MySQL Replication

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Abstract

This is the MySQL Replication extract from the MySQL 6.0 Reference Manual.

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

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Replication

Replication enables data from one MySQL database server (called the master) to be replicated to one or more MySQL database servers (slaves). Replication is asynchronous by default - your replication slaves do not need to be connected permanently to receive updates from the master, which means that updates can occur over long-distance connections and even temporary solutions such as a dial-up service. Depending on the configuration, you can replicate all databases, selected databases, or even selected tables within a database.

The target uses for replication in MySQL include:

- Scale-out solutions - spreading the load among multiple slaves to improve performance. In this environment, all writes and updates must take place on the master server. Reads, however, may take place on one or more slaves. This model can improve the performance of writes (since the master is dedicated to updates), while dramatically increasing read speed across an increasing number of slaves.
- Data security - because data is replicated to the slave, and the slave can pause the replication process, it is possible to run backup services on the slave without corrupting the corresponding master data.
- Analytics - live data can be created on the master, while the analysis of the information can take place on the slave without affecting the performance of the master.
- Long-distance data distribution - if a branch office would like to work with a copy of your main data, you can use replication to create a local copy of the data for their use without requiring permanent access to the master.

Replication in MySQL features support for one-way, asynchronous replication, in which one server acts as the master, while one or more other servers act as slaves. This is in contrast to the *synchronous* replication which is a characteristic of MySQL Cluster (see MySQL Cluster NDB 6.X/7.X). As of version 6.0.8, MySQL supports an interface to semisynchronous replication in addition to the built-in asynchronous replication. With semisynchronous replication, a commit performed on the master side blocks before returning to the session that performed the transaction until at least one slave acknowleges that it has received and logged the events for the transaction.

There are a number of solutions available for setting up replication between two servers, but the best method to use depends on the presence of data and the engine types you are using. For more information on the available options, see Section 1.1, "How to Set Up Replication".

There are two core types of replication format, Statement Based Replication (SBR), which replicates entire SQL statements, and Row Based Replication (RBR), which replicates only the changed rows. You may also use a third variety, Mixed Based Replication (MBR), which is the default mode. For more information on the different replication formats, see Section 1.2, "Replication Formats".

Replication is controlled through a number of different options and variables. These control the core operation of the replication, timeouts and the databases and filters that can be applied on databases and tables. For more information on the available options, see Section 1.3, "Replication and Binary Logging Options and Variables".

You can use replication to solve a number of different problems, including problems with performance, supporting the backup of different databases and for use as part of a larger solution to alleviate system failures. For information on how to address these issues, see Chapter 2, *Replication Solutions*.

For notes and tips on how different data types and statements are treated during replication, including details of replication features, version compatibility, upgrades, and problems and their resolution, including an FAQ, see Chapter 3, *Replication Notes and Tips*.

Detailed information on the implementation of replication, how replication works, the process and contents of the binary log, background threads and the rules used to decide how statements are recorded and replication, see Chapter 4, *Replication Implementation*.

MySQL Enterprise
The MySQL Enterprise Monitor provides numerous advisors that provide immediate feedback about replication-related problems. For more information, see http://www.mysql.com/products/enterprise/advisors.html.

Chapter 1. Replication Configuration

Replication between servers in MySQL works through the use of the binary logging mechanism. The MySQL instance operating as the master (the source of the database changes) writes updates and changes as “events” to the binary log. The information in the binary log is stored in different logging formats according to the database changes being recorded. Slaves are configured to read the binary log from the master and to execute the events in the binary log on the slave's local database.

The master is “dumb” in this scenario. Once binary logging has been enabled, all statements are recorded in the binary log. Each slave will receive a copy of the entire contents of the binary log. It is the responsibility of the slave to decide which statements in the binary log should be executed; you cannot configure the master to log only certain events. If you do not specify otherwise, all events in the master binary log are executed on the slave. If required, you can configure the slave to process only events that apply to particular databases or tables.

Each slave keeps a record of the binary log file and position within the log file that it has read and processed from the master. This means that multiple slaves can be connected to the master and executing different parts of the same binary log. Because the slaves control this process, individual slaves can be connected and disconnected from the server without affecting the master's operation. Also, because each slave remembers the position within the binary log, it is possible for slaves to be disconnected, reconnect and then “catch up” by continuing from the recorded position.

Both the master and each slave must be configured with a unique ID (using the `server-id` option). In addition, the slave must be configured with information about the master host name, log file name and position within that file. These details can be controlled from within a MySQL session using the `CHANGE MASTER TO` statement. The details are stored within the `master.info` file.

In this section the setup and configuration required for a replication environment is described, including step-by-step instructions for creating a new replication environment. The major components of this section are:

- For a guide to setting up two or more servers for replication see Section 1.1, “How to Set Up Replication”. This section deals with the setup of the systems and provides methods for copying data between the master and slaves.
- Events in the binary log are recorded using a number of formats. These are referred to as statement-based replication (SBR) or row-based replication (RBR). A third type, mixed-format replication (MIXED), uses SBR or RBR replication automatically to take advantage of the benefits of both SBR and RBR formats when appropriate. The different formats are discussed in Section 1.2, “Replication Formats”.
- Detailed information on the different configuration options and variables that apply to replication is provided in Section 1.3, “Replication and Binary Logging Options and Variables”.
- Once started, the replication process should require little administration or monitoring. However, for advice on common tasks that you may want to execute, see Section 1.4, “Common Replication Administration Tasks”.

1.1. How to Set Up Replication

This section describes how to set up complete replication of a MySQL server. There are a number of different methods for setting up replication, and the exact method that you use will depend on how you are setting up replication, and whether you already have data within your master database.

There are some generic tasks which may be required for all replication setups:

- You may want to create a separate user that will be used by your slaves to authenticate with the master to read the binary log for replication. The step is optional. See Section 1.1.1, “Creating a User for Replication”.
- You must configure the master to support the binary log and configure a unique ID. See Section 1.1.2, “Setting the Replication Master Configuration”.
- You must configure a unique ID for each slave that you want to connect to the master. See Section 1.1.3, “Setting the Replication Slave Configuration”.
- Before starting a data snapshot or the replication process, you should record the position of the binary log on the master. You will need this information when configuring the slave so that the slave knows where within the binary log to start executing events. See Section 1.1.4, “Obtaining the Master Replication Information”.
- If you already have data on your master and you want to synchronize your slave with this base data, then you will need to create a data snapshot of your database. You can create a snapshot using `mysqldump` (see Section 1.1.5, “Creating a Data Snapshot Using `mysqldump`”) or by copying the data files directly (see Section 1.1.6, “Creating a Data Snapshot Using Raw Data Files”).

- You will need to configure the slave with the master settings, such as the host name, login credentials and binary log name and positions. See Section 1.1.10, "Setting the Master Configuration on the Slave".

Once you have configured the basic options, you will need to follow the instructions for your replication setup. A number of alternatives are provided:

- If you are establishing a new MySQL master and one or more slaves, then you need only set up the configuration, as you have no data to exchange. For guidance on setting up replication in this situation, see Section 1.1.7, "Setting Up Replication with New Master and Slaves".
- If you are already running a MySQL server, and therefore already have data that will need to be transferred to your slaves before replication starts, have not previously configured the binary log and are able to shut down your MySQL server for a short period during the process, see Section 1.1.8, "Setting Up Replication with Existing Data".
- If you are setting up additional slaves to an existing replication environment then you can set up the slaves without affecting the master. See Section 1.1.9, "Introducing Additional Slaves to an Existing Replication Environment".

If you want to administer a MySQL replication setup, we suggest that you read this entire chapter through and try all statements mentioned in SQL Statements for Controlling Master Servers, and SQL Statements for Controlling Slave Servers. You should also familiarize yourself with the replication startup options described in Section 1.3, "Replication and Binary Logging Options and Variables".

