stores a key in the keyring initially must be the same user who performs subsequent operations on the key later, as determined from the `CURRENT_USER()` value in effect for each UDF call. To permit key operations to users who do not have the global `EXECUTE` privilege or who may not be the key “owner,” use this technique:

1. Define “wrapper” stored programs that encapsulate the required key operations and have a `DEFINER` value equal to the key owner.
2. Grant the `EXECUTE` privilege for specific stored programs to the individual users who should be able to invoke them.
3. If the operations implemented by the wrapper stored programs do not include key creation, create any necessary keys in advance, using the account named as the `DEFINER` in the stored program definitions.

This technique enables keys to be shared among users and provides to DBAs more fine-grained control over who can do what with keys, without having to grant global privileges.

The following example shows how to set up a shared key named `SharedKey` that is owned by the DBA, and a `get_shared_key()` stored function that provides access to the current key value. The value can be retrieved by any user with the `EXECUTE` privilege for that function, which is created in the `key_schema` schema.

From a MySQL administrative account (`'root'@'localhost'` in this example), create the administrative schema and the stored function to access the key:

```
mysql> CREATE SCHEMA key_schema;
mysql> CREATE DEFINER = 'root'@'localhost'
    -> FUNCTION key_schema.get_shared_key()
    -> RETURNS BLOB READS SQL DATA
    -> RETURN keyring_key_fetch('SharedKey');
```

From the administrative account, ensure that the shared key exists:

```
mysql> SELECT keyring_key_generate('SharedKey', 'DSA', 8);
+-------------------------------------------+
| keyring_key_generate('SharedKey', 'DSA', 8) |
+-------------------------------------------+
|                                         1 |
+-------------------------------------------+
```

From the administrative account, create an ordinary user account to which key access is to be granted:

```
mysql> CREATE USER 'key_user'@'localhost'
    -> IDENTIFIED BY 'key_user_pwd';
```

From the `key_user` account, verify that, without the proper `EXECUTE` privilege, the new account cannot access the shared key:

```
mysql> SELECT HEX(key_schema.get_shared_key());
ERROR 1370 (42000): execute command denied to user 'key_user'@'localhost'
for routine 'key_schema.get_shared_key'
```

From the administrative account, grant `EXECUTE` to `key_user` for the stored function:

```
mysql> GRANT EXECUTE ON FUNCTION key_schema.get_shared_key
    -> TO 'key_user'@'localhost';
```

From the `key_user` account, verify that the key is now accessible:

```
mysql> SELECT HEX(key_schema.get_shared_key());
+---------------------------------+
| HEX(key_schema.get_shared_key()) |
+---------------------------------+
| 9BAFB9E75CEEB013                |
+---------------------------------+
```

7.3.4.3 Keyring Function Reference

This section describes, for each keyring user-defined function (UDF), its purpose, calling sequence, and return value. For information about the conditions under which these UDFs can be invoked, see Section 7.3.4.2, “Using Keyring Functions”.

These keyring UDFs are available:

- `keyring_key_fetch()`

  Given a key ID, deobfuscates and returns the key value.

  Syntax:

  ```
  STRING keyring_key_fetch(STRING key_id)
  ```

  Arguments:

  - `key_id`: The key ID as a string.

  Return values:

  Returns the key value for success, `NULL` if the key does not exist, or `NULL` and an error for failure.

  > **Note**
  >
  > Keyring values retrieved using `keyring_key_fetch()` are limited to 2,048 bytes. A keyring value longer than that length can be stored using a keyring service function (see The Keyring Service), but if retrieved using `keyring_key_fetch()`, will be truncated to 2,048 bytes.

  Example:

  ```
  mysql> SELECT keyring_key_generate('RSA_key', 'RSA', 16);
  +-----------------------------------------+
  | keyring_key_generate('RSA_key', 'RSA', 16) |
  +-----------------------------------------+
  |                                       1 |
  +-----------------------------------------+
  ```

```
mysql> SELECT HEX(keyring_key_fetch('RSA_key'));
+----------------------------------+
| HEX(keyring_key_fetch('RSA_key')) |
+----------------------------------+
| 91C2253B696064D3556984B6630F891A  |
+----------------------------------+
mysql> SELECT keyring_key_type_fetch('RSA_key');
+----------------------------------+
| keyring_key_type_fetch('RSA_key') |
+----------------------------------+
| RSA                              |
+----------------------------------+
mysql> SELECT keyring_key_length_fetch('RSA_key');
+-----------------------------------+
| keyring_key_length_fetch('RSA_key') |
+-----------------------------------+
|                                16 |
+-----------------------------------+
```

The example uses `HEX()` to display the key value because it may contain nonprintable characters. The example also uses a short key for brevity, but be aware that longer keys provide better security.

- `keyring_key_generate()`

  Generates a new random key with a given ID, type, and length, and stores it in the keyring. The type and length values must be consistent with the values supported by the underlying keyring plugin, with the exception that keys cannot be longer than 2,048 bytes (16,384 bits). For the permitted types per plugin, see The Keyring Service.

  Syntax:

  ```
  STRING keyring_key_generate(STRING key_id, STRING key_type, INTEGER key_length)
  ```

  Arguments:

  - `key_id`: The key ID as a string.
  - `key_type`: The key type as a string.
  - `key_length`: The key length in bytes as an integer. The maximum length is 2,048.

  Return values:

  Returns 1 for success, or `NULL` and an error for failure.

  Example:

  ```
  mysql> SELECT keyring_key_generate('RSA_key', 'RSA', 384);
  +-------------------------------------------+
  | keyring_key_generate('RSA_key', 'RSA', 384) |
  +-------------------------------------------+
  |                                         1 |
  +-------------------------------------------+
  ```

- `keyring_key_length_fetch()`

  Given a key ID, returns the key length.

  Syntax:

  ```
  INTEGER keyring_key_length_fetch(STRING key_id)
  ```

  Arguments:

- `key_id`: The key ID as a string.

Return values:

Returns the key length in bytes as an integer for success, `NULL` if the key does not exist, or `NULL` and an error for failure.

Example:

See the description of `keyring_key_fetch()`.

- `keyring_key_remove()`

  Removes the key with a given ID from the keyring.

  Syntax:

```
INTEGER keyring_key_remove(STRING key_id)
```

  Arguments:

  - `key_id`: The key ID as a string.

  Return values:

  Returns 1 for success, or `NULL` for failure.

  Example:

```
mysql> SELECT keyring_key_remove('AES_key');
+------------------------------+
| keyring_key_remove('AES_key') |
+------------------------------+
|                            1 |
+------------------------------+
```

- `keyring_key_store()`

  Obfuscates and stores a key in the keyring.

  Syntax:

```
INTEGER keyring_key_store(STRING key_id, STRING key_type, STRING key)
```

  Arguments:

  - `key_id`: The key ID as a string.
  - `key_type`: The key type as a string.
  - `key`: The key value as a string.

  Return values:

  Returns 1 for success, or `NULL` and an error for failure.

  Example:

```
mysql> SELECT keyring_key_store('new key', 'DSA', 'My key value');
+--------------------------------------------------+
| keyring_key_store('new key', 'DSA', 'My key value') |
```

```
+--------------------------------------------------+
|                                                1 |
+--------------------------------------------------+
```

- `keyring_key_type_fetch()`

  Given a key ID, returns the key type.

  Syntax:

  ```
  STRING keyring_key_type_fetch(STRING key_id)
  ```

  Arguments:

  - `key_id`: The key ID as a string.

  Return values:

  Returns the key type as a string for success, `NULL` if the key does not exist, or `NULL` and an error for failure.

  Example:

  See the description of `keyring_key_fetch()`.

7.4 MySQL Enterprise Audit

> **Note**
>
> MySQL Enterprise Audit is an extension included in MySQL Enterprise Edition, a commercial product. To learn more about commercial products, see http://www.mysql.com/products/.

As of MySQL 5.7.9, MySQL Enterprise Edition includes MySQL Enterprise Audit, implemented using a server plugin named `audit_log`. MySQL Enterprise Audit uses the open MySQL Audit API to enable standard, policy-based monitoring and logging of connection and query activity executed on specific MySQL servers. Designed to meet the Oracle audit specification, MySQL Enterprise Audit provides an out of box, easy to use auditing and compliance solution for applications that are governed by both internal and external regulatory guidelines.

When installed, the audit plugin enables MySQL Server to produce a log file containing an audit record of server activity. The log contents include when clients connect and disconnect, and what actions they perform while connected, such as which databases and tables they access.

After you install the plugin (see Section 7.4.2, “Installing or Uninstalling MySQL Enterprise Audit”), it writes an audit log file. By default, the file is named `audit.log` in the server data directory. To change the name of the file, set the `audit_log_file` system variable at server startup.

Audit log file contents are not encrypted. See Section 7.4.3, “MySQL Enterprise Audit Security Considerations”.

The audit log file is written in XML, with auditable events encoded as `<AUDIT_RECORD>` elements. To select the file format, set the `audit_log_format` system variable at server startup. For details on file format and contents, see Section 7.4.4, “The Audit Log File”.

For more information about controlling how logging occurs, see Section 7.4.5, “Audit Log Logging Control”. To perform filtering of audited events, see Section 7.4.6, “Audit Log Filtering”. For descriptions of the parameters used to configure the audit log plugin, see Section 7.4.7.4, “Audit Log Options and Variables”.

If the `audit_log` plugin is enabled, the Performance Schema (see MySQL Performance Schema) has instrumentation for the audit log plugin. To identify the relevant instruments, use this query:

```
SELECT NAME FROM performance_schema.setup_instruments
WHERE NAME LIKE '%/alog/%';
```

7.4.1 Audit Log Components

MySQL Enterprise Audit is based on the `audit_log` plugin and related components:

- A server-side plugin named `audit_log` examines auditable events and determines whether to write them to the audit log.
- User-defined functions enable manipulation of filtering definitions that control logging behavior.
- Tables in the `mysql` system database provide persistent storage of filter and user account data.
- The `audit_log_filter_id` system variable provides information about whether the current session has an audit filter assigned.

Prior to MySQL 5.7.13, MySQL Enterprise Audit consists only of the `audit_log` plugin and operates in legacy mode. See Section 7.4.6.3, “Legacy Mode Audit Log Filtering”.

7.4.2 Installing or Uninstalling MySQL Enterprise Audit

This section describes how to install or uninstall MySQL Enterprise Audit, which is implemented using the `audit_log` plugin and related components described in Section 7.4.1, “Audit Log Components”. For general information about installing plugins, see Installing and Uninstalling Plugins.

The instructions here apply for MySQL 5.7.13 or higher. For MySQL versions prior to 5.7.13, see Installing MySQL Enterprise Audit in MySQL 5.6 Reference Manual.

> **Note**
>
> If installed, the `audit_log` plugin involves some minimal overhead even when disabled. To avoid this overhead, do not install MySQL Enterprise Audit unless you plan to use it.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, set the value of `plugin_dir` at server startup to tell the server the plugin directory location.

Prior to MySQL 5.7.13, MySQL Enterprise Audit consists only of the `audit_log` plugin and includes none of the other components described in Section 7.4.1, “Audit Log Components”. If the `audit_log` plugin is already installed from a version of MySQL before 5.7.13, uninstall it using the following statement and restart the server before installing the current version:

```
UNINSTALL PLUGIN audit_log;
```

To install MySQL Enterprise Audit, look in the `share` directory of your MySQL installation and choose the script that is appropriate for your platform. The available scripts differ in the suffix used to refer to the plugin library file:

- `audit_log_filter_win_install.sql`: Choose this script for Windows systems that use `.dll` as the file name suffix.
- `audit_log_filter_linux_install.sql`: Choose this script for Linux and similar systems that use `.so` as the file name suffix.

Run the script as follows. The example here uses the Linux installation script. Make the appropriate substitution for your system.

```
shell> mysql -u root -p < audit_log_filter_linux_install.sql
Enter password: (enter root password here)
```

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Obtaining Server Plugin Information). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS FROM INFORMATION_SCHEMA.PLUGINS
    -> WHERE PLUGIN_NAME LIKE 'audit%';
+-------------+---------------+
| PLUGIN_NAME | PLUGIN_STATUS |
+-------------+---------------+
| audit_log   | ACTIVE        |
+-------------+---------------+
```

After MySQL Enterprise Audit is installed, you can use the `--audit-log` option for subsequent server startups to control `audit_log` plugin activation. For example, to prevent the plugin from being removed at runtime, use this option:

```
[mysqld]
audit-log=FORCE_PLUS_PERMANENT
```

If it is desired to prevent the server from running without the audit plugin, use `--audit-log` with a value of `FORCE` or `FORCE_PLUS_PERMANENT` to force server startup to fail if the plugin does not initialize successfully.

> **Note**
>
> By default, rule-based audit log filtering logs no auditable events for any users. This differs from legacy audit log behavior (before MySQL 5.7.13), which logs all auditable events for all users. Should you wish to produce log-everything behavior with rule-based filtering, create a simple filter to enable logging and assign it to the default account:
>
> ```
> SELECT audit_log_filter_set_filter('log_all', '{ "filter": { "log": true } }');
> SELECT audit_log_filter_set_user('%', 'log_all');
> ```
>
> The filter assigned to `%` is used for connections from any account that has no explicitly assigned filter (which initially is true for all accounts).

Once installed as just described, MySQL Enterprise Audit remains installed until uninstalled. To remove it, execute the following statements:

```
DROP TABLE IF EXISTS mysql.audit_log_filter;
DROP TABLE IF EXISTS mysql.audit_log_user;
UNINSTALL PLUGIN audit_log;
DROP FUNCTION audit_log_filter_set_filter;
DROP FUNCTION audit_log_filter_remove_filter;
DROP FUNCTION audit_log_filter_set_user;
DROP FUNCTION audit_log_filter_remove_user;
DROP FUNCTION audit_log_filter_flush;
```

7.4.3 MySQL Enterprise Audit Security Considerations

Contents of the audit log file produced by the `audit_log` plugin are not encrypted and may contain sensitive information, such as the text of SQL statements. For security reasons, this file should be written to a directory accessible only to the MySQL server and users with a legitimate reason to view the log. The default file is `audit.log` in the data directory. This can be changed by setting the `audit_log_file` system variable at server startup.

7.4.4 The Audit Log File

Audit log file contents are not encrypted. See Section 7.4.3, “MySQL Enterprise Audit Security Considerations”.

The audit log file is written as XML, using UTF-8 (up to 4 bytes per character). The root element is `<AUDIT>`. The closing `</AUDIT>` tag of the root element is written when the audit log plugin terminates, so the tag is not present in the file while the plugin is active.

The root element contains `<AUDIT_RECORD>` elements, each of which provides information about an audited event.

MySQL 5.7 changed audit log file output to a new format, it is possible to select either the old or new format using the `audit_log_format` system variable, which has permitted values of `OLD` and `NEW` (default `NEW`).

This section describes only the new log file format. For details about the old format, see The Audit Log File in MySQL 5.6 Reference Manual.

If you change the value of `audit_log_format`, use this procedure to avoid writing log entries in one format to an existing log file that contains entries in a different format:

1. Stop the server.
2. Rename the current audit log file manually.
3. Restart the server with the new value of `audit_log_format`. The audit log plugin will create a new log file, which will contain log entries in the selected format.

Here is a sample log file in the default (new) format, reformatted slightly for readability:

```
<?xml version="1.0" encoding="utf-8"?>
<AUDIT>
 <AUDIT_RECORD>
  <TIMESTAMP>2013-09-17T15:03:24 UTC</TIMESTAMP>
  <RECORD_ID>1_2013-09-17T15:03:24</RECORD_ID>
  <NAME>Audit</NAME>
  <SERVER_ID>1</SERVER_ID>
  <VERSION>1</VERSION>
  <STARTUP_OPTIONS>/usr/local/mysql/bin/mysqld
    --socket=/usr/local/mysql/mysql.sock
    --port=3306</STARTUP_OPTIONS>
  <OS_VERSION>x86_64-osx10.6</OS_VERSION>
  <MYSQL_VERSION>5.7.2-m12-log</MYSQL_VERSION>
 </AUDIT_RECORD>
 <AUDIT_RECORD>
  <TIMESTAMP>2013-09-17T15:03:40 UTC</TIMESTAMP>
  <RECORD_ID>2_2013-09-17T15:03:24</RECORD_ID>
  <NAME>Connect</NAME>
  <CONNECTION_ID>2</CONNECTION_ID>
  <STATUS>0</STATUS>
  <STATUS_CODE>0</STATUS_CODE>
  <USER>root</USER>
  <OS_LOGIN></OS_LOGIN>
  <HOST>localhost</HOST>
  <IP>127.0.0.1</IP>
  <COMMAND_CLASS>connect</COMMAND_CLASS>
  <PRIV_USER>root</PRIV_USER>
  <PROXY_USER></PROXY_USER>
  <DB>test</DB>
 </AUDIT_RECORD>
...
 <AUDIT_RECORD>
  <TIMESTAMP>2013-09-17T15:03:41 UTC</TIMESTAMP>
  <RECORD_ID>4_2013-09-17T15:03:24</RECORD_ID>
  <NAME>Query</NAME>
  <CONNECTION_ID>2</CONNECTION_ID>
  <STATUS>0</STATUS>
  <STATUS_CODE>0</STATUS_CODE>
  <USER>root[root] @ localhost [127.0.0.1]</USER>
  <OS_LOGIN></OS_LOGIN>
```

```
  <HOST>localhost</HOST>
  <IP>127.0.0.1</IP>
  <COMMAND_CLASS>drop_table</COMMAND_CLASS>
  <SQLTEXT>DROP TABLE IF EXISTS t</SQLTEXT>
 </AUDIT_RECORD>
 <AUDIT_RECORD>
  <TIMESTAMP>2013-09-17T15:03:41 UTC</TIMESTAMP>
  <RECORD_ID>5_2013-09-17T15:03:24</RECORD_ID>
  <NAME>Query</NAME>
  <CONNECTION_ID>2</CONNECTION_ID>
  <STATUS>0</STATUS>
  <STATUS_CODE>0</STATUS_CODE>
  <USER>root[root] @ localhost [127.0.0.1]</USER>
  <OS_LOGIN></OS_LOGIN>
  <HOST>localhost</HOST>
  <IP>127.0.0.1</IP>
  <COMMAND_CLASS>create_table</COMMAND_CLASS>
  <SQLTEXT>CREATE TABLE t (i INT)</SQLTEXT>
 </AUDIT_RECORD>
...
 <AUDIT_RECORD>
  <TIMESTAMP>2013-09-17T15:03:41 UTC</TIMESTAMP>
  <RECORD_ID>7_2013-09-17T15:03:24</RECORD_ID>
  <NAME>Quit</NAME>
  <CONNECTION_ID>2</CONNECTION_ID>
  <STATUS>0</STATUS>
  <STATUS_CODE>0</STATUS_CODE>
  <USER></USER>
  <OS_LOGIN></OS_LOGIN>
  <HOST></HOST>
  <IP></IP>
  <COMMAND_CLASS>connect</COMMAND_CLASS>
 </AUDIT_RECORD>
...
 <AUDIT_RECORD>
  <TIMESTAMP>2013-09-17T15:03:47 UTC</TIMESTAMP>
  <RECORD_ID>9_2013-09-17T15:03:24</RECORD_ID>
  <NAME>Shutdown</NAME>
  <CONNECTION_ID>3</CONNECTION_ID>
  <STATUS>0</STATUS>
  <STATUS_CODE>0</STATUS_CODE>
  <USER>root[root] @ localhost [127.0.0.1]</USER>
  <OS_LOGIN></OS_LOGIN>
  <HOST>localhost</HOST>
  <IP>127.0.0.1</IP>
  <COMMAND_CLASS></COMMAND_CLASS>
 </AUDIT_RECORD>
 <AUDIT_RECORD>
  <TIMESTAMP>2013-09-17T15:03:47 UTC</TIMESTAMP>
  <RECORD_ID>10_2013-09-17T15:03:24</RECORD_ID>
  <NAME>Quit</NAME>
  <CONNECTION_ID>3</CONNECTION_ID>
  <STATUS>0</STATUS>
  <STATUS_CODE>0</STATUS_CODE>
  <USER></USER>
  <OS_LOGIN></OS_LOGIN>
  <HOST></HOST>
  <IP></IP>
  <COMMAND_CLASS>connect</COMMAND_CLASS>
 </AUDIT_RECORD>
 <AUDIT_RECORD>
  <TIMESTAMP>2013-09-17T15:03:49 UTC</TIMESTAMP>
  <RECORD_ID>11_2013-09-17T15:03:24</RECORD_ID>
  <NAME>NoAudit</NAME>
  <SERVER_ID>1</SERVER_ID>
 </AUDIT_RECORD>
</AUDIT>
```

Elements within `<AUDIT_RECORD>` elements have these characteristics:

- Some elements appear in every `<AUDIT_RECORD>` element, but many are optional and do not necessarily appear in every element.

- Order of elements within an <AUDIT_RECORD> element is not guaranteed.
- Element values are not fixed length. Long values may be truncated as indicated in the element descriptions given later.
- The <, >, ", and & characters are encoded as <, >, ", and &, respectively. NUL bytes (U+00) are encoded as the ? character.
- Characters not valid as XML characters are encoded using numeric character references. Valid XML characters are:

```
#x9 | #xA | #xD | [#x20-#xD7FF] | [#xE000-#xFFFD] | [#x10000-#x10FFFF]
```

Every <AUDIT_RECORD> element contains a set of mandatory elements. Other optional elements may appear, depending on the audit record type.

The following elements are mandatory in every <AUDIT_RECORD> element:

- <NAME>

  A string representing the type of instruction that generated the audit event, such as a command that the server received from a client.

  Example:

  ```
  <NAME>Query</NAME>
  ```

  Some common <NAME> values:

  ```
  Audit    When auditing starts, which may be server startup time
  Connect  When a client connects, also known as logging in
  Query    An SQL statement (executed directly)
  Prepare  Preparation of an SQL statement; usually followed by Execute
  Execute  Execution of an SQL statement; usually follows Prepare
  Shutdown Server shutdown
  Quit     When a client disconnects
  NoAudit  Auditing has been turned off
  ```

  The possible values are Audit, Binlog Dump, Change user, Close stmt, Connect Out, Connect, Create DB, Daemon, Debug, Delayed insert, Drop DB, Execute, Fetch, Field List, Init DB, Kill, Long Data, NoAudit, Ping, Prepare, Processlist, Query, Quit, Refresh, Register Slave, Reset stmt, Set option, Shutdown, Sleep, Statistics, Table Dump, Time.

  With the exception of Audit and NoAudit, these values correspond to the COM_*xxx* command values listed in the mysql_com.h header file. For example, Create DB and Shutdown correspond to COM_CREATE_DB and COM_SHUTDOWN, respectively.

- <RECORD_ID>

  A unique identifier for the audit record. The value is composed from a sequence number and timestamp, in the format *SEQ_TIMESTAMP*. The sequence number is initialized to the size of the audit log file at the time the audit log plugin opens it and increments by 1 for each record logged. The timestamp is a UTC value in *yyyy-mm-dd*T*hh:mm:ss* format indicating the time when the audit log plugin opened the file.

  Example:

  ```
  <RECORD_ID>28743_2013-09-18T21:03:24</RECORD_ID>
  ```

- <TIMESTAMP>

The date and time that the audit event was generated. For example, the event corresponding to execution of an SQL statement received from a client has a `<TIMESTAMP>` value occurring after the statement finishes, not when it is received. The value has the format *`yyyy-mm-dd`*`Thh:mm:ss UTC` (with `T`, no decimals). The format includes a time zone specifier at the end. The time zone is always UTC.

Example:

```
<TIMESTAMP>2013-09-17T15:03:49 UTC</TIMESTAMP>
```

The following elements are optional in `<AUDIT_RECORD>` elements. Many of them occur only with specific `<NAME>` values.

- `<COMMAND_CLASS>`

  A string that indicates the type of action performed.

  Example:

  ```
  <COMMAND_CLASS>drop_table</COMMAND_CLASS>
  ```

  The values come from the `com_status_vars` array in the `sql/mysqld.cc` file in a MySQL source distribution. They correspond to the status variables displayed by this statement:

  ```
  SHOW STATUS LIKE 'Com%';
  ```

- `<CONNECTION_ID>`

  An unsigned integer representing the client connection identifier. This is the same as the `CONNECTION_ID()` function value within the session.

  Example:

  ```
  <CONNECTION_ID>127</CONNECTION_ID>
  ```

- `<DB>`

  A string representing the default database name. This element appears only if the `<NAME>` value is `Connect` or `Change user`.

- `<HOST>`

  A string representing the client host name. This element appears only if the `<NAME>` value is `Connect`, `Change user`, or `Query`.

  Example:

  ```
  <HOST>localhost</HOST>
  ```

- `<IP>`

  A string representing the client IP address. This element appears only if the `<NAME>` value is `Connect`, `Change user`, or `Query`.

  Example:

  ```
  <IP>127.0.0.1</IP>
  ```

- `<MYSQL_VERSION>`

  A string representing the MySQL server version. This is the same as the value of the `VERSION()` function or `version` system variable. This element appears only if the `<NAME>` value is `Audit`.

  Example:

  ```
  <MYSQL_VERSION>5.7.1-m11-log</MYSQL_VERSION>
  ```

- `<OS_LOGIN>`

  A string representing the external user name used during the authentication process, as set by the plugin used to authenticate the client. With native (built-in) MySQL authentication, or if the plugin does not set the value, this variable is `NULL`. The value is the same as that of the `external_user` system variable. See Section 5.9, “Proxy Users”.

  This element appears only if the `<NAME>` value is `Connect`, `Change user`, or `Query`.

- `<OS_VERSION>`

  A string representing the operating system on which the server was built or is running. This element appears only if the `<NAME>` value is `Audit`.

  Example:

  ```
  <OS_VERSION>x86_64-Linux</OS_VERSION>
  ```

- `<PRIV_USER>`

  A string representing the user that the server authenticated the client as. This is the user name that the server uses for privilege checking, and may differ from the `<USER>` value. This element appears only if the `<NAME>` value is `Connect` or `Change user`.

- `<PROXY_USER>`

  A string representing the proxy user. The value is empty if user proxying is not in effect. This element appears only if the `<NAME>` value is `Connect` or `Change user`.

- `<SERVER_ID>`

  An unsigned integer representing the server ID. This is the same as the value of the `server_id` system variable. This element appears only if the `<NAME>` value is `Audit` or `NoAudit`.

  Example:

  ```
  <SERVER_ID>1</SERVER_ID>
  ```

- `<SQLTEXT>`

  A string representing the text of an SQL statement. The value can be empty. Long values may be truncated. This element appears only if the `<NAME>` value is `Query` or `Execute`.

  The string, like the audit log file itself, is written using UTF-8 (up to 4 bytes per character), so the value may be the result of conversion. For example, the original statement might have been received from the client as an SJIS string.

  Example:

  ```
  <SQLTEXT>DELETE FROM t1</SQLTEXT>
  ```

- `<STARTUP_OPTIONS>`

  A string representing the options that were given on the command line or in option files when the MySQL server was started. This element appears only if the `<NAME>` value is `Audit`.

  Example:

```
<STARTUP_OPTIONS>/usr/local/mysql/bin/mysqld
  --port=3306 --log-output=FILE</STARTUP_OPTIONS>
```

- `<STATUS>`

  An unsigned integer representing the command status: 0 for success, nonzero if an error occurred. This is the same as the value of the `mysql_errno()` C API function.

  The audit log does not contain the SQLSTATE value or error message. To see the associations between error codes, SQLSTATE values, and messages, see Server Error Codes and Messages.

  Warnings are not logged.

  See the description for `<STATUS_CODE>` for information about how it differs from `<STATUS>`.

  Example:

```
<STATUS>1051</STATUS>
```

- `<STATUS_CODE>`

  An unsigned integer representing the command status: 0 for success, 1 if an error occurred.

  The `STATUS_CODE` value differs from the `STATUS` value: `STATUS_CODE` is 0 for success and 1 for error, which is compatible with the EZ_collector consumer for Audit Vault. `STATUS` is the value of the `mysql_errno()` C API function. This is 0 for success and nonzero for error, and thus is not necessarily 1 for error.

  Example:

```
<STATUS_CODE>0</STATUS_CODE>
```

- `<USER>`

  A string representing the user name sent by the client. This may differ from the `<PRIV_USER>` value. This element appears only if the `<NAME>` value is `Connect`, `Change user`, or `Query`.

  Example:

```
<USER>root[root] @ localhost [127.0.0.1]</USER>
```

- `<VERSION>`

  An unsigned integer representing the version of the audit log file format. This element appears only if the `<NAME>` value is `Audit`.

  Example:

```
<VERSION>1</VERSION>
```

7.4.5 Audit Log Logging Control

This section describes how the `audit_log` plugin performs logging and the system variables that control how logging occurs. It assumes familiarity with the log file format described in Section 7.4.4, “The Audit Log File”.

The `audit_log` plugin can also control whether audited events are written to the audit log file based on the account from which events originate or event status. See Section 7.4.6, “Audit Log Filtering”.

When the audit log plugin opens its log file, it checks whether the XML declaration and opening `<AUDIT>` root element tag must be written and writes them if so. When the audit log plugin terminates, it writes a closing `</AUDIT>` tag to the file.

If the log file exists at open time, the plugin checks whether the file ends with an `</AUDIT>` tag and truncates it if so before writing any `<AUDIT_RECORD>` elements. If the log file exists but does not end with `</AUDIT>` or the `</AUDIT>` tag cannot be truncated, the plugin considers the file malformed and fails to initialize. This can occur if the server crashes or is killed with the audit log plugin running. No logging occurs until the problem is rectified. Check the error log for diagnostic information:

```
[ERROR] Plugin 'audit_log' init function returned error.
```

To deal with this problem, either remove or rename the malformed log file and restart the server.

The MySQL server calls the audit log plugin to write an `<AUDIT_RECORD>` element whenever an auditable event occurs, such as when it completes execution of an SQL statement received from a client. Typically the first `<AUDIT_RECORD>` element written after server startup has the server description and startup options. Elements following that one represent events such as client connect and disconnect events, executed SQL statements, and so forth. Only top-level statements are logged, not statements within stored programs such as triggers or stored procedures. Contents of files referenced by statements such as `LOAD DATA INFILE` are not logged.

To permit control over how logging occurs, the `audit_log` plugin provides several system variables, described following. For more information, see Section 7.4.7.4, “Audit Log Options and Variables”.

Audit Log File Naming

To control the audit log file name, set the `audit_log_file` system variable at server startup. By default, the name is `audit.log` in the server data directory. For security reasons, the audit log file should be written to a directory accessible only to the MySQL server and users with a legitimate reason to view the log.

Audit Logging Strategy

The audit log plugin can use any of several strategies for log writes. To specify a strategy, set the `audit_log_strategy` system variable at server startup. By default, the strategy value is `ASYNCHRONOUS` and the plugin logs asynchronously to a buffer, waiting if the buffer is full. It's possible to tell the plugin not to wait (`PERFORMANCE`) or to log synchronously, either using file system caching (`SEMISYNCHRONOUS`) or forcing output with a `sync()` call after each write request (`SYNCHRONOUS`).

Asynchronous logging strategy has these characteristics:

- Minimal impact on server performance and scalability.
- Blocking of threads that generate audit events for the shortest possible time; that is, time to allocate the buffer plus time to copy the event to the buffer.
- Output goes to the buffer. A separate thread handles writes from the buffer to the log file.

A disadvantage of `PERFORMANCE` strategy is that it drops events when the buffer is full. For a heavily loaded server, it is more likely that the audit log will be missing events.

With asynchronous logging, the integrity of the log file may be compromised if a problem occurs during a write to the file or if the plugin does not shut down cleanly (for example, in the event that the server host crashes). To reduce this risk, set `audit_log_strategy` to use synchronous logging. Regardless of strategy, logging occurs on a best-effort basis, with no guarantee of consistency.

Audit Log Space Management

The audit log plugin provides several system variables that enable you to manage the space used by its log files:

- `audit_log_buffer_size`: Set this variable at server startup to set the size of the buffer for asynchronous logging. The plugin uses a single buffer, which it allocates when it initializes and removes when it terminates. The plugin allocates this buffer only if logging is asynchronous.
- `audit_log_rotate_on_size`, `audit_log_flush`: These variables permit audit log file rotation and flushing. The audit log file has the potential to grow very large and consume a lot of disk space. To manage the space used, either enable automatic log rotation, or manually rename the audit file and flush the log to open a new file. The renamed file can be removed or backed up as desired.

  By default, `audit_log_rotate_on_size=0` and there is no log rotation. In this case, the audit log plugin closes and reopens the log file when the `audit_log_flush` value changes from disabled to enabled. Log file renaming must be done externally to the server. Suppose that you want to maintain the three most recent log files, which cycle through the names `audit.log.1.xml` through `audit.log.3.xml`. On Unix, perform rotation manually like this:

  1. From the command line, rename the current log files:

     ```
     mv audit.log.2.xml audit.log.3.xml
     mv audit.log.1.xml audit.log.2.xml
     mv audit.log audit.log.1.xml
     ```

     At this point, the plugin is still writing to the current log file, which has been renamed to `audit.log.1.xml`.

  2. Connect to the server and flush the log file so the plugin closes it and reopens a new `audit.log` file:

     ```
     SET GLOBAL audit_log_flush = ON;
     ```

  If `audit_log_rotate_on_size` is greater than 0, setting `audit_log_flush` has no effect. In this case, the audit log plugin closes and reopens its log file whenever a write to the file causes its size to exceed the `audit_log_rotate_on_size` value. The plugin renames the original file to have an extension consisting of a timestamp and `.xml` suffix. For example, `audit.log` might be renamed to `audit.log.13792588477726520.xml`. The last 7 digits of the timestamp are a fractional second part. The first 10 digits are a Unix timestamp value that can be interpreted using the `FROM_UNIXTIME()` function:

```
mysql> SELECT FROM_UNIXTIME(1379258847);
+---------------------------+
| FROM_UNIXTIME(1379258847) |
+---------------------------+
| 2013-09-15 10:27:27       |
+---------------------------+
```

7.4.6 Audit Log Filtering

> **Note**
>
> This section describes how audit log filtering works as of MySQL 5.7.13 if the `audit_log` plugin and the accompanying audit tables and UDFs are installed.

> If the plugin is installed but not the accompanying audit tables and UDFs, the plugin operates in legacy filtering mode, described in Section 7.4.6.3, “Legacy Mode Audit Log Filtering”. Legacy mode is the behavior that applies prior to MySQL 5.7.13; that is, before the introduction of rule-based filtering.

Prior to MySQL 5.7.13, the audit log plugin had the capability of controlling logging of audited events by filtering them based on the account from which events originate or event status. As of MySQL 5.7.13, filtering capabilities are extended:

- Audited events can be filtered using these characteristics:
  - User account
  - Audit event class
  - Audit event subclass
  - Value of event fields such as those that indicate operation status or SQL statement executed
- Audit filtering is rule based:
  - A filter definition creates a set of auditing rules. Definitions can be configured to include or exclude events based on the characteristics just described.
  - Multiple filters can be defined, and any given filter can be assigned to any number of user accounts.
  - It is possible to define a default filter to use with any user account that has no explicitly assigned filter.
- Audit filters can be defined, displayed, and modified using an SQL interface based on user-defined functions (UDFs).
- Audit filter definitions are stored in the tables in the `mysql` system database.
- Within a given session, the value of the read-only `audit_log_filter_id` system variable indicates whether a filter has been assigned to the session.

The following list provides a brief summary of the UDFs that implement the SQL interface for audit filtering control:

- `audit_log_filter_set_filter()`: Define a filter
- `audit_log_filter_remove_filter()`: Remove a filter
- `audit_log_filter_set_user()`: Start filtering a user account
- `audit_log_filter_remove_user()`: Stop filtering a user account
- `audit_log_filter_flush()`: Flush manual changes to the filter tables to affect ongoing filtering

For usage examples and complete details about the filtering functions, see Section 7.4.6.1, “Using Audit Log Filtering Functions”, and Section 7.4.7.2, “Audit Log Functions”.

The audit log filtering UDFs are subject to these constraints:

- To use any filtering UDF, the `audit_log` plugin must be enabled. Otherwise, an error occurs:

```
mysql> SELECT audit_log_filter_flush();
+-----------------------------------------------------------------------------+
| audit_log_filter_flush()                                                    |
+-----------------------------------------------------------------------------+
```

```
| ERROR: audit_log plugin has not been installed with INSTALL PLUGIN syntax. |
+-----------------------------------------------------------------------------+
```

The audit tables must also exist or an error occurs:

```
mysql> SELECT audit_log_filter_flush();
+------------------------------------------------+
| audit_log_filter_flush()                       |
+------------------------------------------------+
| ERROR: Could not reinitialize audit log filters. |
+------------------------------------------------+
```

To install the `audit_log` plugin, see Section 7.4.2, “Installing or Uninstalling MySQL Enterprise Audit”.

- To use any filtering UDF, a user must possess the `SUPER` privilege. Otherwise, an error occurs:

```
mysql> SELECT audit_log_filter_flush()\G
*************************** 1. row ***************************
audit_log_filter_flush(): ERROR: Request ignored for 'user1'@'localhost'.
                          SUPER_ACL needed to perform operation
```

To grant the `SUPER` privilege to a user account, use this statement:

```
GRANT SUPER ON *.* TO user;
```

Alternatively, should you prefer to avoid granting the `SUPER` privilege while still permitting users to access specific filtering functions, “wrapper” stored programs can be defined. This technique is described in the context of keyring UDFs in Section 7.3.4.2, “Using Keyring Functions”; it can be adapted for use with filtering UDFs.

- The `audit_log` plugin operates in legacy mode if it is installed but the accompanying audit tables and UDFs are not created. These messages are written to the error log at server startup:

```
[Warning] Plugin audit_log reported: 'Failed to open the audit log filter tables.'
[Warning] Plugin audit_log reported: 'Audit Log plugin supports a filtering,
which has not been installed yet. Audit Log plugin will run in the legacy
mode, which will be disabled in the next release.'
```

In legacy mode, filtering can be done based only on event account or status. For details, see Section 7.4.6.3, “Legacy Mode Audit Log Filtering”.

7.4.6.1 Using Audit Log Filtering Functions

Before using the audit log user-defined functions (UDFs), install them according to the instructions provided at Section 7.4.2, “Installing or Uninstalling MySQL Enterprise Audit”.

The audit log filtering functions enable filtering control by providing an interface to create, modify, and remove filter definitions and assign filters to user accounts.

Filter definitions are `JSON` values. For information about using `JSON` data in MySQL, see The JSON Data Type. This section shows some simple filter definitions. For more information about filter definitions, see Section 7.4.6.2, “Writing Audit Log Filter Definitions”.

When a connection arrives, the `audit_log` plugin determines which filter to use for the new session by searching for the user account name in the current filter assignments:

- If a filter is assigned to the user, that filter is used.
- Otherwise, if no assignment exists, but there is a filter assigned to the default account (`%`), the default filter is used.

- Otherwise, no audit events are logged for the session.

If a change-user operation occurs during a session (see mysql_change_user()), filter assignment for the session is updated using the same rules but for the new user.

By default, no accounts have a filter assigned, so no logging of auditable events occurs for any account.

Suppose that instead you want the default to be to log only connection-related activity (for example, to see connect, change-user, and disconnect events, but not the SQL statements users execute while connected). To achieve this, define a filter (shown here named `log_conn_events`) that enables logging only of events in the `connection` class, and assign that filter to the default account, represented by the `%` account name:

```
SET @f = '{ "filter": { "class": { "name": "connection" } } }';
SELECT audit_log_filter_set_filter('log_conn_events', @f);
SELECT audit_log_filter_set_user('%', 'log_conn_events');
```

Now connections from any account that has no explicitly defined filter use this default account filter.

To assign a filter explicitly to a particular user account or accounts, define the filter, then assign it to the relevant accounts:

```
SELECT audit_log_filter_set_filter('log_all', '{ "filter": { "log": true } }');
SELECT audit_log_filter_set_user('user1@localhost', 'log_all');
SELECT audit_log_filter_set_user('user2@localhost', 'log_all');
```

Now full logging is enabled for `user1@localhost` and `user2@localhost`. Connections from other accounts continue to be filtered using the default account filter.

To disassociate a user account from its current filter, either unassign the filter or assign a different filter:

- Unassign the filter from the user account:

  ```
  SELECT audit_log_filter_remove_user('user1@localhost');
  ```

  Filtering of current sessions for the account remains unaffected. Subsequent connections from the account are filtered using the default account filter if there is one, and are not logged otherwise.

- Assign a different filter to the user account:

  ```
  SELECT audit_log_filter_set_filter('log_nothing', '{ "filter": { "log": false } }');
  SELECT audit_log_filter_set_user('user1@localhost', 'log_nothing');
  ```

  Filtering of current sessions for the account remains unaffected. Subsequent connections from the account are filtered using the new filter. For the filter shown here, that means no logging for new connections from `user1@localhost`.

For audit log filtering, user name and host name comparisons are case sensitive. This differs from comparisons for privilege checking, for which host name comparisons are not case sensitive.

To remove a filter, do this:

```
SELECT audit_log_filter_remove_filter('log_nothing');
```

Removing a filter also unassigns it from any users to whom it has been assigned, including any current sessions for those users.

The filtering UDFs just described affect audit filtering immediately and update the audit log tables in the `mysql` system database that store filters and user accounts (see Section 7.4.7.1, “Audit Log Tables”).

It is also possible to modify those tables directly using statements such as `INSERT`, `UPDATE`, and `DELETE`, but such changes do not affect filtering immediately. To flush your changes and make them operational, call `audit_log_filter_flush()`:

```
SELECT audit_log_filter_flush();
```

To determine whether a filter has been assigned to the current session, check the session value of the read-only `audit_log_filter_id` system variable. If the value is 0, no filter is assigned. If the value is nonzero, it is the internally maintained ID of the assigned filter:

```
mysql> SELECT @@audit_log_filter_id;
+-----------------------+
| @@audit_log_filter_id |
+-----------------------+
|                     2 |
+-----------------------+
```

7.4.6.2 Writing Audit Log Filter Definitions

Filter definitions are `JSON` values. For information about using `JSON` data in MySQL, see The JSON Data Type.

Filter definitions have this form, where *`actions`* indicates how filtering takes place:

```
{ "filter": actions }
```

The following discussion describes permitted constructs in filter definitions.

Logging All Events

To explicitly enable or disable logging of all events, use a `log` element in the filter:

```
{
  "filter": { "log": true }
}
```

The `log` value can be either `true` or `false`.

The preceding filter enables logging of all events. It is equivalent to:

```
{
  "filter": { }
}
```

Logging behavior depends on the `log` value and whether `class` or `event` items are specified:

- With `log` specified, its given value is used.
- Without `log` specified, logging is `true` if no `class` or `event` item is specified, and `false` otherwise (in which case, `class` or `event` can include their own `log` item).

Logging Specific Event Classes

To log events of a specific class, use a `class` element in the filter, with its `name` field denoting the name of the class to log:

```
{
  "filter": {
    "class": { "name": "connection" }
  }
}
```

The `name` value can be `connection`, `general`, or `table_access` to log connection, general, or table-access events, respectively.

The preceding filter enables logging of events in the `connection` class. It is equivalent to the following filter with `log` items made explicit:

```
{
  "filter": {
    "log": false,
    "class": { "log": true,
               "name": "connection" }
  }
}
```

To enable logging of multiple classes, define the `class` value as a `JSON` array element that names the classes:

```
{
  "filter": {
    "class": [
      { "name": "connection" },
      { "name": "general" },
      { "name": "table_access" }
    ]
  }
}
```

> **Note**
>
> When multiple instances of a given item appear at the same level within a filter definition, the item values can be combined into a single instance of that item within an array value. The preceding definition can be written like this:
>
> ```
> {
>   "filter": {
>     "class": [
>       { "name": [ "connection", "general", "table_access" ] }
>     ]
>   }
> }
> ```

Logging Specific Event Subclasses

To enable logging for specific event subclasses, use an `event` item:

```
{
  "filter": {
    "class": [
      {
        "name": "connection",
        "event": [
          { "name": "connect" },
          { "name": "disconnect" }
        ]
      },
      { "name": "general" },
      {
        "name": "table_access",
        "event": [
          { "name": "insert" },
          { "name": "delete" },
          { "name": "update" }
        ]
      },
    ]
  }
```

```
}
```

Table 7.10, “Subclass Values Per Event Class” describes the permitted subclass values for each event class.

Table 7.10 Subclass Values Per Event Class

Event Class	Event Subclass	Description
`connection`	`connect`	Connection initiation (successful or unsuccessful)
	`change_user`	User re-authentication with different user/password during session
	`disconnect`	Connection termination
`general`	`status`	General operation information
`table_access`	`read`	Table read statements, such as `SELECT` or `INSERT INTO ... SELECT`
	`delete`	Table delete statements, such as `DELETE` or `TRUNCATE TABLE`
	`insert`	Table insert statements, such as `INSERT` or `REPLACE`
	`update`	Table update statements, such as `UPDATE`

Inclusive and Exclusive Logging

A filter can be defined in inclusive or exclusive mode:

- Inclusive mode logs only explicitly specified items.
- Exclusive mode logs everything but explicitly specified items.

To perform inclusive logging, disable logging globally and enable logging for specific classes. This filter logs `connect` and `disconnect` events in the `connection` class, and events in the `general` class:

```
{
  "filter": {
    "log": false,
    "class": [
      {
        "name": "connection",
        "event": [
          { "name": "connect", "log": true },
          { "name": "disconnect", "log": true }
        ]
      },
      { "name": "general", "log": true }
    ]
  }
}
```

To perform exclusive logging, enable logging globally and disable logging for specific classes. This filter logs everything except events in the `general` class:

```
{
  "filter": {
    "log": true,
    "class":
      { "name": "general", "log": false }
  }
}
```

This filter logs `change_user` events in the `connection` class, and `table_access` events:

```
{
  "filter": {
```

```
    "log": true,
    "class": [
      {
        "name": "connection",
        "event": [
          { "name": "connect", "log": false },
          { "name": "disconnect", "log": false }
        ]
      },
      { "name": "general", "log": false }
    ]
  }
}
```

Testing Event Field Values

To enable logging based on specific event field values, specify a `field` item within the `log` item that indicates the field name and its expected value:

```
{
  "filter": {
    "class": {
    "name": "general",
      "event": {
        "name": "status",
        "log": {
          "field": { "name": "general_command.str", "value": "Query" }
        }
      }
    }
  }
}
```

Each event contains event class-specific fields that can be accessed from within a filter to perform custom filtering.

A connection event indicates when a connection-related activity occurs during a session, such as a user connecting to or disconnecting from the server. Table 7.11, “Connection Event Fields” indicates the permitted fields for connection events.

Table 7.11 Connection Event Fields

Field Name	Field Type	Description
`status`	integer	Event status:
		0: OK
		Otherwise: Failed
`connection_id`	unsigned integer	Connection ID
`user.str`	string	User name specified during authentication
`user.length`	unsigned integer	User name length
`priv_user.str`	string	Authenticated user name (account user name)
`priv_user.length`	unsigned integer	Authenticated user name length
`external_user.str`	string	External user name (provided by third-party authentication plugin)
`external_user.length`	unsigned integer	External user name length
`proxy_user.str`	string	Proxy user name
`proxy_user.length`	unsigned integer	Proxy user name length
`host.str`	string	Connected user host
`host.length`	unsigned integer	Connected user host length

Field Name	Field Type	Description
ip.str	string	Connected user IP address
ip.length	unsigned integer	Connected user IP address length
database.str	string	Database name specified at connect time
database.length	unsigned integer	Database name length
connection_type	integer	Connection type:
		0 or "::undefined": Undefined
		1 or "::tcp/ip": TCP/IP
		2 or "::socket": Socket
		3 or "::named_pipe": Named pipe
		4 or "::ssl": SSL
		5 or "::shared_memory": Shared memory

The "::*xxx*" values are symbolic pseudo-constants that may be given instead of the literal numeric values. They must be quoted as strings and are case sensitive.

A general event indicates the status code of an operation and its details. Table 7.12, "General Event Fields" indicates the permitted fields for general events.

Table 7.12 General Event Fields

Field Name	Field Type	Description
general_error_code	integer	Event status:
		0: OK
		Otherwise: Failed
general_thread_id	unsigned integer	Connection/thread ID
general_user.str	string	User name specified during authentication
general_user.length	unsigned integer	User name length
general_command.str	string	Command name
general_command.length	unsigned integer	Command name length
general_query.str	string	SQL statement text
general_query.length	unsigned integer	SQL statement text length
general_host.str	string	Host name
general_host.length	unsigned integer	Host name length
general_sql_command.str	string	SQL command type name
general_sql_command.length	unsigned integer	SQL command type name length
general_external_user.str	string	External user name (provided by third-party authentication plugin)
general_external_user.length	unsigned integer	External user name length
general_ip.str	string	Connected user IP address
general_ip.length	unsigned integer	Connection user IP address length

general_command.str indicates a command name: Query, Execute, Quit, or Change user.

A general event with the general_command.str field set to Query or Execute contains general_sql_command.str set to a value that specifies the type of SQL command: alter_db, alter_db_upgrade, admin_commands, and so forth. These values can be seen as the last components of the Performance Schema instruments displayed by this statement:

```
mysql> SELECT NAME FROM performance_schema.setup_instruments
    -> WHERE NAME LIKE 'statement/sql/%' ORDER BY NAME;
+--------------------------------------+
| NAME                                 |
+--------------------------------------+
| statement/sql/alter_db               |
| statement/sql/alter_db_upgrade       |
| statement/sql/alter_event            |
| statement/sql/alter_function         |
| statement/sql/alter_instance         |
| statement/sql/alter_procedure        |
| statement/sql/alter_server           |
...
```

A table-access event provides information about specific table accesses. Table 7.13, “Table-Access Event Fields” indicates the permitted fields for table-access events.

Table 7.13 Table-Access Event Fields

Field Name	Field Type	Description
`connection_id`	unsigned integer	Event connection ID
`sql_command_id`	integer	SQL command ID
`query.str`	string	SQL statement text
`query.length`	unsigned integer	SQL statement text length
`table_database.str`	string	Database name associated with event
`table_database.length`	unsigned integer	Database name length
`table_name.str`	string	Table name associated with event
`table_name.length`	unsigned integer	Table name length

The following list shows which statements produce which table-access events:

- `read` event:
  - `SELECT`
  - `INSERT ... SELECT` (for tables referenced in `SELECT` clause)
  - `REPLACE ... SELECT` (for tables referenced in `SELECT` clause)
  - `UPDATE ... WHERE` (for tables referenced in `WHERE` clause)
  - `HANDLER ... READ`
- `delete` event:
  - `DELETE`
  - `TRUNCATE TABLE`
- `insert` event:
  - `INSERT`
  - `INSERT ... SELECT` (for table referenced in `INSERT` clause)
  - `REPLACE`
  - `REPLACE ... SELECT` (for table referenced in `REPLACE` clause
  - `LOAD DATA INFILE`

  - `LOAD XML INFILE`
- `update` event:
  - `UPDATE`
  - `UPDATE ... WHERE` (for tables referenced in `UPDATE` clause)

Logical Operators

Logical operators (`and`, `or`, `not`) can be used in `log` items. This permits construction of more advanced filtering configurations:

```
{
  "filter": {
    "class": {
      "name": "general",
      "event": {
        "name": "status",
        "log": {
          "or": [
            {
              "and": [
                { "field": { "name": "general_command.str",    "value": "Query" } },
                { "field": { "name": "general_command.length", "value": 5 } }
              ]
            },
            {
              "and": [
                { "field": { "name": "general_command.str",    "value": "Execute" } },
                { "field": { "name": "general_command.length", "value": 7 } }
              ]
            }
          ]
        }
      }
    }
  }
}
```

Referencing Predefined Variables

To refer to a predefined variable in a `log` condition, use a `variable` item, which tests equality against a given value:

```
{
  "filter": {
    "class": {
      "name": "general",
      "event": {
        "name": "status",
        "log": {
          "variable": {
            "name": "audit_log_connection_policy_value", "value": "::none"
          }
        }
      }
    }
  }
}
```

Each predefined variable corresponds to a system variable. By writing a filter that tests a predefined variable, you can modify filter operation by setting the corresponding system variable, without having to redefine the filter. For example, by writing a filter that tests the value of the `audit_log_connection_policy_value` predefined variable, you can modify filter operation by changing the value of the `audit_log_connection_policy` system variable.

The `audit_log_xxx_policy` system variables are used for the legacy mode audit log (see Section 7.4.6.3, “Legacy Mode Audit Log Filtering”). With rule-based audit log filtering, those variables remain visible (for example, using `SHOW VARIABLES`), but changes to them have no effect unless you write filters containing constructs that refer to them.

The following list describes the permitted predefined variables for `variable` items:

- `audit_log_connection_policy_value`

  This variable corresponds to the value of the `audit_log_connection_policy` system variable. The value is an unsigned integer. Table 7.14, “audit_log_connection_policy_value Values” shows the permitted values and the corresponding `audit_log_connection_policy` values.

  Table 7.14 audit_log_connection_policy_value Values

Value	Corresponding audit_log_connection_policy Value
`0` or `"::none"`	`NONE`
`1` or `"::errors"`	`ERRORS`
`2` or `"::all"`	`ALL`

  The `"::xxx"` values are symbolic pseudo-constants that may be given instead of the literal numeric values. They must be quoted as strings and are case sensitive.

- `audit_log_policy_value`

  This variable corresponds to the value of the `audit_log_policy` system variable. The value is an unsigned integer. Table 7.15, “audit_log_policy_value Values” shows the permitted values and the corresponding `audit_log_policy` values.

  Table 7.15 audit_log_policy_value Values

Value	Corresponding audit_log_policy Value
`0` or `"::none"`	`NONE`
`1` or `"::logins"`	`LOGINS`
`2` or `"::all"`	`ALL`
`3` or `"::queries"`	`QUERIES`

  The `"::xxx"` values are symbolic pseudo-constants that may be given instead of the literal numeric values. They must be quoted as strings and are case sensitive.

- `audit_log_statement_policy_value`

  This variable corresponds to the value of the `audit_log_statement_policy` system variable. The value is an unsigned integer. Table 7.16, “audit_log_statement_policy_value Values” shows the permitted values and the corresponding `audit_log_statement_policy` values.

  Table 7.16 audit_log_statement_policy_value Values

Value	Corresponding audit_log_statement_policy Value
`0` or `"::none"`	`NONE`
`1` or `"::errors"`	`ERRORS`
`2` or `"::all"`	`ALL`

  The `"::xxx"` values are symbolic pseudo-constants that may be given instead of the literal numeric values. They must be quoted as strings and are case sensitive.

Referencing Predefined Functions

To refer to a predefined function in a `log` condition, use a `function` item, which takes `name` and `args` values to specify the function name and its arguments, respectively:

```
{
  "filter": {
    "class": {
      "name": "general",
      "event": {
        "name": "status",
        "log": {
          "function": {
            "name": "find_in_include_list",
            "args": [ { "string": [ { "field": "user.str" },
                                    { "string": "@"},
                                    { "field": "host.str" } ] } ]
          }
        }
      }
    }
  }
}
```

The function as specified in the `name` item should be the function name only, without parentheses or the argument list. Arguments in the `args` item, if there is one, must be given in the order listed in the function description. Arguments can refer to predefined variables, event fields, or string or numeric constants.

The preceding filter determines whether to log `general` class `status` events depending on whether the current user is found in the `audit_log_include_accounts` system variable. That user is constructed using fields in the event.

The following list describes the permitted predefined functions for `function` items:

- `audit_log_exclude_accounts_is_null()`

  Checks whether the `audit_log_exclude_accounts` system variable is `NULL`. This function can be helpful when defining filters that correspond to the legacy audit log implementation.

  Arguments:

  None.

- `audit_log_include_accounts_is_null()`

  Checks whether the `audit_log_include_accounts` system variable is `NULL`. This function can be helpful when defining filters that correspond to the legacy audit log implementation.

  Arguments:

  None.

- `debug_sleep(millisec)`

  Sleeps for the given number of milliseconds. This function is used during performance measurement.

  `debug_sleep()` is available for debug builds only.

  Arguments:

  - `millisec`: The number of milliseconds to sleep as an unsigned integer.

- `find_in_exclude_list(account)`

Checks whether an account string exists in the audit log exclude list (the value of the `audit_log_exclude_accounts` system variable).

Arguments:

- `account`: The user account name as a string.

- `find_in_include_list(account)`

  Checks whether an account string exists in the audit log include list (the value of the `audit_log_include_accounts` system variable).

  Arguments:

  - `account`: The user account name as a string.

- `string_find(text, substr)`

  Checks whether the `substr` value is contained in the `text` value.

  Arguments:

  - `text`: The text string to search.
  - `substr`: The substring to search for in `text`.

Replacing a User Filter

In some cases, the filter definition can be changed dynamically. To do this, define a `filter` configuration within an existing `filter`. For example:

```
{
  "filter": {
    "id": "main",
    "class": {
      "name": "table_access",
      "event": {
        "name": [ "update", "delete" ],
        "log": false,
        "filter": {
          "class": {
            "name": "general",
            "event" : { "name": "status",
                        "filter": { "ref": "main" } }
          },
          "activate": {
            "or": [
              { "field": { "name": "table_name.str", "value": "temp_1" } },
              { "field": { "name": "table_name.str", "value": "temp_2" } }
            ]
          }
        }
      }
    }
  }
}
```

A new filter is activated when the `activate` element within a subfilter evaluates to `true`. Using `activate` in a top-level `filter` is not permitted.

A new filter can be replaced with the original one by using a `ref` item inside the subfilter to refer to the original filter `id`.

The filter shown operates like this:

- The `main` filter waits for `table_access` events, either `update` or `delete`.
- If the `update` or `delete` `table_access` event occurs on the `temp_1` or `temp_2` table, the filter is replaced with the internal one (without an `id`, since there is no need to refer to it explicitly).
- If the end of the command is signalled (`general` / `status` event), an entry is written to the audit log file and the filter is replaced with the `main` filter.

The filter is useful to log statements that update or delete anything from the `temp_1` or `temp_2` tables, such as this one:

```
UPDATE temp_1, temp_3 SET temp_1.a=21, temp_3.a=23;
```

The statement generates multiple `table_access` events, but the audit log file will contain only `general` / `status` entries.

> **Note**
>
> Any `id` values used in the definition are evaluated with respect only to that definition. They have nothing to do with the value of the `audit_log_filter_id` system variable.

7.4.6.3 Legacy Mode Audit Log Filtering

> **Note**
>
> This section describes legacy audit log filtering, which applies under either of these circumstances:
>
> - Before MySQL 5.7.13, that is, prior to the introduction of rule-based audit log filtering described in Section 7.4.6, “Audit Log Filtering”.
> - As of MySQL 5.7.13, if the `audit_log` plugin is installed but not the accompanying audit tables and UDFs needed for rule-based filtering.

The `audit_log` plugin can filter audited events. This enables you to control whether audited events are written to the audit log file based on the account from which events originate or event status. Status filtering occurs separately for connection events and statement events.

Event Filtering by Account

To filter audited events based on the originating account, set one of these system variables at server startup or runtime:

- `audit_log_include_accounts`: The accounts to include in audit logging. If this variable is set, only these accounts are audited.
- `audit_log_exclude_accounts`: The accounts to exclude from audit logging. If this variable is set, all but these accounts are audited.

The value for either variable can be `NULL` or a string containing one or more comma-separated account names, each in *`user_name@host_name`* format. By default, both variables are `NULL`, in which case, no account filtering is done and auditing occurs for all accounts.

Modifications to `audit_log_include_accounts` or `audit_log_exclude_accounts` affect only connections created subsequent to the modification, not existing connections.

Example: To enable audit logging only for the `user1` and `user2` local host account accounts, set the `audit_log_include_accounts` system variable like this:

```
SET GLOBAL audit_log_include_accounts = 'user1@localhost,user2@localhost';
```

Only one of `audit_log_include_accounts` or `audit_log_exclude_accounts` can be non-`NULL` at a time:

- If you set `audit_log_include_accounts`, the server sets `audit_log_exclude_accounts` to `NULL`.
- If you attempt to set `audit_log_exclude_accounts`, an error occurs unless `audit_log_include_accounts` is `NULL`. In this case, you must first clear `audit_log_include_accounts` by setting it to `NULL`.