> **Note**
>
> Note that certain steps within the setup process require the `SUPER` privilege. If you do not have this privilege then enabling replication may not be possible.

1.1.1. Creating a User for Replication

Each slave must connect to the master using a standard MySQL user name and password, so there must be a user account on the master that the slave can use to connect. Any account can be used for this operation, providing it has been granted the `REPLICATION SLAVE` privilege.

You do not need to create a specific user for replication. However, you should be aware that the user name and password will be stored in plain text within the `master.info` file. Therefore, you may want to create a user that only has privileges for the replication process.

To create a user or grant an existing user the privileges required for replication, use the `GRANT` statement. If you create a user solely for the purposes of replication then that user needs only the `REPLICATION SLAVE` privilege. For example, to create a user, `repl`, that can connect for replication from any host within the `mydomain.com` domain, issue this statement on the master:

```
mysql> GRANT REPLICATION SLAVE ON *.*
    -> TO 'repl'@'%.mydomain.com' IDENTIFIED BY 'slavepass';
```

See `GRANT` Syntax, for more information on the `GRANT` statement.

You may wish to create a different user for each slave, or use the same user for each slave that needs to connect. As long as each user that you want to use for the replication process has the `REPLICATION SLAVE` privilege you can create as many users as you require.

1.1.2. Setting the Replication Master Configuration

For replication to work you *must* enable binary logging on the master. If binary logging is not enabled, replication will not be possible as it is the binary log that is used to exchange data between the master and slaves.

Each server within a replication group must be configured with a unique `server-id` value. The server ID is used to identify individual servers within the group, and must be positive integer between 1 and (2^{32})–1. How you organize and select the numbers is entirely up to you.

To configure the binary log and server ID options, you will need to shut down your MySQL server and edit the configuration of the `my.cnf` or `my.ini` file.

You will need to add the following options to the configuration file within the `[mysqld]` section. If these options already exist, but are commented out, uncomment the options and alter them according to your needs. For example, to enable binary logging, using a log file name prefix of `mysql-bin`, and setting a server ID of 1:

```
[mysqld]
```

```
log-bin=mysql-bin
server-id=1
```

Note

For the greatest possible durability and consistency in a replication setup using `InnoDB` with transactions, you should use `innodb_flush_log_at_trx_commit=1` and `sync_binlog=1` in the master `my.cnf` file.

Note

Ensure that the `skip-networking` option has not been enabled on your replication master. If networking has been disabled, then your slave will not able to communicate with the master and replication will fail.

1.1.3. Setting the Replication Slave Configuration

The only option you must configure on the slave is to set the unique server ID. If this option is not already set, or the current value conflicts with the value that you have chosen for the master server, then you should shut down your slave server, and edit the configuration to specify the server ID. For example:

```
[mysqld]
server-id=2
```

If you are setting up multiple slaves, each one must have a unique `server-id` value that differs from that of the master and from each of the other slaves. Think of `server-id` values as something similar to IP addresses: These IDs uniquely identify each server instance in the community of replication partners.

If you do not specify a `server-id` value, it defaults to 0.

Note

If you omit `server-id` (or set it explicitly to 0), a master refuses connections from all slaves, and a slave refuses to connect to a master. Thus, omitting `server-id` is good only for backup with a binary log.

You do not have to enable binary logging on the slave for replication to be enabled. However, if you enable binary logging on the slave then you can use the binary log for data backups and crash recovery on the slave, and also use the slave as part of a more complex replication topology (for example, where the slave acts as a master to other slaves).

1.1.4. Obtaining the Master Replication Information

To configure replication on the slave you must determine the master's current point within the master binary log. You will need this information so that when the slave starts the replication process, it is able to start processing events from the binary log at the correct point.

If you have existing data on your master that you want to synchronize on your slaves before starting the replication process, then you must stop processing statements on the master, obtain the current position, and then dump the data, before allowing the master to continue executing statements. If you do not stop the execution of statements, the data dump and the master status information that you use will not match and you will end up with inconsistent or corrupted databases on the slaves.

To get the master status information, follow these steps:

1. Start the command-line client and flush all tables and block write statements by executing the `FLUSH TABLES WITH READ LOCK` statement:

   ```
   mysql> FLUSH TABLES WITH READ LOCK;
   ```

   For `InnoDB` tables, note that `FLUSH TABLES WITH READ LOCK` also blocks `COMMIT` operations.

   Warning

   Leave the client from which you issued the `FLUSH TABLES` statement running so that the read lock remains in effect. If you exit the client, the lock is released.

2. Use the `SHOW MASTER STATUS` statement to determine the current binary log file name and offset on the master:

   ```
   mysql > SHOW MASTER STATUS;
   +---------------+----------+--------------+------------------+
   | File          | Position | Binlog_Do_DB | Binlog_Ignore_DB |
   +---------------+----------+--------------+------------------+
   | mysql-bin.003 | 73       | test         | manual,mysql     |
   ```

```
+---------------+----------+-------------+-----------------+
```

The `File` column shows the name of the log file and `Position` shows the offset within the file. In this example, the binary log file is `mysql-bin.003` and the offset is 73. Record these values. You need them later when you are setting up the slave. They represent the replication coordinates at which the slave should begin processing new updates from the master.

If the master has been running previously without binary logging enabled, the log name and position values displayed by `SHOW MASTER STATUS` or `mysqldump --master-data` will be empty. In that case, the values that you need to use later when specifying the slave's log file and position are the empty string (`''`) and `4`.

You now have the information you need to enable the slave to start reading from the binary log in the correct place to start replication.

If you have existing data that needs be to synchronized with the slave before you start replication, leave the client running so that the lock remains in place and then proceed to Section 1.1.5, “Creating a Data Snapshot Using `mysqldump`”, or Section 1.1.6, “Creating a Data Snapshot Using Raw Data Files”.

If you are setting up a brand new master and slave replication group, then you can exit the client and release the locks.

1.1.5. Creating a Data Snapshot Using `mysqldump`

One way to create a snapshot of the data in an existing master database is to use the `mysqldump` tool. Once the data dump has been completed, you then import this data into the slave before starting the replication process.

To obtain a snapshot of the data using `mysqldump`:

- If you haven't already locked the tables on the server to prevent statements that update data from executing:

  Start the command-line client and flush all tables and block write statements by executing the `FLUSH TABLES WITH READ LOCK` statement:

  ```
  mysql> FLUSH TABLES WITH READ LOCK;
  ```

  Remember to use `SHOW MASTER STATUS` and record the binary log details for use when starting up the slave. The point in time of your snapshot and the binary log position must match. See Section 1.1.4, “Obtaining the Master Replication Information”.

- In another session, use `mysqldump` to create a dump either of all the databases you want to replicate, or of selected individual databases. For example:

  ```
  shell> mysqldump --all-databases --lock-all-tables >dbdump.db
  ```

- An alternative to using a bare dump, is to use the `--master-data` option, which automatically appends the `CHANGE MASTER TO` statement required on the slave to start the replication process.

  ```
  shell> mysqldump --all-databases --master-data >dbdump.db
  ```

- In the client where you acquired the read lock, release the lock:

  ```
  mysql> UNLOCK TABLES;
  ```

When choosing databases to include in the dump, remember that you will need to filter out databases on each slave that you do not want to include in the replication process.

You will need either to copy the dump file to the slave, or to use the file from the master when connecting remotely to the slave to import the data.

1.1.6. Creating a Data Snapshot Using Raw Data Files

If your database is particularly large, copying the raw data files may be more efficient than using `mysqldump` and importing the file on each slave.

However, using this method with tables in storage engines with complex caching or logging algorithms may not give you a perfect “in time” snapshot as cache information and logging updates may not have been applied, even if you have acquired a global read lock. How the storage engine responds to this depends on its crash recovery abilities.

In addition, this method does not work reliably if the master and slave have different values for `ft_stopword_file`, `ft_min_word_len`, or `ft_max_word_len` and you are copying tables having fulltext indexes.

If you are using `InnoDB` tables, you should use the `InnoDB Hot Backup` tool to obtain a consistent snapshot. This tool records the log name and offset corresponding to the snapshot to be later used on the slave. `Hot Backup` is a non-free (commercial) tool that is not included in the standard MySQL distribution. See the `InnoDB Hot Backup` home page at http://www.innodb.com/hot-backup for detailed information.

Otherwise, you can obtain a reliable binary snapshot of `InnoDB` tables only after shutting down the MySQL Server.

To create a raw data snapshot of `MyISAM` tables you can use standard copy tools such as `cp` or `copy`, a remote copy tool such as `scp` or `rsync`, an archiving tool such as `zip` or `tar`, or a file system snapshot tool such as `dump`, providing that your MySQL data files exist on a single file system. If you are replicating only certain databases then make sure you copy only those files that related to those tables. (For `InnoDB`, all tables in all databases are stored in a single file unless you have the `innodb_file_per_table` option enabled.)

You may want to specifically exclude the following files from your archive:

- Files relating to the `mysql` database.
- The `master.info` file.
- The master's binary log files.
- Any relay log files.

To get the most consistent results with a raw data snapshot you should shut down the server during the process, as below:

1. Acquire a read lock and get the master's status. See Section 1.1.4, “Obtaining the Master Replication Information”.
2. In a separate session, shut down the MySQL server:

   ```
   shell> mysqladmin shutdown
   ```

3. Make a copy of the MySQL data files. Examples are shown below for common ways to do this - you need to choose only one of them:

   ```
   shell> tar cf /tmp/db.tar ./data
   shell> zip -r /tmp/db.zip ./data
   shell> rsync --recursive ./data /tmp/dbdata
   ```

4. Start up the MySQL instance on the master.

If you are not using `InnoDB` tables, you can get a snapshot of the system from a master without shutting down the server as described in the following steps:

1. Acquire a read lock and get the master's status. See Section 1.1.4, “Obtaining the Master Replication Information”.
2. Take a copy of the MySQL data files. Examples are shown below for common solutions - you need to choose only one of these solutions:

   ```
   shell> tar cf /tmp/db.tar ./data
   shell> zip -r /tmp/db.zip ./data
   shell> rsync --recursive ./data /tmp/dbdata
   ```

3. In the client where you acquired the read lock, release the lock:

   ```
   mysql> UNLOCK TABLES;
   ```

Once you have created the archive or copy of the database, you will need to copy the files to each slave before starting the slave replication process.

1.1.7. Setting Up Replication with New Master and Slaves

Setting up replication with a new master and slaves (that is, with no existing data) is the easiest and most straightforward method for setting up replication.

You can also use this method if you are setting up new servers but have an existing dump of the databases from a different server that you want to load into your replication configuration. By loading the data into a new master, the data will be automatically replicated to the slaves.

To set up replication between a new master and slave:

1. Configure the MySQL master with the necessary configuration properties. See Section 1.1.2, “Setting the Replication Master Configuration”.
2. Start up the MySQL master.
3. Set up a user. See Section 1.1.1, “Creating a User for Replication”.
4. Obtain the master status information. See Section 1.1.4, “Obtaining the Master Replication Information”.
5. On the master, release the read lock:

   ```
   mysql> UNLOCK TABLES;
   ```

6. On the slave, edit the MySQL configuration. See Section 1.1.3, “Setting the Replication Slave Configuration”.
7. Start up the MySQL slave.
8. Execute the `CHANGE MASTER TO` statement to set the master replication server configuration.

Perform the slave setup steps on each slave.

Because there is no data to load or exchange on a new server configuration you do not need to copy or import any information.

If you are setting up a new replication environment using the data from a different existing database server, you will now need to run the dump file generated from that server on the new master. The database updates will automatically be propagated to the slaves:

```
shell> mysql -h master < fulldb.dump
```

1.1.8. Setting Up Replication with Existing Data

When setting up replication with existing data, you will need to decide how best to get the data from the master to the slave before starting the replication service.

The basic process for setting up replication with existing data is as follows:

1. If you have not already configured the `server-id` and binary logging, you will need to shut down your master to configure these options. See Section 1.1.2, “Setting the Replication Master Configuration”.

   If you have to shut down your master server, this is a good opportunity to take a snapshot of its databases. You should obtain the master status (see Section 1.1.4, “Obtaining the Master Replication Information”) before taking down the master, updating the configuration and taking a snapshot. For information on how to create a snapshot using raw data files, see Section 1.1.6, “Creating a Data Snapshot Using Raw Data Files”.

2. If your server is already correctly configured, obtain the master status (see Section 1.1.4, “Obtaining the Master Replication Information”) and then use `mysqldump` to take a snapshot (see Section 1.1.5, “Creating a Data Snapshot Using `mysqldump`”) or take a raw snapshot of the live server using the guide in Section 1.1.6, “Creating a Data Snapshot Using Raw Data Files”.
3. With the MySQL master running, create a user to be used by the slave when connecting to the master during replication. See Section 1.1.1, “Creating a User for Replication”.
4. Update the configuration of the slave. See Section 1.1.3, “Setting the Replication Slave Configuration”.
5. The next step depends on how you created the snapshot of data on the master.

   If you used `mysqldump`:

   a. Start the slave, skipping replication by using the `--skip-slave` option.

   b. Import the dump file:

      ```
      shell> mysql < fulldb.dump
      ```

   If you created a snapshot using the raw data files:

   a. Extract the data files into your slave data directory. For example:

      ```
      shell> tar xvf dbdump.tar
      ```

      You may need to set permissions and ownership on the files to match the configuration of your slave.

   b. Start the slave, skipping replication by using the `--skip-slave` option.

6. Configure the slave with the master status information. This will tell the slave the binary log file and position within the file where replication needs to start, and configure the login credentials and host name of the master. For more information on the statement required, see Section 1.1.10, “Setting the Master Configuration on the Slave”.

7. Start the slave threads:

   ```
   mysql> START SLAVE;
   ```

After you have performed this procedure, the slave should connect to the master and catch up on any updates that have occurred since the snapshot was taken.

If you have forgotten to set the `server-id` option for the master, slaves cannot connect to it.

If you have forgotten to set the `server-id` option for the slave, you get the following error in the slave's error log:

```
Warning: You should set server-id to a non-0 value if master_host
is set; we will force server id to 2, but this MySQL server will
not act as a slave.
```

You also find error messages in the slave's error log if it is not able to replicate for any other reason.

Once a slave is replicating, you can find in its data directory one file named `master.info` and another named `relay-log.info`. The slave uses these two files to keep track of how much of the master's binary log it has processed. Do *not* remove or edit these files unless you know exactly what you are doing and fully understand the implications. Even in that case, it is preferred that you use the `CHANGE MASTER TO` statement to change replication parameters. The slave will use the values specified in the statement to update the status files automatically.

> **Note**
>
> The content of `master.info` overrides some of the server options specified on the command line or in `my.cnf`. See Section 1.3, “Replication and Binary Logging Options and Variables”, for more details.

Once you have a snapshot of the master, you can use it to set up other slaves by following the slave portion of the procedure just described. You do not need to take another snapshot of the master; you can use the same one for each slave.

1.1.9. Introducing Additional Slaves to an Existing Replication Environment

If you want to add another slave to the existing replication configuration then you can do so without stopping the master. Instead, you duplicate the settings on the slaves by making a copy of one of the slaves.

To duplicate the slave:

1. Shut down the existing slave:

   ```
   shell> mysqladmin shutdown
   ```

2. Copy the data directory from the existing slave to the new slave. You can do this by creating an archive using `tar` or `WinZip`, or by performing a direct copy using a tool such as `cp` or `rsync`. Ensure that you also copy the log files and relay log files.