```
-- This sets audit_log_exclude_accounts to NULL
SET GLOBAL audit_log_include_accounts = value;
-- This fails because audit_log_include_accounts is not NULL
SET GLOBAL audit_log_exclude_accounts = value;
-- To set audit_log_exclude_accounts, first set
-- audit_log_include_accounts to NULL
SET GLOBAL audit_log_include_accounts = NULL;
SET GLOBAL audit_log_exclude_accounts = value;
```

If you inspect the value of either variable, be aware that `SHOW VARIABLES` displays `NULL` as an empty string. To avoid this, use `SELECT` instead:

```
mysql> SHOW VARIABLES LIKE 'audit_log_include_accounts';
+-----------------------------+-------+
| Variable_name               | Value |
+-----------------------------+-------+
| audit_log_include_accounts |       |
+-----------------------------+-------+
mysql> SELECT @@audit_log_include_accounts;
+------------------------------+
| @@audit_log_include_accounts |
+------------------------------+
| NULL                         |
+------------------------------+
```

If a user name or host name requires quoting because it contains a comma, space, or other special character, quote it using single quotes. If the variable value itself is quoted with single quotes, double each inner single quote or escape it with a backslash. The following statements each enable audit logging for the local `root` account and are equivalent, even though the quoting styles differ:

```
SET GLOBAL audit_log_include_accounts = 'root@localhost';
SET GLOBAL audit_log_include_accounts = '''root''@''localhost''';
SET GLOBAL audit_log_include_accounts = '\'root\'@\'localhost\'';
SET GLOBAL audit_log_include_accounts = "'root'@'localhost'";
```

The last statement will not work if the `ANSI_QUOTES` SQL mode is enabled because in that mode double quotes signify identifier quoting, not string quoting.

Event Filtering by Status

To filter audited events based on status, set these system variables at server startup or runtime:

- `audit_log_connection_policy`: Logging policy for connection events
- `audit_log_statement_policy`: Logging policy for statement events

Each variable takes a value of `ALL` (log all associated events; this is the default), `ERRORS` (log only failed events), or `NONE` (do not log events). For example, to log all statement events but only failed connection events, use these settings:

```
SET GLOBAL audit_log_statement_policy = ALL;
SET GLOBAL audit_log_connection_policy = ERRORS;
```

Another policy system variable, `audit_log_policy`, is available but does not afford as much control as `audit_log_connection_policy` and `audit_log_statement_policy`. It can be set only at server startup. At runtime, it is a read-only variable. It takes a value of `ALL` (log all events; this is the default), `LOGINS` (log connection events), `QUERIES` (log statement events), or `NONE` (do not log events). For any of those values, the audit log plugin logs all selected events without distinction as to success or failure. Use of `audit_log_policy` at startup works as follows:

- If you do not set `audit_log_policy` or set it to its default of `ALL`, any explicit settings for `audit_log_connection_policy` or `audit_log_statement_policy` apply as specified. If not specified, they default to `ALL`.
- If you set `audit_log_policy` to a non-`ALL` value, that value takes precedence over and is used to set `audit_log_connection_policy` and `audit_log_statement_policy`, as indicated in the following table. If you also set either of those variables to a value other than their default of `ALL`, the server writes a message to the error log to indicate that their values are being overridden.

Startup audit_log_policy Value	Resulting audit_log_connection_policy Value	Resulting audit_log_statement_policy Value
`LOGINS`	`ALL`	`NONE`
`QUERIES`	`NONE`	`ALL`
`NONE`	`NONE`	`NONE`

Event Filtering Reporting

To check the effect of filtering, you can inspect the values of these status variables:

- `Audit_log_events`: The number of events handled by the audit log plugin, whether or not they were written to the log based on filtering policy.
- `Audit_log_events_filtered`: The number of events handled by the audit log plugin that were filtered (not written to the log) based on filtering policy.
- `Audit_log_events_written`: The number of events written to the audit log.

7.4.7 Audit Log Reference

The following discussion serves as a reference to MySQL Enterprise Audit components:

- Section 7.4.7.1, “Audit Log Tables”
- Section 7.4.7.2, “Audit Log Functions”
- Section 7.4.7.3, “Audit Log Option and Variable Reference”
- Section 7.4.7.4, “Audit Log Options and Variables”
- Section 7.4.7.5, “Audit Log Status Variables”

To install the `audit_log` tables and functions, use the instructions provided in Section 7.4.2, “Installing or Uninstalling MySQL Enterprise Audit”. Unless those components are installed, the `audit_log` plugin operates in legacy mode. See Section 7.4.6.3, “Legacy Mode Audit Log Filtering”.

7.4.7.1 Audit Log Tables

MySQL Enterprise Audit uses tables in the `mysql` system database for persistent storage of filter and user account data. The tables can be accessed only by users with privileges for that database. The tables use the `MyISAM` storage engine.

If these tables are missing, the `audit_log` plugin operates in legacy mode. See Section 7.4.6.3, “Legacy Mode Audit Log Filtering”.

The `audit_log_filter` table stores filter definitions. The table has these columns:

- `NAME`

  The filter name.

- `FILTER`

  The filter definition associated with the filter name. Definitions are stored as `JSON` values.

The `audit_log_user` table stores user account information. The table has these columns:

- `USER`

  The user name part of an account. For an account `user1@localhost`, the `USER` part is `user1`.

- `HOST`

  The host name part of an account. For an account `user1@localhost`, the `HOST` part is `localhost`.

- `FILTERNAME`

  The name of the filter assigned to the account. The filter name associates the account with a filter defined in the `audit_log_filter` table.

7.4.7.2 Audit Log Functions

This section describes, for each audit log user-defined function (UDF), its purpose, calling sequence, and return value. For information about the conditions under which these UDFs can be invoked, see Section 7.4.6, “Audit Log Filtering”.

Each audit log UDF returns `OK` for success, `ERROR: message` for failure.

These audit log UDFs are available:

- `audit_log_filter_flush()`

  Calling any of the other filtering UDFs affects operational audit log filtering immediately and updates the audit log tables. If instead you modify the contents of those tables directly using statements such as `INSERT`, `UPDATE`, and `DELETE`, the changes do not affect filtering immediately. To flush your changes and make them operational, call `audit_log_filter_flush()`.

  `audit_log_filter_flush()` affects all current sessions and detaches them from their previous filters. Current sessions are no longer logged unless they disconnect and reconnect, or execute a change-user operation.

  If this function fails, an error message is returned and the audit log is disabled until the next successful call to `audit_log_filter_flush()`.

  Syntax:

  ```
  STRING audit_log_filter_flush()
  ```

  Arguments:

  None.

  Return values:

  `OK` for success, `ERROR: message` for failure.

  Example:

```
mysql> SELECT audit_log_filter_flush();
+--------------------------+
| audit_log_filter_flush() |
+--------------------------+
| OK                       |
+--------------------------+
```

- `audit_log_filter_remove_filter()`

  Given a filter name, removes the filter from the current set of filters. It is not an error for the filter not to exist.

  If a removed filter is assigned to any user accounts, those users stop being filtered (they are removed from the `audit_log_user` table). Termination of filtering includes any current sessions for those users: They are detached from the filter and no longer logged.

  Syntax:

  ```
  STRING audit_log_filter_remove_filter(STRING filter_name)
  ```

  Arguments:

  - `filter_name`: The filter name as a string.

  Return values:

  `OK` for success, `ERROR: message` for failure.

  Example:

  ```
  mysql> SELECT audit_log_filter_remove_filter('SomeFilter');
  +-----------------------------------------------+
  | audit_log_filter_remove_filter('SomeFilter') |
  +-----------------------------------------------+
  | OK                                            |
  +-----------------------------------------------+
  ```

- `audit_log_filter_remove_user()`

  Given a user account name, cause the user to be no longer assigned to a filter. It is not an error if the user has no filter assigned. Filtering of current sessions for the user remains unaffected. New connections for the user are filtered using the default account filter if there is one, and are not logged otherwise.

  If the name is `%`, the function removes the default account filter that is used for any user account that has no explicitly assigned filter.

  Syntax:

  ```
  STRING audit_log_filter_remove_user(STRING user_name)
  ```

  Arguments:

  - `user_name`: The user account name as a string in *`user_name@host_name`* format, or `%` to represent the default account.

  Return values:

  `OK` for success, `ERROR: message` for failure.

Example:

```
mysql>t; SELECT audit_log_filter_remove_user('user1@localhost');
+-------------------------------------------------+
| audit_log_filter_remove_user('user1@localhost') |
+-------------------------------------------------+
| OK                                              |
+-------------------------------------------------+
```

- `audit_log_filter_set_filter()`

  Given a filter name and definition, adds the filter to the current set of filters. If the filter already exists and is used by any current sessions, those sessions are detached from the filter and are no longer logged. This occurs because the new filter definition has a new filter ID that differs from its previous ID.

  Syntax:

  ```
  STRING audit_log_filter_set_filter(STRING filter_name, STRING definition)
  ```

  Arguments:

  - `filter_name`: The filter name as a string.
  - `definition`: The filter definition as a `JSON` value.

  Return values:

  `OK` for success, `ERROR: message` for failure.

  Example:

  ```
  mysql>t; SET @f = '{ "filter": { "log": false } }';
  mysql>t; SELECT audit_log_filter_set_filter('SomeFilter', @f);
  +-----------------------------------------------+
  | audit_log_filter_set_filter('SomeFilter', @f) |
  +-----------------------------------------------+
  | OK                                            |
  +-----------------------------------------------+
  ```

- `audit_log_filter_set_user()`

  Given a user account name and a filter name, assigns the filter to the user. A user can be assigned only one filter, so if the user was already assigned a filter, the assignment is replaced. Filtering of current sessions for the user remains unaffected. New connections are filtered using the new filter.

  As a special case, the name `%` represents the default account. The filter is used for connections from any user account that has no explicitly assigned filter.

  Syntax:

  ```
  STRING audit_log_filter_set_user(STRING user_name, STRING filter_name)
  ```

  Arguments:

  - `user_name`: The user account name as a string in *`user_name@host_name`* format, or `%` to represent the default account.
  - `filter_name`: The filter name as a string.

Return values:

`OK` for success, `ERROR: message` for failure.

Example:

```
mysql>t; SELECT audit_log_filter_set_user('user1@localhost', 'SomeFilter');
+-----------------------------------------------------------+
| audit_log_filter_set_user('user1@localhost', 'SomeFilter') |
+-----------------------------------------------------------+
| OK                                                        |
+-----------------------------------------------------------+
```

7.4.7.3 Audit Log Option and Variable Reference

Table 7.17 Audit Log Option/Variable Reference

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
audit-log	Yes	Yes				
audit_log_buffer_size	Yes	Yes	Yes		Global	No
audit_log_connection_policy	Yes	Yes	Yes		Global	Yes
audit_log_current_session			Yes		Both	No
Audit_log_current_size				Yes	Global	No
Audit_log_event_max_drop_size				Yes	Global	No
Audit_log_events				Yes	Global	No
Audit_log_events_filtered				Yes	Global	No
Audit_log_events_lost				Yes	Global	No
Audit_log_events_written				Yes	Global	No
audit_log_exclude_accounts	Yes	Yes	Yes		Global	Yes
audit_log_file	Yes	Yes	Yes		Global	No
audit_log_flush			Yes		Global	Yes
audit_log_format	Yes	Yes	Yes		Global	No
audit_log_include_accounts	Yes	Yes	Yes		Global	Yes
audit_log_policy	Yes	Yes	Yes		Global	No
audit_log_rotate_on_size	Yes	Yes	Yes		Global	Yes
audit_log_statement_policy	Yes	Yes	Yes		Global	Yes
audit_log_strategy	Yes	Yes	Yes		Global	No
Audit_log_total_size				Yes	Global	No
Audit_log_write_waits				Yes	Global	No

7.4.7.4 Audit Log Options and Variables

This section describes the command options and system variables that control operation of MySQL Enterprise Audit. If values specified at startup time are incorrect, the `audit_log` plugin may fail to initialize properly and the server does not load it. In this case, the server may also produce error messages for other audit log settings because it will not recognize them.

To control the activation of the `audit_log` plugin, use this option:

- `--audit-log[=value]`

Introduced	5.7.9

Command-Line Format	--audit-log[=value]	
Permitted Values	Type	enumeration
	Default	ON
	Valid Values	ON
		OFF
		FORCE
		FORCE_PLUS_PERMANENT

This option controls how the server loads the audit_log plugin at startup. It is available only if the plugin has been previously registered with INSTALL PLUGIN or is loaded with --plugin-load. See Section 7.4.2, “Installing or Uninstalling MySQL Enterprise Audit”.

The option value should be one of those available for plugin-loading options, as described in Installing and Uninstalling Plugins. For example, --audit-log=FORCE_PLUS_PERMANENT tells the server to load the plugin and prevent it from being removed while the server is running.

If the audit_log plugin is enabled, it exposes several system variables that permit control over logging:

```
mysql> SHOW VARIABLES LIKE 'audit_log%';
+-------------------------------+--------------+
| Variable_name                 | Value        |
+-------------------------------+--------------+
| audit_log_buffer_size         | 1048576      |
| audit_log_connection_policy   | ALL          |
| audit_log_current_session     | OFF          |
| audit_log_exclude_accounts    |              |
| audit_log_file                | audit.log    |
| audit_log_filter_id           | 0            |
| audit_log_flush               | OFF          |
| audit_log_format              | NEW          |
| audit_log_include_accounts    |              |
| audit_log_policy              | ALL          |
| audit_log_rotate_on_size      | 0            |
| audit_log_statement_policy    | ALL          |
| audit_log_strategy            | ASYNCHRONOUS |
+-------------------------------+--------------+
```

You can set any of these variables at server startup, and some of them at runtime.

- audit_log_buffer_size

Introduced	5.7.9	
Command-Line Format	--audit_log_buffer_size=value	
System Variable	Name	audit_log_buffer_size
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values (32-bit platforms)	Type	integer
	Default	1048576
	Min Value	4096
	Max Value	4294967295

Permitted Values (64-bit platforms)	**Type**	integer
	Default	`1048576`
	Min Value	`4096`
	Max Value	`18446744073709547520`

When the audit log plugin writes events to the log asynchronously, it uses a buffer to store event contents prior to writing them. This variable controls the size of that buffer, in bytes. The server adjusts the value to a multiple of 4096. The plugin uses a single buffer, which it allocates when it initializes and removes when it terminates. The plugin allocates this buffer only if logging is asynchronous.

- `audit_log_connection_policy`

Introduced	5.7.9	
Command-Line Format	`--audit_log_connection_policy=value`	
System Variable	**Name**	`audit_log_connection_policy`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	enumeration
	Default	`ALL`
	Valid Values	`ALL`
		`ERRORS`
		`NONE`

The policy controlling how the audit log plugin writes connection events to its log file. The following table shows the permitted values.

Value	Description
`ALL`	Log all connection events
`ERRORS`	Log only failed connection events
`NONE`	Do not log connection events

> **Note**
>
> At server startup, any explicit value given for `audit_log_connection_policy` may be overridden if `audit_log_policy` is also specified, as described in Section 7.4.5, “Audit Log Logging Control”.

- `audit_log_current_session`

Introduced	5.7.9	
System Variable	**Name**	`audit_log_current_session`
	Variable Scope	Global, Session
	Dynamic Variable	No

Permitted Values	Type	boolean
	Default	`depends on filtering policy`

Whether audit logging is enabled for the current session. The session value of this variable is read only. It is set when the session begins based on the values of the `audit_log_include_accounts` and `audit_log_exclude_accounts` system variables. The audit log plugin uses the session value to determine whether to audit events for the session. (There is a global value, but the plugin does not use it.)

- `audit_log_exclude_accounts`

Introduced	5.7.9	
Command-Line Format	`--audit_log_exclude_accounts=value`	
System Variable	Name	`audit_log_exclude_accounts`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	string
	Default	`NULL`

The accounts for which events should not be logged. The value should be `NULL` or a string containing a list of one or more comma-separated account names. For more information, see Section 7.4.5, “Audit Log Logging Control”.

Modifications to `audit_log_exclude_accounts` affect only connections created subsequent to the modification, not existing connections.

- `audit_log_file`

Introduced	5.7.9	
Command-Line Format	`--audit_log_file=file_name`	
System Variable	Name	`audit_log_file`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	file name
	Default	`audit.log`

The name of the file to which the audit log plugin writes events. The default value is `audit.log`. If the value of `audit_log_file` is a relative path name, the server interprets it relative to the data directory. If the value is a full path name, the server uses the value as is. A full path name may be useful if it is desirable to locate audit files on a separate file system or directory. For security reasons, the audit log file should be written to a directory accessible only to the MySQL server and users with a legitimate reason to view the log. For more information, see Section 7.4.5, “Audit Log Logging Control”.

- `audit_log_filter_id`

Introduced	5.7.13	
System Variable	Name	`audit_log_filter_id`

	Variable Scope	Global, Session
	Dynamic Variable	No
Permitted Values	**Type**	integer

The session value of this variable indicates the internally maintained ID of the audit filter for the current session. A value of 0 means that the session has no filter assigned.

- `audit_log_flush`

Introduced	5.7.9	
System Variable	**Name**	`audit_log_flush`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	boolean
	Default	`OFF`

When this variable is set to enabled (1 or `ON`), the audit log plugin closes and reopens its log file to flush it. (The value remains `OFF` so that you need not disable it explicitly before enabling it again to perform another flush.) Enabling this variable has no effect unless `audit_log_rotate_on_size` is 0. For more information, see Section 7.4.5, “Audit Log Logging Control”.

- `audit_log_format`

Introduced	5.7.9	
Command-Line Format	`--audit_log_format=value`	
System Variable	**Name**	`audit_log_format`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values (>= 5.7.9)	**Type**	enumeration
	Default	`NEW`
	Valid Values	`OLD`
		`NEW`

The audit log file format. Permitted values are `OLD` and `NEW` (default `NEW`). For details about the new format, see Section 7.4.4, “The Audit Log File”. For details about the old format, see The Audit Log File in MySQL 5.6 Reference Manual.

If you change the value of `audit_log_format`, use this procedure to avoid writing log entries in one format to an existing log file that contains entries in a different format:

1. Stop the server.
2. Rename the current audit log file manually.
3. Restart the server with the new value of `audit_log_format`. The audit log plugin will create a new log file, which will contain log entries in the selected format.

- `audit_log_include_accounts`

Introduced	5.7.9	
Command-Line Format	`--audit_log_include_accounts=value`	
System Variable	**Name**	`audit_log_include_accounts`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	string
	Default	`NULL`

The accounts for which events should be logged. The value should be `NULL` or a string containing a list of one or more comma-separated account names. For more information, see Section 7.4.5, "Audit Log Logging Control".

Modifications to `audit_log_include_accounts` affect only connections created subsequent to the modification, not existing connections.

- `audit_log_policy`

Introduced	5.7.9	
Command-Line Format	`--audit_log_policy=value`	
System Variable	**Name**	`audit_log_policy`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	enumeration
	Default	`ALL`
	Valid Values	`ALL`
		`LOGINS`
		`QUERIES`
		`NONE`

The policy controlling how the audit log plugin writes events to its log file. The following table shows the permitted values.

Value	Description
`ALL`	Log all events
`LOGINS`	Log only login events
`QUERIES`	Log only query events
`NONE`	Log nothing (disable the audit stream)

`audit_log_policy` can be set only at server startup. At runtime, it is a read-only variable. Two other system variables, `audit_log_connection_policy` and `audit_log_statement_policy`, provide finer control over logging policy and can be set either at startup or at runtime. If you use `audit_log_policy` at startup instead of the other two variables, the server uses its value to set those variables. For more information about the policy variables and their interaction, see Section 7.4.5, "Audit Log Logging Control".

- `audit_log_rotate_on_size`

Introduced	5.7.9	
Command-Line Format	`--audit_log_rotate_on_size=N`	
System Variable	**Name**	`audit_log_rotate_on_size`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	integer
	Default	`0`

If the `audit_log_rotate_on_size` value is greater than 0, the audit log plugin closes and reopens its log file if a write to the file causes its size to exceed this value. The original file is renamed to have a timestamp extension.

If the `audit_log_rotate_on_size` value is 0, the plugin does not close and reopen its log based on size. Instead, use `audit_log_flush` to close and reopen the log on demand. In this case, rename the file externally to the server before flushing it.

For more information about audit log file rotation and timestamp interpretation, see Section 7.4.5, “Audit Log Logging Control”.

If you set this variable to a value that is not a multiple of 4096, it is truncated to the nearest multiple. (Thus, setting it to a value less than 4096 has the effect of setting it to 0 and no rotation occurs.)

- `audit_log_statement_policy`

Introduced	5.7.9	
Command-Line Format	`--audit_log_statement_policy=value`	
System Variable	**Name**	`audit_log_statement_policy`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	enumeration
	Default	`ALL`
	Valid Values	`ALL`
		`ERRORS`
		`NONE`

The policy controlling how the audit log plugin writes statement events to its log file. The following table shows the permitted values.

Value	Description
`ALL`	Log all statement events
`ERRORS`	Log only failed statement events
`NONE`	Do not log statement events

> **Note**
>
> At server startup, any explicit value given for `audit_log_statement_policy` may be overridden if `audit_log_policy` is also specified, as described in Section 7.4.5, “Audit Log Logging Control”.

- `audit_log_strategy`

Introduced	5.7.9	
Command-Line Format	`--audit_log_strategy=value`	
System Variable	**Name**	`audit_log_strategy`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	enumeration
	Default	`ASYNCHRONOUS`
	Valid Values	`ASYNCHRONOUS`
		`PERFORMANCE`
		`SEMISYNCHRONOUS`
		`SYNCHRONOUS`

The logging method used by the audit log plugin. The following table describes the permitted values.

Table 7.18 Audit Log Strategies

Value	Meaning
`ASYNCHRONOUS`	Log asynchronously, wait for space in output buffer
`PERFORMANCE`	Log asynchronously, drop request if insufficient space in output buffer
`SEMISYNCHRONOUS`	Log synchronously, permit caching by operating system
`SYNCHRONOUS`	Log synchronously, call `sync()` after each request

7.4.7.5 Audit Log Status Variables

If the `audit_log` plugin is enabled, it exposes several status variables that provide operational information.

- `Audit_log_current_size`

  The size of the current audit log file. The value increases when an event is written to the log and is reset to 0 when the log is rotated.

- `Audit_log_event_max_drop_size`

  The size of the largest dropped event in performance logging mode. For a description of logging modes, see Section 7.4.5, “Audit Log Logging Control”.

- `Audit_log_events`

  The number of events handled by the audit log plugin, whether or not they were written to the log based on filtering policy (see Section 7.4.5, “Audit Log Logging Control”).

- `Audit_log_events_filtered`

The number of events handled by the audit log plugin that were filtered (not written to the log) based on filtering policy (see Section 7.4.5, “Audit Log Logging Control”).

- `Audit_log_events_lost`

  The number of events lost in performance logging mode because an event was larger than than the available audit log buffer space. This value may be useful for assessing how to set `audit_log_buffer_size` to size the buffer for performance mode. For a description of logging modes, see Section 7.4.5, “Audit Log Logging Control”.

- `Audit_log_events_written`

  The number of events written to the audit log.

- `Audit_log_total_size`

  The total size of events written to all audit log files. Unlike `Audit_log_current_size`, the value of `Audit_log_total_size` increases even when the log is rotated.

- `Audit_log_write_waits`

  The number of times an event had to wait for space in the audit log buffer in asynchronous logging mode. For a description of logging modes, see Section 7.4.5, “Audit Log Logging Control”.

7.4.8 Audit Log Restrictions

MySQL Enterprise Audit is subject to these general restrictions:

- Only SQL statements are logged. Changes made by no-SQL APIs, such as memcached, Node.JS, and the NDB API, are not logged.
- Only top-level statements are logged, not statements within stored programs such as triggers or stored procedures.
- Contents of files referenced by statements such as `LOAD DATA INFILE` are not logged.

MySQL Cluster. It is possible to use MySQL Enterprise Audit with MySQL Cluster, subject to the following conditions:

- All changes to be logged must be done using the SQL interface. Changes using no-SQL interfaces, such as those provided by the NDB API, memcached, or ClusterJ, are not logged.
- The plugin must be installed on each MySQL server that is used to execute SQL on the cluster.
- Audit plugin data must be aggregated amongst all MySQL servers used with the cluster. This aggregation is the responsibility of the application or user.

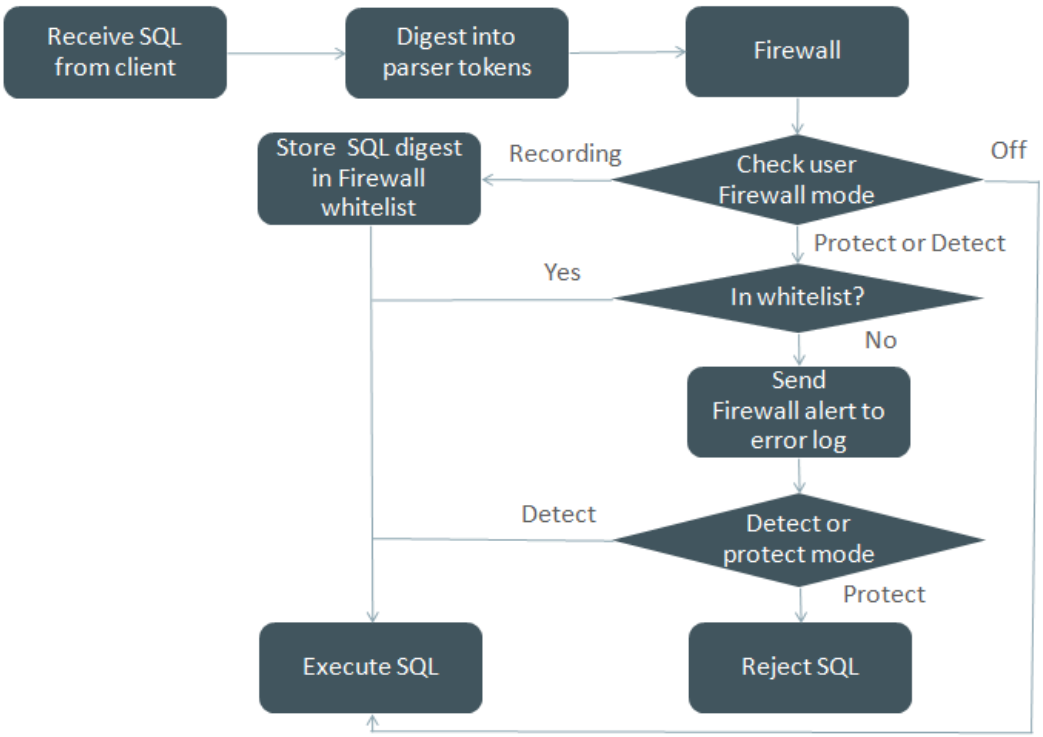
7.5 MySQL Enterprise Firewall

> **Note**
>
> MySQL Enterprise Firewall is an extension included in MySQL Enterprise Edition, a commercial product. To learn more about commercial products, see http://www.mysql.com/products/.

As of MySQL 5.7.9, MySQL Enterprise Edition includes MySQL Enterprise Firewall, an application-level firewall that enables database administrators to permit or deny SQL statement execution based on matching against whitelists of accepted statement patterns. This helps harden MySQL Server against attacks such as SQL injection or attempts to exploit applications by using them outside of their legitimate query workload characteristics.

Each MySQL account registered with the firewall has its own statement whitelist, enabling protection to be tailored per account. For a given account, the firewall can operate in recording, protecting, or detecting mode, for training in the accepted statement patterns, active protection against unacceptable statements, or passive detection of unacceptable statements. The diagram illustrates how the firewall processes incoming statements in each mode.

Figure 7.1 MySQL Enterprise Firewall Operation



The following sections describe the components of MySQL Enterprise Firewall, discuss how to install and use it, and provide reference information for its components.

7.5.1 MySQL Enterprise Firewall Components

MySQL Enterprise Firewall is based on a plugin library that implements these components:

- A server-side plugin named `MYSQL_FIREWALL` examines SQL statements before they execute and, based on its in-memory cache, renders a decision whether to execute or reject each statement.
- Server-side plugins named `MYSQL_FIREWALL_USERS` and `MYSQL_FIREWALL_WHITELIST` implement `INFORMATION_SCHEMA` tables that provide views into the firewall data cache.
- System tables named `firewall_users` and `firewall_whitelist` in the `mysql` database provide persistent storage of firewall data.
- Stored procedures named `sp_set_firewall_mode()` and `sp_reload_firewall_rules()` perform tasks such as registering MySQL accounts with the firewall, establishing their operational mode, and managing transfer of firewall data between the cache and the underlying system tables.
- A set of user-defined functions provides an SQL-level API for lower-level tasks such as synchronizing the cache with the underlying system tables.
- System variables enable firewall configuration and status variables provide runtime operational information.

7.5.2 Installing or Uninstalling MySQL Enterprise Firewall

MySQL Enterprise Firewall installation is a one-time operation that installs the components described in Section 7.5.1, “MySQL Enterprise Firewall Components”. Installation can be performed using a graphical interface or manually:

- On Windows, MySQL Installer includes an option to enable MySQL Enterprise Firewall for you.
- MySQL Workbench 6.3.4 or higher can install MySQL Enterprise Firewall, enable or disable an installed firewall, or uninstall the firewall.
- Manual MySQL Enterprise Firewall installation involves running a script located in the `share` directory of your MySQL installation.

> **Note**
>
> If installed, MySQL Enterprise Firewall involves some minimal overhead even when disabled. To avoid this overhead, do not install the firewall unless you plan to use it.

> **Note**
>
> MySQL Enterprise Firewall does not work together with the query cache. If the query cache is enabled, disable it before installing the firewall (see Query Cache Configuration).

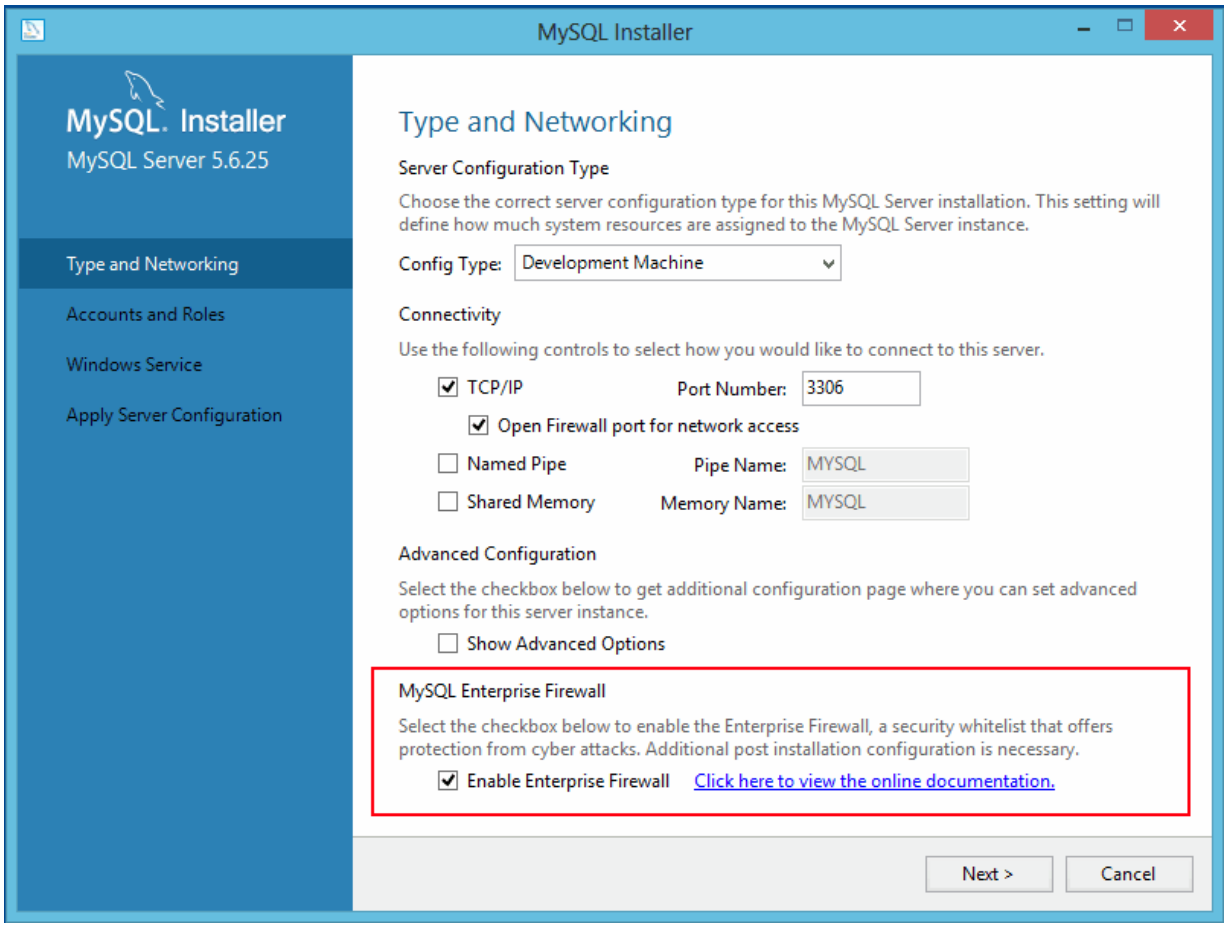
For usage instructions, see Section 7.5.3, “Using MySQL Enterprise Firewall”. For reference information, see Section 7.5.4, “MySQL Enterprise Firewall Reference”.

Installing MySQL Enterprise Firewall

If MySQL Enterprise Firewall is already installed from an older version of MySQL, uninstall it using the instructions given later in this section and then restart your server before installing the current version. In this case, it is also necessary to register your configuration again.

On Windows, you can use MySQL Installer to install MySQL Enterprise Firewall, as shown in Figure 7.2, “MySQL Enterprise Firewall Installation on Windows”. Check the **Enable Enterprise Firewall** checkbox. (**Open Firewall port for network access** has a different purpose. It refers to Windows Firewall and controls whether Windows blocks the TCP/IP port on which the MySQL server listens for client connections.)

Figure 7.2 MySQL Enterprise Firewall Installation on Windows



To install MySQL Enterprise Firewall using MySQL Workbench 6.3.4 or higher, see MySQL Enterprise Firewall Interface.

To install MySQL Enterprise Firewall manually, look in the `share` directory of your MySQL installation and choose the script that is appropriate for your platform. The available scripts differ in the suffix used to refer to the plugin library file:

- `win_install_firewall.sql`: Choose this script for Windows systems that use `.dll` as the file name suffix.
- `linux_install_firewall.sql`: Choose this script for Linux and similar systems that use `.so` as the file name suffix.

The installation script creates stored procedures in the default database, so choose a database to use. Then run the script as follows, naming the chosen database on the command line. The example here uses the `mysql` database and the Linux installation script. Make the appropriate substitutions for your system.