Note

A common problem that is encountered when adding new replication slaves is that the new slave fails with a series of warning and error messages like these:

```
071118 16:44:10 [Warning] Neither --relay-log nor --relay-log-index were used; so
replication may break when this MySQL server acts as a slave and has his hostname
changed!! Please use '--relay-log=new_slave_hostname-relay-bin' to avoid this problem.
071118 16:44:10 [ERROR] Failed to open the relay log './old_slave_hostname-relay-bin.003525'
(relay_log_pos 22940879)
071118 16:44:10 [ERROR] Could not find target log during relay log initialization
071118 16:44:10 [ERROR] Failed to initialize the master info structure
```

This is due to the fact that, if the `--relay-log` option is not specified, the relay log files contain the host name as part of their file names. (This is also true of the relay log index file if the `--relay-log-index` option is not used. See Section 1.3, “Replication and Binary Logging Options and Variables”, for more information about these options.)

To avoid this problem, use the same value for `--relay-log` on the new slave that was used on the existing slave. (If this option was not set explicitly on the existing slave, use *`existing_slave_hostname`*`-relay-bin`.) If this is not feasible, then copy the existing slave's relay log index file to the new slave and set the `--relay-log-index` option on the new slave to match what was used on the existing slave. (If this option was not set explicitly on the existing slave, use *`existing_slave_hostname`*`-relay-bin.index`.) Alternatively — if you have already tried to start the new slave (after following the remaining steps in this section) and have encountered errors like those described previously — then perform the following steps:

a. If you have not already done so, issue a `STOP SLAVE` on the new slave.

   If you have already started the existing slave again, issue a `STOP SLAVE` on the existing slave as well.

b. Copy the contents of the existing slave's relay log index file into the new slave's relay log index file, making sure to overwrite any content already in the file.

c. Proceed with the remaining steps in this section.

3. Copy the `master.info` and `relay-log.info` files from the existing slave to the new slave. These files hold the current log positions.

4. Start the existing slave.

5. On the new slave, edit the configuration and the give the new slave a new unique `server-id`.

6. Start the new slave; the `master.info` file options will be used to start the replication process.

1.1.10. Setting the Master Configuration on the Slave

To set up the slave to communicate with the master for replication, you must tell the slave the necessary connection information. To do this, execute the following statement on the slave, replacing the option values with the actual values relevant to your system:

```
mysql> CHANGE MASTER TO
    ->     MASTER_HOST='master_host_name',
    ->     MASTER_USER='replication_user_name',
    ->     MASTER_PASSWORD='replication_password',
    ->     MASTER_LOG_FILE='recorded_log_file_name',
    ->     MASTER_LOG_POS=recorded_log_position;
```

Note

Replication cannot use Unix socket files. You must be able to connect to the master MySQL server using TCP/IP.

The following table shows the maximum allowable length for the string-valued options.

Option	Maximum Length
`MASTER_HOST`	60
`MASTER_USER`	16
`MASTER_PASSWORD`	32
`MASTER_LOG_FILE`	255

1.2. Replication Formats

Replication works because events written to the binary log are read from the master and then processed on the slave. The events are recorded within the binary log in different formats according the type of event being recorded. The different replication formats used correspond to the binary logging format used when the events were recorded in the master's binary log. The correlation between binary logging formats and the terms used during replication are:

- Replication capabilities in MySQL originally were based on propagation of SQL statements from master to slave. This is called *statement-based replication* (often abbreviated as *SBR*), which corresponds to the standard statement-based binary logging format. In older versions of MySQL (5.1.4 and earlier), binary logging and replication used this format exclusively.
- Row-based binary logging logs changes in individual table rows. When used with MySQL replication, this is known as *row-based replication* (often abbreviated as *RBR*). In row-based replication, the master writes messages known as *events* to the binary log that indicate how individual table rows are changed.
- The binary logging format can be changed in real time according to the event being logged using *mixed-format logging*.

  When the mixed format is in effect, statement-based logging is used by default, but automatically switches to row-based logging in particular cases as described below. Replication using the mixed format is often referred to as *mixed-based replication* or *mixed-format replication*. For more information, see Mixed Binary Logging Format.

The mixed format is the default for MySQL replication.

The binary logging format is determined in part by the storage engine being used and the statement being executed. For more information on mixed-format logging and the rules governing the support of different logging formats, see Mixed Binary Logging Format.

You must have the `SUPER` privilege to set the binary logging format on the global level. Starting with MySQL 6.0.8, you must also have the `SUPER` privilege to set the binary logging format for the current session. (Bug#39106)

The logging format in a running MySQL server is controlled by setting the `binlog_format` server system variable. This variable can be set with session or global scope. The rules governing when and how the new setting takes effect are the same as for other MySQL server system variables — setting the variable for the current session lasts only until the end of that session, and the change is not visible to other sessions; setting the variable globally requires a restart of the server in order to take effect. For more information, see `SET` Syntax.

The statement-based and row-based replication formats have different issues and limitations. For a comparison of their relative advantages and disadvantages, see Section 1.2.1, "Comparison of Statement-Based and Row-Based Replication".

With statement-based replication, you may encounter issues with replicating stored routines or triggers. You can avoid these issues by using row-based replication instead. For more information, see Binary Logging of Stored Programs.

If you build MySQL from source, row-based replication is available by default unless you invoke `configure` with the `--without-row-based-replication` option.

For MySQL 5.1.20 and later (and MySQL 5.0.46 for backward compatibility), the following session variables are written to the binary log and honored by the replication slave when parsing the binary log:

- `sql_mode`
- `foreign_key_checks`
- `unique_checks`
- `character_set_client`
- `collation_connection`
- `collation_database`
- `collation_server`
- `sql_auto_is_null`

> **Important**
>
> Even though session variables relating to character sets and collations are written to the binary log, replication

between different character sets is not supported.

1.2.1. Comparison of Statement-Based and Row-Based Replication

Each binary logging format has advantages and disadvantages. For most users, the mixed replication format should provide the best combination of data integrity and performance. If, however, you want to take advantage of the features specific to the statement-based or row-based replication format when performing certain tasks, then you can use the information in this section, which provides a summary of their relative advantages and disadvantages, to determine which is best for your needs.

Advantages of statement-based replication:

- Proven technology that has existed in MySQL since 3.23.
- Less data written to log files. When updates or deletes affect many rows, this results in *much* less storage space required for log files. This also means that taking and restoring from backups can be accomplished more quickly.
- Log files contain all statements that made any changes, so they can be used to audit the database.
- Tables replicated using statement-based replication are not required to have explicit primary keys.

Disadvantages of statement-based replication:

- **Statements which are unsafe for SBR.** Not all statements which modify data (such as `INSERT` `DELETE`, `UPDATE`, and `REPLACE` statements) can be replicated using statement-based replication. Any non-deterministic behavior is difficult to replicate when using statement-based replication. Examples of such DML (Data Modification Language) statements include the following:
  - A statement that depends on a UDF or stored program that is non-deterministic, since the value returned by such a UDF or stored program or depends on factors other than the parameters supplied to it. (Row-based replication, however, simply replicates the value returned by the UDF or stored program, so its effect on table rows and data is the same on both the master and slave.) See Section 3.1.7, “Replication of Invoked Features”, for more information.
  - `DELETE` and `UPDATE` statements that use a `LIMIT` clause without an `ORDER BY` are also non-deterministic. See Section 3.1.11, “Replication and `LIMIT`”.
  - Statements using any of the following functions cannot be replicated properly using statement-based replication:
    - `LOAD_FILE()`
    - `UUID()`, `UUID_SHORT()`
    - `USER()`
    - `FOUND_ROWS()`
    - `SYSDATE()` (unless the server is started with the `--sysdate-is-now` option)

    However, all other functions are replicated correctly using statement-based replication, including `RAND()`, `NOW()`, `LOAD DATA INFILE`, and so forth.

    For more information, see Section 3.1.10, “Replication and System Functions”.

  When using statement-based replication, statements that cannot be replicated correctly using statement-based mode are logged with a warning like the one shown here:

  ```
  090213 16:58:54 [Warning] Statement is not safe to log in statement format.
  ```

  A similar warning is also issued to the client in such cases.
- `INSERT ... SELECT` requires a greater number of row-level locks than with row-based replication.
- `UPDATE` statements that require a table scan (because no index is used in the `WHERE` clause) must lock a greater number of rows than with row-based replication.
- For `InnoDB`: An `INSERT` statement that uses `AUTO_INCREMENT` blocks other non-conflicting `INSERT` statements.
- For complex statements, the statement must be evaluated and executed on the slave before the rows are updated or inserted.

With row-based replication, the slave only has to run the statement to apply the differences, not the full statement.

- Stored functions execute with the same `NOW()` value as the calling statement. However, this is not true of stored procedures.
- Deterministic UDFs must be applied on the slaves.
- If there is an error in evaluation on the slave, particularly when executing complex statements, then using statement-based replication may slowly increase the margin of error across the affected rows over time. See Section 3.1.20, “Slave Errors during Replication”.
- Tables must be (nearly) identical on master and slave. See Section 3.1.4, “Replication with Differing Tables on Master and Slave”, for more information.

Advantages of row-based replication:

- All changes can be replicated. This is the safest form of replication.

  The `mysql` database is not replicated. The `mysql` database is instead seen as a node-specific database. Row-based replication is not supported on tables in this database. Instead, statements that would normally update this information — such as `GRANT`, `REVOKE` and the manipulation of triggers, stored routines (including stored procedures), and views — are all replicated to slaves using statement-based replication.

  For statements like `CREATE ... SELECT`, a `CREATE` statement is generated from the table definition and replicated using the statement-based format, while the row insertions are replicated using the row-based format.
- The technology is the same as in most other database management systems; knowledge about other systems transfers to MySQL.
- Fewer locks are needed (and thus higher concurrency) on the master for the following types of statements:
  - `INSERT ... SELECT`
  - `INSERT` statements with `AUTO_INCREMENT`
  - `UPDATE` or `DELETE` statements with `WHERE` clauses that don't use keys or don't change most of the examined rows.
- Fewer locks are required on the slave for any `INSERT`, `UPDATE`, or `DELETE` statement.

Disadvantages of row-based replication:

- RBR tends to generate more data that must be logged. This is because, when using row-based replication to replicate a DML statement (such as an `UPDATE` or `DELETE` statement), each changed row must be written to the binary log. (When using statement-based replication, only the statement is written to the binary log.) This means that, if the statement changes many rows, row-based replication may write significantly more data to the binary log; this is true even for statements that are rolled back. This also means that taking and restoring from backup can require more time. In addition, the binary log is locked for a longer time to write the data, which may cause concurrency problems.
- All tables replicated using row-based replication must have explicit primary keys.
- Deterministic UDFs that generate large `BLOB` values take longer to replicate with row-based replication than with statement-based replication. This is because, when using row-based replication, the `BLOB` column data is itself logged, rather than the statement generating the data.
- You cannot examine the logs to see what statements were executed, nor can you see on the slave what statements were received from the master and executed.

  However, beginning with MySQL 6.0.7, you can see what data was changed using `mysqlbinlog` with the options `--base64-output=DECODE-ROWS` and `--verbose`.
- When performing a bulk operation that includes non-transactional storage engines, changes are applied as the statement executes. With row-based replication logging, this means that the binary log is written while the statement is running. On the master, this does not cause problems with concurrency, because tables are locked until the bulk operation terminates. On the slave server, however, tables are not locked while the slave applies changes, because the slave does not know that those changes are part of a bulk operation.

  In such cases, if you retrieve data from a table on the master (for example, using `SELECT * FROM table_name`), the server waits for the bulk operation to complete before executing the `SELECT` statement, because the table is read-locked. On the slave, the server does not wait (because there is no lock). This means that, until the bulk operation on the slave has completed, you obtain different results for the same `SELECT` query on the master and on the slave.

This behavior is expected to change in a future MySQL release; however, until it changes, you may prefer to use statement-based replication when your application requires concurrent large bulk inserts and selects.

1.2.2. Usage of Row-based Logging and Row-Based Replication

Using row-based logging or replication, rather than statement-based logging or replication, can result in major changes in the replication environment and in the behavior of applications. This section describes a number of issues known to exist when using row-based logging or row-based replication, and discusses some best practices for taking advantage of row-based logging (RBL) and row-based replication (RBR).

For additional information, see Section 1.2.1, “Comparison of Statement-Based and Row-Based Replication”, and Section 1.2, “Replication Formats”.

- **RBR and primary keys.** Currently, row-based replication may fail if any table to be replicated does not have an explicit primary key. This is a known issue which we are working to fix in a future MySQL release.

- **RBL, RBR, and temporary tables.** As noted elsewhere in this chapter (see Section 3.1.22, “Replication and Temporary Tables”), temporary tables are not replicated when using the row-based format. However, you can use the mixed format; when mixed format is in effect, “safe” statements involving temporary tables are logged using the statement-based format. For more information, see Section 1.2.1, “Comparison of Statement-Based and Row-Based Replication”.

  > **Note**
  >
  > There is actually no need to replicate temporary tables when using RBR. In addition, since temporary tables can be read only from the thread which created them, there is seldom if ever any benefit obtained from replicating them, even when using statement-based mode.

- **RBL and the `BLACKHOLE` storage engine.** Prior to MySQL 6.0.7, `DELETE` and `UPDATE` statements did not work with RBL and `BLACKHOLE` tables (Bug#38360).

- **RBL and synchronization of non-transactional tables.** When using row-based replication of a `MyISAM` or other non-transactional table, changed rows are written to the transaction cache. Often, when many rows are affected, the set of changes are split into several events; when the statement commits, all of these events are written to the binary log. When executing on the slave, a table lock is taken on all tables involved, then the rows are applied in batch mode. (This may or may not be effective, depending on the engine used for the slave's copy of the table).

- **Latency and binary log size.** Because RBL writes changes for each row to the binary log, the size of the binary log can grow quite rapidly. When used in a replication environment, this can significantly increase the time required for making the changes on the slave that match those on the master. You should be aware of the potential for this delay in your applications.

- **Reading the binary log.** With the `--base64-output=DECODE-ROWS` and `--verbose` options, `mysqlbinlog` is able to format the contents of the binary log in a manner that is easily human-readable, in case you want to read or recover from a replication or database failure using the contents of the binary log. For more information, see `mysqlbinlog` Row Event Display. Before MySQL 6.0.7, this was not possible (Bug#31455).

- **Binary log execution errors and `slave_exec_mode`.** If you use `slave_exec_mode=IDEMPOTENT`, a failure to apply changes from RBL because the original row cannot be found does not trigger an error, and does not cause replication to fail. This means that it is possible that updates are not applied on the slave, so that the master and slave are no longer synchronized. Latency issues and use of non-transactional tables when using `slave_exec_mode=IDEMPOTENT` and RBR can cause the master and slave to diverge even further. For more information about `slave_exec_mode`, see Server System Variables.

  > **Note**
  >
  > `slave_exec_mode=IDEMPOTENT` is generally useful only for circular replication or multi-master replication with MySQL Cluster. For other scenarios, the default value (`slave_exec_mode=STRICT`) is normally sufficient.
  >
  > The `NDBCLUSTER` storage engine is currently not supported in MySQL 6.0. MySQL Cluster users wishing to upgrade from MySQL 5.0 should instead migrate to MySQL Cluster NDB 6.2 or 6.3; these are based on MySQL 5.1 but contain the latest improvements and fixes for `NDBCLUSTER`. For more information, see MySQL Cluster NDB 6.X/7.X.