```
shell> mysql -u root -p mysql < linux_install_firewall.sql
Enter password: (enter root password here)
```

Installing MySQL Enterprise Firewall either using a graphical interface or manually should enable the firewall. To verify that, connect to the server and execute this statement:

```
mysql> SHOW GLOBAL VARIABLES LIKE 'mysql_firewall_mode';
+---------------------+-------+
| Variable_name       | Value |
```

```
+--------------------+-------+
| mysql_firewall_mode | ON    |
+--------------------+-------+
```

Uninstalling MySQL Enterprise Firewall

MySQL Enterprise Firewall can be uninstalled using MySQL Workbench or manually.

To uninstall MySQL Enterprise Firewall using MySQL Workbench 6.3.4 or higher, see MySQL Enterprise Firewall Interface.

To uninstall MySQL Enterprise Firewall manually, execute the following statements. It is assumed that the stored procedures were created in the `mysql` database. Adjust the `DROP PROCEDURE` statements appropriately if the procedures were created in a different database.

```
DROP TABLE mysql.firewall_whitelist;
DROP TABLE mysql.firewall_users;
UNINSTALL PLUGIN mysql_firewall;
UNINSTALL PLUGIN mysql_firewall_whitelist;
UNINSTALL PLUGIN mysql_firewall_users;
DROP FUNCTION set_firewall_mode;
DROP FUNCTION normalize_statement;
DROP FUNCTION read_firewall_whitelist;
DROP FUNCTION read_firewall_users;
DROP FUNCTION mysql_firewall_flush_status;
DROP PROCEDURE mysql.sp_set_firewall_mode;
DROP PROCEDURE mysql.sp_reload_firewall_rules;
```

7.5.3 Using MySQL Enterprise Firewall

Before using MySQL Enterprise Firewall, install it according to the instructions provided at Section 7.5.2, “Installing or Uninstalling MySQL Enterprise Firewall”. Also, MySQL Enterprise Firewall does not work together with the query cache; disable the query cache if it is enabled (see Query Cache Configuration).

This section describes how to configure MySQL Enterprise Firewall using SQL statements. Alternatively, MySQL Workbench 6.3.4 or higher provides a graphical interface for firewall control. See MySQL Enterprise Firewall Interface.

To enable or disable the firewall, set the `mysql_firewall_mode` system variable. By default, this variable is enabled when the firewall is installed. To control the initial firewall state explicitly, you can set the variable at server startup. For example, to enable the firewall in an option file, use these lines:

```
[mysqld]
mysql_firewall_mode=ON
```

It is also possible to disable or enable the firewall at runtime:

```
mysql> SET GLOBAL mysql_firewall_mode = OFF;
mysql> SET GLOBAL mysql_firewall_mode = ON;
```

In addition to the global on/off firewall mode, each account registered with the firewall has its own operational mode. For an account in recording mode, the firewall learns an application's “fingerprint,” that is, the acceptable statement patterns that, taken together, form a whitelist. After training, switch the firewall to protecting mode to harden MySQL against access by statements that deviate from the fingerprint. For additional training, switch the firewall back to recording mode as necessary to update the whitelist with new statement patterns. An intrusion-detection mode is available that writes suspicious statements to the error log but does not deny access.

The firewall maintains whitelist rules on a per-account basis, enabling implementation of protection strategies such as these:

- For an application that has unique protection requirements, configure it to use an account that is not used for any other purpose.
- For applications that are related and share protection requirements, configure them as a group to use the same account.

Firewall operation is based on conversion of SQL statements to normalized digest form. Firewall digests are like the statement digests used by the Performance Schema (see Performance Schema Statement Digests). However, unlike the Performance Schema, the relevant digest-related system variable is `max_digest_length`.

For a connection from a registered account, the firewall converts each incoming statement to normalized form and processes it according to the account mode:

- In recording mode, the firewall adds the normalized statement to the account whitelist rules.
- In protecting mode, the firewall compares the normalized statement to the account whitelist rules. If there is a match, the statement passes and the server continues to process it. Otherwise, the server rejects the statement and returns an error to the client. The firewall also writes the rejected statement to the error log if the `mysql_firewall_trace` system variable is enabled.
- In detecting mode, the firewall matches statements as in protecting mode, but writes nonmatching statements to the error log without denying access.

Accounts that have a mode of `OFF` or are not registered with the firewall are ignored by it.

To protect an account using MySQL Enterprise Firewall, follow these steps:

1. Register the account and put it in recording mode.
2. Connect to the MySQL server using the registered account and execute statements to be learned. This establishes the account's whitelist of accepted statements.
3. Switch the registered account to protecting mode.

The following example shows how to register an account with the firewall, use the firewall to learn acceptable statements for that account, and protect the account against execution of unacceptable statements. The example account, `'fwuser'@'localhost'`, is for use by an application that accesses tables in the `sakila` database. (This database is available at http://dev.mysql.com/doc/index-other.html.)

> **Note**
>
> The user and host parts of the account name are quoted separately for statements such as `CREATE USER` and `GRANT`, whereas to specify an account for use with a firewall component, name it as a single quoted string `'fwuser@localhost'`.
>
> The convention for naming accounts as a single quoted string for firewall components means that you cannot use accounts that have embedded `@` characters in the user name.

Perform the steps in the following procedure using an administrative MySQL account, except those designated for execution by the account registered with the firewall. The default database should be `sakila` for statements executed using the registered account.

1. If necessary, create the account to be protected (choose an appropriate password) and grant it privileges for the `sakila` database:

```
mysql> CREATE USER 'fwuser'@'localhost' IDENTIFIED BY 'fWp@3sw0rd';
```

```
mysql> GRANT ALL ON sakila.* TO 'fwuser'@'localhost';
```

2. Use the `sp_set_firewall_mode()` stored procedure to register the account with the firewall and place it in recording mode (if the procedure is located in a database other than `mysql`, adjust the statement accordingly):

```
mysql> CALL mysql.sp_set_firewall_mode('fwuser@localhost', 'RECORDING');
```

   During the course of its execution, the stored procedure invokes firewall user-defined functions, which may produce output of their own.

3. Using the registered account, connect to the server, then execute some statements that are legitimate for it:

```
mysql> SELECT first_name, last_name FROM customer WHERE customer_id = 1;
mysql> UPDATE rental SET return_date = NOW() WHERE rental_id = 1;
mysql> SELECT get_customer_balance(1, NOW());
```

   The firewall converts the statements to digest form and records them in the account whitelist.

   > **Note**
   >
   > Until the account executes statements in recording mode, its whitelist is empty, which is equivalent to “deny all.” If switched to protecting mode, the account will be effectively prohibited from executing statements.

4. At this point, the user and whitelist information is cached and can be seen in the firewall `INFORMATION_SCHEMA` tables:

```
mysql> SELECT MODE FROM INFORMATION_SCHEMA.MYSQL_FIREWALL_USERS
    -> WHERE USERHOST = 'fwuser@localhost';
+-----------+
| MODE      |
+-----------+
| RECORDING |
+-----------+
mysql> SELECT RULE FROM INFORMATION_SCHEMA.MYSQL_FIREWALL_WHITELIST
    -> WHERE USERHOST = 'fwuser@localhost';
+----------------------------------------------------------------------------+
| RULE                                                                       |
+----------------------------------------------------------------------------+
| SELECT `first_name` , `last_name` FROM `customer` WHERE `customer_id` = ?  |
| SELECT `get_customer_balance` ( ? , NOW ( ) )                              |
| UPDATE `rental` SET `return_date` = NOW ( ) WHERE `rental_id` = ?          |
| SELECT @@`version_comment` LIMIT ?                                         |
+----------------------------------------------------------------------------+
```

   > **Note**
   >
   > The `@@version_comment` rule comes from a statement sent automatically by the `mysql` client when you connect to the server as the registered user.
   >
   > It is important to train the firewall under conditions matching application use. For example, a given MySQL connector might send statements to the server at the beginning of a connection to determine server characteristics and capabilities. If an application normally is used through that connector, train the firewall that way, too. That enables those initial statements to become part of the whitelist for the account associated with the application.

5. Use the stored procedure to switch the registered user to protecting mode:

```
mysql> CALL mysql.sp_set_firewall_mode('fwuser@localhost', 'PROTECTING');
```

> **Important**
>
> Switching the account out of `RECORDING` mode synchronizes its firewall cache data to the underlying `mysql` system database tables for persistent storage. If you do not switch the mode for a user who is being recorded, the cached whitelist data is not written to the system tables and will be lost when the server is restarted.

6. Using the registered account, execute some acceptable and unacceptable statements. The firewall matches each one against the account whitelist and accepts or rejects it.

   This statement is not identical to a training statement but produces the same normalized statement as one of them, so the firewall accepts it:

   ```
   mysql> SELECT first_name, last_name FROM customer WHERE customer_id = '48';
   +------------+-----------+
   | first_name | last_name |
   +------------+-----------+
   | ANN        | EVANS     |
   +------------+-----------+
   ```

   These statements do not match anything in the whitelist and each results in an error:

   ```
   mysql> SELECT first_name, last_name FROM customer WHERE customer_id = 1 OR TRUE;
   ERROR 1045 (28000): Statement was blocked by Firewall
   mysql> SHOW TABLES LIKE 'customer%';
   ERROR 1045 (28000): Statement was blocked by Firewall
   mysql> TRUNCATE TABLE mysql.slow_log;
   ERROR 1045 (28000): Statement was blocked by Firewall
   ```

   The firewall also writes the rejected statements to the error log if the `mysql_firewall_trace` system variable is enabled. For example:

   ```
   [Note] Plugin MYSQL_FIREWALL reported:
   'ACCESS DENIED for fwuser@localhost. Reason: No match in whitelist.
   Statement: TRUNCATE TABLE `mysql` . `slow_log` '
   ```

   You can use these log messages in your efforts to identify the source of attacks.

7. You can log nonmatching statements as suspicious without denying access. To do this, put the account in intrusion-detecting mode:

   ```
   mysql> CALL mysql.sp_set_firewall_mode('fwuser@localhost', 'DETECTING');
   ```

8. Using the registered account, connect to the server, then execute some statement does not match the whitelist:

   ```
   mysql> SHOW TABLES LIKE 'customer%';
   +------------------------------+
   | Tables_in_sakila (customer%) |
   +------------------------------+
   | customer                     |
   | customer_list                |
   +------------------------------+
   ```

   In detecting mode, the firewall permits the nonmatching statement to execute but writes a message to the error log:

   ```
   [Note] Plugin MYSQL_FIREWALL reported:
   'SUSPICIOUS STATEMENT from 'fwuser@localhost'. Reason: No match in whitelist.
   ```

```
Statement: SHOW TABLES LIKE ? '
```

9. To assess firewall activity, examine its status variables:

```
mysql> SHOW GLOBAL STATUS LIKE 'Firewall%';
+----------------------------+-------+
| Variable_name              | Value |
+----------------------------+-------+
| Firewall_access_denied     | 3     |
| Firewall_access_granted    | 4     |
| Firewall_access_suspicious | 1     |
| Firewall_cached_entries    | 4     |
+----------------------------+-------+
```

The variables indicate the number of statements rejected, accepted, logged as suspicious, and added to the cache, respectively. The `Firewall_access_granted` count is 4 because of the `@@version_comment` statement sent by the `mysql` client each of the three time you used it to connect as the registered user, plus the `SHOW TABLES` statement that was not blocked in `DETECTING` mode.

Should additional training for an account be necessary, switch it to recording mode again, then back to protecting mode after executing statements to be added to the whitelist.

7.5.4 MySQL Enterprise Firewall Reference

The following discussion serves as a reference to MySQL Enterprise Firewall components:

- Section 7.5.4.1, “MySQL Enterprise Firewall Tables”
- Section 7.5.4.2, “MySQL Enterprise Firewall Procedures and Functions”
- Section 7.5.4.3, “MySQL Enterprise Firewall System Variables”
- Section 7.5.4.4, “MySQL Enterprise Firewall Status Variables”

7.5.4.1 MySQL Enterprise Firewall Tables

MySQL Enterprise Firewall maintains account and whitelist information. It uses `INFORMATION_SCHEMA` tables to provide views into cached data, and tables in the `mysql` system database to store this data in persistent form. When enabled, the firewall bases its operational decisions on the cached data.

The `INFORMATION_SCHEMA` tables are accessible by anyone. The `mysql` tables can be accessed only by users with privileges for that database.

The `INFORMATION_SCHEMA.MYSQL_FIREWALL_USERS` and `mysql.firewall_users` tables list registered firewall accounts and their operational modes. The tables have these columns:

- `USERHOST`

  An account registered with the firewall. Each account has the format *`user_name@host_name`* and represents actual user and host names as authenticated by the server. Patterns and netmasks should not be used when registering users.

- `MODE`

  The current firewall operational mode for the account. The permitted mode values are `OFF`, `DETECTING`, `PROTECTING`, `RECORDING`, and `RESET`. For details about their meanings, see the description of `sp_set_firewall_mode()` in Section 7.5.4.2, “MySQL Enterprise Firewall Procedures and Functions”.

The `INFORMATION_SCHEMA.MYSQL_FIREWALL_WHITELIST` and `mysql.firewall_whitelist` tables list registered firewall accounts and their whitelists. The tables have these columns:

- `USERHOST`

  An account registered with the firewall. The format is the same as for the user account tables.

- `RULE`

  A normalized statement indicating an acceptable statement pattern for the account. An account whitelist is the union of its rules.

7.5.4.2 MySQL Enterprise Firewall Procedures and Functions

MySQL Enterprise Firewall has stored procedures that perform tasks such as registering MySQL accounts with the firewall, establishing their operational mode, and managing transfer of firewall data between the cache and the underlying system tables. It also has a set of user-defined functions (UDFs) that provides an SQL-level API for lower-level tasks such as synchronizing the cache with the underlying system tables.

Under normal operation, the stored procedures implement the user interface. The UDFs are invoked by the stored procedures, not directly by users.

To invoke a stored procedure when the default database is not the database that contains the procedure, qualify the procedure name with the database name. For example:

```
CALL mysql.sp_set_firewall_mode(user, mode);
```

The following list describes each firewall stored procedure and UDF:

- `sp_reload_firewall_rules(user)`

  This stored procedure uses firewall UDFs to reset a registered account and reload the in-memory rules for it from the rules stored in the `mysql.firewall_whitelist` table. This procedure provides control over firewall operation for individual accounts.

  The *`user`* argument names the affected account, as a string in *`user_name@host_name`* format.

  Example:

  ```
  CALL mysql.sp_reload_firewall_rules('fwuser@localhost');
  ```

  > **Warning**
  >
  > This procedure sets the account mode to `RESET`, which clears the account whitelist and sets its mode to `OFF`. If the account mode was not `OFF` prior to the `sp_reload_firewall_rules()` call, use `sp_set_firewall_mode()` to restore its previous mode after reloading the rules. For example, if the account was in `PROTECTING` mode, that is no longer true after calling `sp_reload_firewall_rules()` and you must set it to `PROTECTING` again explicitly.

- `sp_set_firewall_mode(user, mode)`

  This stored procedure registers a MySQL account with the firewall and establishes its operational mode. The procedure also invokes firewall UDFs as necessary to transfer firewall data between the cache and the underlying system tables. This procedure may be called even if the `mysql_firewall_mode` system variable is `OFF`, although setting the mode for an account has no operational effect while the firewall is disabled.

  The *`user`* argument names the affected account, as a string in *`user_name@host_name`* format.

  The *`mode`* is the operational mode for the user, as a string. These mode values are permitted:

- `OFF`: Disable the firewall for the account.
- `DETECTING`: Intrusion-detection mode: Write suspicious (nonmatching) statements to the error log but do not deny access.
- `PROTECTING`: Protect the account by matching incoming statements against the account whitelist.
- `RECORDING`: Training mode: Record acceptable statements for the account. Incoming statements that do not immediately fail with a syntax error are recorded to become part of the account whitelist rules.
- `RESET`: Clear the account whitelist and set the account mode to `OFF`.

Switching the mode for an account to any mode but `RECORDING` synchronizes the firewall cache data to the underlying `mysql` system database tables for persistent storage. Switching the mode from `OFF` to `RECORDING` reloads the whitelist from the `mysql.firewall_whitelist` table into the cache.

If an account has an empty whitelist, setting its mode to `PROTECTING` produces an error message that is returned in a result set, but not an SQL error:

```
mysql> CALL mysql.sp_set_firewall_mode('a@b','PROTECTING');
+-----------------------------------------------------------------------+
| set_firewall_mode(arg_userhost, arg_mode)                             |
+-----------------------------------------------------------------------+
| ERROR: PROTECTING mode requested for a@b but the whitelist is empty. |
+-----------------------------------------------------------------------+
1 row in set (0.02 sec)
Query OK, 0 rows affected (0.02 sec)
```

- `mysql_firewall_flush_status()`

  This UDF resets several firewall status variables to 0:

  ```
  Firewall_access_denied
  Firewall_access_granted
  Firewall_access_suspicious
  ```

  Example:

  ```
  SELECT mysql_firewall_flush_status();
  ```

- `normalize_statement(stmt)`

  This UDF normalizes an SQL statement into the digest form used for whitelist rules.

  Example:

  ```
  SELECT normalize_statement('SELECT * FROM t1 WHERE c1 > 2');
  ```

- `read_firewall_users(user, mode)`

  This aggregate UDF updates the firewall user cache through a `SELECT` statement on the `mysql.firewall_users` table.

  Example:

  ```
  SELECT read_firewall_users('fwuser@localhost', 'RECORDING')
  FROM mysql.firewall_users;
  ```

- `read_firewall_whitelist(user, rule)`

  This aggregate UDF updates the recorded statement cache through a `SELECT` statement on the `mysql.firewall_whitelist` table.

  Example:

```
SELECT read_firewall_whitelist('fwuser@localhost', 'RECORDING')
FROM mysql.firewall_whitelist;
```

- `set_firewall_mode(user, mode)`

  This UDF manages the user cache and establishes the user operational mode.

  Example:

```
SELECT set_firewall_mode('fwuser@localhost', 'RECORDING');
```

7.5.4.3 MySQL Enterprise Firewall System Variables

MySQL Enterprise Firewall supports the following system variables. Use them to configure firewall operation. These variables are unavailable unless the firewall is installed (see Section 7.5.2, “Installing or Uninstalling MySQL Enterprise Firewall”).

- `mysql_firewall_mode`

Introduced	5.7.9	
Command-Line Format	`--mysql_firewall_mode={OFF|ON}`	
System Variable	**Name**	`mysql_firewall_mode`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	boolean
	Default	`ON`

Whether MySQL Enterprise Firewall is enabled (the default) or disabled.

- `mysql_firewall_trace`

Introduced	5.7.9	
Command-Line Format	`--mysql_firewall_trace={OFF|ON}`	
System Variable	**Name**	`mysql_firewall_trace`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	boolean
	Default	`OFF`

Whether the MySQL Enterprise Firewall trace is enabled or disabled (the default). When `mysql_firewall_trace` is enabled, for `PROTECTING` mode, the firewall writes rejected statements to the error log.

7.5.4.4 MySQL Enterprise Firewall Status Variables

MySQL Enterprise Firewall supports the following status variables. Use them to obtain information about firewall operational status. These variables are unavailable unless the firewall is installed (see Section 7.5.2, “Installing or Uninstalling MySQL Enterprise Firewall”). Firewall status variables are set to 0 whenever the `MYSQL_FIREWALL` plugin is installed or the server is started. Many of them are reset to zero by the `mysql_firewall_flush_status()` UDF (see Section 7.5.4.2, “MySQL Enterprise Firewall Procedures and Functions”).

- `Firewall_access_denied`

  The number of statements rejected by MySQL Enterprise Firewall.

- `Firewall_access_granted`

  The number of statements accepted by MySQL Enterprise Firewall.

- `Firewall_access_suspicious`

  The number of statements logged by MySQL Enterprise Firewall as suspicious for users who are in `DETECTING` mode.

- `Firewall_cached_entries`

  The number of statements recorded by MySQL Enterprise Firewall, including duplicates.

Appendix A MySQL 5.7 FAQ: Security

Questions

Questions and Answers

A.1: Where can I find documentation that addresses security issues for MySQL?

The best place to start is Chapter 1, *Security*.

Other portions of the MySQL Documentation which you may find useful with regard to specific security concerns include the following:

- Section 2.1, “Security Guidelines”.
- Section 2.3, “Making MySQL Secure Against Attackers”.
- How to Reset the Root Password.
- Section 2.5, “How to Run MySQL as a Normal User”.
- UDF Security Precautions.
- Section 2.4, “Security-Related mysqld Options and Variables”.
- Section 2.6, “Security Issues with LOAD DATA LOCAL”.
- Chapter 3, *Postinstallation Setup and Testing*.
- Chapter 6, *Using Secure Connections*.

A.2: Does MySQL 5.7 have native support for SSL?

Most 5.7 binaries have support for SSL connections between the client and server. See Chapter 6, *Using Secure Connections*.

You can also tunnel a connection using SSH, if (for example) the client application does not support SSL connections. For an example, see Section 6.7, “Connecting to MySQL Remotely from Windows with SSH”.

A.3: Is SSL support built into MySQL binaries, or must I recompile the binary myself to enable it?

Most 5.7 binaries have SSL enabled for client/server connections that are secured, authenticated, or both. See Chapter 6, *Using Secure Connections*.

A.4: Does MySQL 5.7 have built-in authentication against LDAP directories?

The Enterprise edition includes a PAM Authentication Plugin that supports authentication against an LDAP directory.

A.5: Does MySQL 5.7 include support for Roles Based Access Control (RBAC)?

Not at this time.