- **Lack of binary log checksums.** No checksums are used for RBL. This means that network, disk, and other errors may not be identified when processing the binary log. To ensure that data is transmitted without network corruption, you may want to consider using SSL, which adds another layer of checksumming, for replication connections. See Using SSL for Secure Connections, for more information about setting up MySQL with SSL.

- **Filtering based on server ID.** A common practice is to filter out changes on some slaves by using a `WHERE` clause that includes the relation `@server_id <>` *`server-id`* clause with `UPDATE` and DELETE statements, a simple example of such a clause being `WHERE @server_id <> 1`. However, this does not work correctly with row-based logging. If you must use the `server_id` system variable for statement filtering, then you must also use `--binlog_format=STATEMENT`.

  Beginning with MySQL 6.0.10, you can do filtering based on server ID by using the `IGNORE_SERVER_IDS` option for the `CHANGE MASTER TO` statement. This option works with the statement-based and row-based logging formats.

- **Database-level replication options.** The effects of the options `--replicate-do-db`, `--replicate-ignore-db`, and `--replicate-rewrite-db` differ considerably depending on whether row-based or statement-based logging is in use. Because of this, we recommend that you avoid the database-level options and use the table-level options such as `--replicate-do-table` and `--replicate-ignore-table` instead. For more information about these options and the impact that your choice of replication format has on how they operate, see Section 1.3, "Replication and Binary Logging Options and Variables".

1.3. Replication and Binary Logging Options and Variables

The next few sections contain information about `mysqld` options and server variables that are used in replication and for controlling the binary log. Options and variables for use on replication masters and replication slaves are covered separately, as are options and variables relating to binary logging. A set of quick-reference tables providing basic information about these options and variables is also included (in the next section following this one).

Of particular importance is the `--server-id` option.

Command Line Format	`--server-id=#`	
Config File Format	`server-id`	
Option Sets Variable	Yes, `server_id`	
Variable Name	`server_id`	
Variable Scope	Global	
Dynamic Variable	Yes	
Value Set	**Type**	`numeric`
	Default	`0`
	Range	`0-4294967295`

This option is common to both master and slave replication servers, and is used in replication to enable master and slave servers to identify themselves uniquely. For additional information, see Section 1.3.2, "Replication Master Options and Variables", and Section 1.3.3, "Replication Slave Options and Variables".

On the master and each slave, you *must* use the `--server-id` option to establish a unique replication ID in the range from 1 to $2^{32} – 1$; by "unique", we mean that each ID must be different from every other ID in use by any other replication master or slave. Example: `server-id=3`.

If you omit `--server-id`, it assumes the default value 0, in which case a master refuses connections from all slaves, and a slave refuses to connect to a master. See Section 1.1.3, "Setting the Replication Slave Configuration", for more information.

1.3.1. Replication and Binary Logging Option and Variable Reference

The following tables list basic information about the MySQL command-line options and system variables applicable to replication and the binary log.

Table 1.1. `mysqld` Replication Option/Variable Summary

Name	Cmd-Line	Option file	System Var	Status Var	Var Scope	Dynamic
abort-slave-event-count	Yes	Yes				
Com_change_master				Yes	Both	No
Com_show_master_status				Yes	Both	No
Com_show_new_master				Yes	Both	No
Com_show_slave_hosts				Yes	Both	No
Com_show_slave_status				Yes	Both	No

Name	Cmd-Line	Option file	System Var	Status Var	Var Scope	Dynamic
Com_slave_start				Yes	Both	No
Com_slave_stop				Yes	Both	No
disconnect-slave-event-count	Yes	Yes				
init_slave	Yes	Yes	Yes		Global	Yes
log-slave-updates	Yes	Yes			Global	No
- *Variable*: log_slave_updates			Yes		Global	No
master-bind	Yes	Yes	Yes			No
master-info-file	Yes	Yes				
master-retry-count	Yes	Yes				
relay-log	Yes	Yes				
relay-log-index	Yes	Yes				
- *Variable*: relay_log_index						
relay_log_purge	Yes	Yes	Yes		Global	Yes
relay_log_recovery	Yes	Yes	Yes		Global	Yes
replicate-do-db	Yes	Yes				
replicate-do-table	Yes	Yes				
replicate-ignore-db	Yes	Yes				
replicate-ignore-table	Yes	Yes				
replicate-rewrite-db	Yes	Yes				
replicate-same-server-id	Yes	Yes				
replicate-wild-do-table	Yes	Yes				
replicate-wild-ignore-table	Yes	Yes				
report-host	Yes	Yes			Global	No
- *Variable*: report_host			Yes		Global	No
report-password	Yes	Yes			Global	No
- *Variable*: report_password			Yes		Global	No
report-port	Yes	Yes			Global	No
- *Variable*: report_port			Yes		Global	No
report-user	Yes	Yes			Global	No
- *Variable*: report_user			Yes		Global	No
rpl_recovery_rank			Yes		Global	Yes
Rpl_semi_sync_master_clients				Yes	Global	No
rpl_semi_sync_master_enabled			Yes		Global	Yes
Rpl_semi_sync_master_net_avg_wait_time				Yes	Global	No
Rpl_semi_sync_master_net_wait_time				Yes	Global	No
Rpl_semi_sync_master_net_waits				Yes	Global	No
Rpl_semi_sync_master_no_times				Yes	Global	No
Rpl_semi_sync_master_no_tx				Yes	Global	No
rpl_semi_sync_master_reply_log_file_pos			Yes		Global	Yes
Rpl_semi_sync_master_status				Yes	Global	No
Rpl_semi_sync_master_timefunc_failures				Yes	Global	No
rpl_semi_sync_master_timeout			Yes		Global	Yes
rpl_semi_sync_master_trace_level			Yes		Global	Yes
Rpl_semi_sync_master_tx_avg_wait_time				Yes	Global	No
Rpl_semi_sync_master_tx_wait_time				Yes	Global	No
Rpl_semi_sync_master_tx_waits				Yes	Global	No
Rpl_semi_sync_master_wait_pos_backtraverse				Yes	Global	No

Name	Cmd-Line	Option file	System Var	Status Var	Var Scope	Dynamic
Rpl_semi_sync_master_wait_sessions				Yes	Global	No
Rpl_semi_sync_master_yes_tx				Yes	Global	No
rpl_semi_sync_slave_enabled			Yes		Global	Yes
Rpl_semi_sync_slave_status				Yes	Global	No
rpl_semi_sync_slave_trace_level			Yes		Global	Yes
Rpl_status				Yes	Global	No
show-slave-auth-info	Yes	Yes				
skip-slave-start	Yes	Yes				
slave_compressed_protocol	Yes	Yes	Yes		Global	Yes
slave_exec_mode			Yes		Global	Yes
Slave_heartbeat_period				Yes	Global	No
slave-load-tmpdir	Yes	Yes			Global	No
- *Variable*: slave_load_tmpdir			Yes		Global	No
slave-net-timeout	Yes	Yes			Global	Yes
- *Variable*: slave_net_timeout			Yes		Global	Yes
Slave_open_temp_tables				Yes	Global	No
Slave_received_heartbeats				Yes	Global	No
Slave_retried_transactions				Yes	Global	No
Slave_running				Yes	Global	No
slave-skip-errors	Yes	Yes			Global	No
- *Variable*: slave_skip_errors			Yes		Global	No
slave_transaction_retries	Yes	Yes	Yes		Global	Yes
sql_slave_skip_counter			Yes		Global	Yes

Section 1.3.2, “Replication Master Options and Variables”, provides more detailed information about options and variables relating to replication master servers. For more information about options and variables relating to replication slaves Section 1.3.3, “Replication Slave Options and Variables”.

Table 1.2. `mysqld` Binary Logging Option/Variable Summary

Name	Cmd-Line	Option file	System Var	Status Var	Var Scope	Dynamic
Binlog_cache_disk_use				Yes	Global	No
binlog_cache_size	Yes	Yes	Yes		Global	Yes
Binlog_cache_use				Yes	Global	No
binlog-do-db	Yes	Yes				
binlog-format	Yes	Yes			Both	Yes
- *Variable*: binlog_format			Yes		Both	Yes
binlog-ignore-db	Yes	Yes				
binlog-row-event-max-size	Yes	Yes				
Com_show_binlog_events				Yes	Both	No
Com_show_binlogs				Yes	Both	No
max_binlog_cache_size	Yes	Yes	Yes		Global	Yes
max-binlog-dump-events	Yes	Yes				
max_binlog_size	Yes	Yes	Yes		Global	Yes
sporadic-binlog-dump-fail	Yes	Yes				

Section 1.3.4, “Binary Log Options and Variables”, provides more detailed information about options and variables relating to binary logging. For additional general information about the binary log, see The Binary Log.

For a table showing *all* command-line options, system and status variables used with mysqld, see Server Option and Variable Reference.

1.3.2. Replication Master Options and Variables

This section describes the server options and system variables that you can use on replication master servers. You can specify the options either on the command line or in an option file. You can specify system variable values using SET.

On the master and each slave, you must use the server-id option to establish a unique replication ID. For each server, you should pick a unique positive integer in the range from 1 to $2^{32} - 1$, and each ID must be different from every other ID in use by any other replication master or slave. Example: server-id=3.

For options used on the master for controlling binary logging, see Section 1.3.4, “Binary Log Options and Variables”.

- auto_increment_increment

Command Line Format	--auto_increment_increment[=#]	
Config File Format	auto_increment_increment	
Option Sets Variable	Yes, auto_increment_increment	
Variable Name	auto_increment_increment	
Variable Scope	Both	
Dynamic Variable	Yes	
Value Set	**Type**	numeric
	Default	1
	Range	1-65535

auto_increment_increment and auto_increment_offset are intended for use with master-to-master replication, and can be used to control the operation of AUTO_INCREMENT columns. Both variables have global and session values, and each can assume an integer value between 1 and 65,535 inclusive. Setting the value of either of these two variables to 0 causes its value to be set to 1 instead. Attempting to set the value of either of these two variables to an integer greater than 65,535 or less than 0 causes its value to be set to 65,535 instead. Attempting to set the value of auto_increment_increment or auto_increment_offset to a non-integer value gives rise to an error, and the actual value of the variable remains unchanged.

These two variables affect AUTO_INCREMENT column behavior as follows:

- auto_increment_increment controls the interval between successive column values. For example:

```
mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 1     |
| auto_increment_offset    | 1     |
+--------------------------+-------+
2 rows in set (0.00 sec)

mysql> CREATE TABLE autoinc1
    -> (col INT NOT NULL AUTO_INCREMENT PRIMARY KEY);
  Query OK, 0 rows affected (0.04 sec)

mysql> SET @@auto_increment_increment=10;
Query OK, 0 rows affected (0.00 sec)

mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 10    |
| auto_increment_offset    | 1     |
+--------------------------+-------+
2 rows in set (0.01 sec)

mysql> INSERT INTO autoinc1 VALUES (NULL), (NULL), (NULL), (NULL);
Query OK, 4 rows affected (0.00 sec)
Records: 4  Duplicates: 0  Warnings: 0

mysql> SELECT col FROM autoinc1;
+-----+
| col |
+-----+
|   1 |
|  11 |
|  21 |
|  31 |
+-----+
4 rows in set (0.00 sec)
```

(Note how SHOW VARIABLES is used here to obtain the current values for these variables.)

- auto_increment_offset determines the starting point for the AUTO_INCREMENT column value. Consider the following, assuming that these statements are executed during the same session as the example given in the description for auto_increment_increment:

```
mysql> SET @@auto_increment_offset=5;
Query OK, 0 rows affected (0.00 sec)

mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 10    |
| auto_increment_offset    | 5     |
+--------------------------+-------+
2 rows in set (0.00 sec)

mysql> CREATE TABLE autoinc2
    -> (col INT NOT NULL AUTO_INCREMENT PRIMARY KEY);
Query OK, 0 rows affected (0.06 sec)

mysql> INSERT INTO autoinc2 VALUES (NULL), (NULL), (NULL), (NULL);
Query OK, 4 rows affected (0.00 sec)
Records: 4  Duplicates: 0  Warnings: 0

mysql> SELECT col FROM autoinc2;
+-----+
| col |
+-----+
|   5 |
|  15 |
|  25 |
|  35 |
+-----+
4 rows in set (0.02 sec)
```

  If the value of auto_increment_offset is greater than that of auto_increment_increment, the value of auto_increment_offset is ignored.

Should one or both of these variables be changed and then new rows inserted into a table containing an AUTO_INCREMENT column, the results may seem counterintuitive because the series of AUTO_INCREMENT values is calculated without regard to any values already present in the column, and the next value inserted is the least value in the series that is greater than the maximum existing value in the AUTO_INCREMENT column. In other words, the series is calculated like so:

auto_increment_offset + *N* × auto_increment_increment

where *N* is a positive integer value in the series [1, 2, 3, ...]. For example:

```
mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 10    |
| auto_increment_offset    | 5     |
+--------------------------+-------+
2 rows in set (0.00 sec)

mysql> SELECT col FROM autoinc1;
+-----+
| col |
+-----+
|   1 |
|  11 |
|  21 |
|  31 |
+-----+
4 rows in set (0.00 sec)

mysql> INSERT INTO autoinc1 VALUES (NULL), (NULL), (NULL), (NULL);
Query OK, 4 rows affected (0.00 sec)
Records: 4  Duplicates: 0  Warnings: 0

mysql> SELECT col FROM autoinc1;
+-----+
| col |
+-----+
|   1 |
|  11 |
|  21 |
|  31 |
|  35 |
|  45 |
|  55 |
|  65 |
+-----+
8 rows in set (0.00 sec)
```

The values shown for `auto_increment_increment` and `auto_increment_offset` generate the series 5 + *N* × 10, that is, [5, 15, 25, 35, 45, ...]. The greatest value present in the `col` column prior to the `INSERT` is 31, and the next available value in the `AUTO_INCREMENT` series is 35, so the inserted values for `col` begin at that point and the results are as shown for the `SELECT` query.

It is not possible to confine the effects of these two variables to a single table, and thus they do not take the place of the sequences offered by some other database management systems; these variables control the behavior of all `AUTO_INCREMENT` columns in *all* tables on the MySQL server. If the global value of either variable is set, its effects persist until the global value is changed or overridden by setting the session value, or until `mysqld` is restarted. If the local value is set, the new value affects `AUTO_INCREMENT` columns for all tables into which new rows are inserted by the current user for the duration of the session, unless the values are changed during that session.

The default value of `auto_increment_increment` is 1. See Section 3.1.1, "Replication and `AUTO_INCREMENT`".

- `auto_increment_offset`

Command Line Format	`--auto_increment_offset[=#]`	
Config File Format	`auto_increment_offset`	
Option Sets Variable	Yes, `auto_increment_offset`	
Variable Name	`auto_increment_offset`	
Variable Scope	Both	
Dynamic Variable	Yes	
Value Set	**Type**	`numeric`
	Default	`1`
	Range	`1-65535`

This variable has a default value of 1. For particulars, see the description for `auto_increment_increment`.

1.3.3. Replication Slave Options and Variables

This section describes the server options and system variables that you can use on slave replication servers. You can specify the options either on the command line or in an option file. Many of the options can be reset while the server is running by using the `CHANGE MASTER TO` statement. You can specify system variable values using `SET`.

Server ID. On the master and each slave, you must use the `server-id` option to establish a unique replication ID. For each server, you should pick a unique positive integer in the range from 1 to $2^{32} – 1$, and each ID must be different from every other ID. Example: `server-id=3`.

The `master.info` file format in MySQL 6.0 includes values corresponding to the SSL options. In addition, the file format includes as its first line the number of lines in the file. (See Section 4.2, "Replication Relay and Status Files".) If you upgrade an older server (before MySQL 4.1.1) to a newer version, the new server upgrades the `master.info` file to the new format automatically when it starts. However, if you downgrade a newer server to an older version, you should remove the first line manually before starting the older server for the first time.

If no `master.info` file exists when the slave server starts, it uses the values for those options that are specified in option files or on the command line. This occurs when you start the server as a replication slave for the very first time, or when you have run `RESET SLAVE` and then have shut down and restarted the slave.

If the `master.info` file exists when the slave server starts, the server uses its contents and ignores any options that correspond to the values listed in the file. Thus, if you start the slave server with different values of the startup options that correspond to values in the `master.info` file, the different values have no effect, because the server continues to use the `master.info` file. To use different values, you must either restart after removing the `master.info` file or (preferably) use the `CHANGE MASTER TO` statement to reset the values while the slave is running.

Suppose that you specify this option in your `my.cnf` file:

```
[mysqld]
master-host=some_host
```

The first time you start the server as a replication slave, it reads and uses that option from the `my.cnf` file. The server then records the value in the `master.info` file. The next time you start the server, it reads the master host value from the `master.info` file only and ignores the value in the option file. If you modify the `my.cnf` file to specify a different master host of *`some_other_host`*, the change still has no effect. You should use `CHANGE MASTER TO` instead.

This example shows a more extensive use of startup options to configure a slave server:

```
[mysqld]
server-id=2
master-host=db-master.mycompany.com
master-port=3306
master-user=pertinax
master-password=freitag
master-connect-retry=60
report-host=db-slave.mycompany.com
```

Note

Because the server gives an existing `master.info` file precedence over the startup options just described, you might prefer not to use startup options for these values at all, and instead to specify them by using the `CHANGE MASTER TO` statement. See `CHANGE MASTER TO` Syntax.

Startup options for replication slaves. The following list describes startup options for controlling replication slaves. Many of these options can be reset while the server is running by using the `CHANGE MASTER TO` statement. Others, such as the `--replicate-*` options, can be set only when the slave server starts. Replication-related system variables are discussed later in this section.

- `--log-slave-updates`

  Normally, a slave does not log to its own binary log any updates that are received from a master server. This option tells the slave to log the updates performed by its SQL thread to its own binary log. For this option to have any effect, the slave must also be started with the `--log-bin` option to enable binary logging. `--log-slave-updates` is used when you want to chain replication servers. For example, you might want to set up replication servers using this arrangement:

  ```
  A -> B -> C
  ```

  Here, `A` serves as the master for the slave `B`, and `B` serves as the master for the slave `C`. For this to work, `B` must be both a master *and* a slave. You must start both `A` and `B` with `--log-bin` to enable binary logging, and `B` with the `--log-slave-updates` option so that updates received from `A` are logged by `B` to its binary log.

- `--log-slow-slave-statements`

Version Introduced	6.0.4	
Command Line Format	`--log-slow-slave-statements`	
Config File Format	`log-slow-slave-statements`	
Value Set	**Type**	`boolean`
	Default	`off`

  When the slow query log is enabled, this option enables logging for queries that have taken more than `long_query_time` seconds to execute on the slave.

  This option was added in MySQL 6.0.4.

- `--log-warnings[=`*`level`*`]`

  This option causes a server to print more messages to the error log about what it is doing. With respect to replication, the server generates warnings that it succeeded in reconnecting after a network/connection failure, and informs you as to how each slave thread started. This option is enabled by default; to disable it, use `--skip-log-warnings`. Aborted connections are not logged to the error log unless the value is greater than 1.

  Note that the effects of this option are not limited to replication. It produces warnings across a spectrum of server activities.

- `--master-info-file=`*`file_name`*

  The name to use for the file in which the slave records information about the master. The default name is `master.info` in the data directory.

- `--master-retry-count=count`

  The number of times that the slave tries to connect to the master before giving up. Reconnects are attempted at intervals set by `--master-connect-retry` and reconnects are triggered when data reads by the slave time out according to the `--slave-net-timeout` option. The default value is 86400.

  You can also set the retry count by using the `MASTER_CONNECT_RETRY` option for the `CHANGE MASTER TO` statement.

- `--max-relay-log-size=size`

  The size at which the server rotates relay log files automatically. For more information, see Section 4.2, "Replication Relay and Status Files". The default size is 1GB.

- `--read-only`

  Cause the slave to allow no updates except from slave threads or from users having the `SUPER` privilege. On a slave server, this can be useful to ensure that the slave accepts updates only from its master server and not from clients. This variable does not apply to `TEMPORARY` tables.

- `--relay-log=file_name`

  The basename for the relay log. The default basename is `host_name-relay-bin`. The server creates relay log files in sequence by adding a numeric suffix to the basename.

  Due to the manner in which MySQL parses server options, if you specify this option, you must supply a value; *the default basename is used only if the option is not actually specified*. If you use the `--relay-log` option without specifying a value, unexpected behavior is likely to result; this behavior depends on the other options used, the order in which they are specified, and whether they are specified on the command line or in an option file. For more information about how MySQL handles server options, see Specifying Program Options.

  If you specify this option, the value specified is also used as the basename for the relay log index file. You can override this behavior by specifying a different relay log index file basename using the `--relay-log-index` option.

  You may find the `--relay-log` option useful in performing the following tasks:

  - Creating relay logs whose names are independent of host names.
  - If you need to put the relay logs in some area other than the data directory, because your relay logs tend to be very large and you do not want to decrease `max_relay_log_size`.
  - To increase speed by using load-balancing between disks.

- `--relay-log-index=file_name`

  The name to use for the relay log index file. The default name is `host_name-relay-bin.index` in the data directory, where `host_name` is the name of the slave server.

  Due to the manner in which MySQL parses server options, if you specify this option, you must supply a value; *the default basename is used only if the option is not actually specified*. If you use the `--relay-log-index` option without specifying a value, unexpected behavior is likely to result; this behavior depends on the other options used, the order in which they are specified, and whether they are specified on the command line or in an option file. For more information about how MySQL handles server options, see Specifying Program Options.

  If you specify this option, the value specified is also used as the basename for the relay logs. You can override this behavior by specifying a different relay log file basename using the `--relay-log` option.

- `--relay-log-info-file=file_name`

  The name to use for the file in which the slave records information about the relay logs. The default name is `relay-log.info` in the data directory.

- `--relay-log-purge={0|1}`

  Disable or enable automatic purging of relay logs as soon as they are no longer needed. The default value is 1 (enabled). This is a global variable that can be changed dynamically with `SET GLOBAL relay_log_purge = N`.

- `--relay-log-recovery={0|1}`

  Enables automatic relay log recovery immediately following server startup, which means that the replication slave discards all unprocessed relay logs and retrieves them from the replication master. This should be used following a crash on the replication slave to insure that no possibly corrupted relay logs are processed. The default value is 0 (disabled).

- `--relay-log-space-limit=size`

  This option places an upper limit on the total size in bytes of all relay logs on the slave. A value of 0 means “no limit.” This is useful for a slave server host that has limited disk space. When the limit is reached, the I/O thread stops reading binary log events from the master server until the SQL thread has caught up and deleted some unused relay logs. Note that this limit is not absolute: There are cases where the SQL thread needs more events before it can delete relay logs. In that case, the I/O thread exceeds the limit until it becomes possible for the SQL thread to delete some relay logs, because not doing so would cause a deadlock. You should not set `--relay-log-space-limit` to less than twice the value of `--max-relay-log-size` (or `--max-binlog-size` if `--max-relay-log-size` is 0). In that case, there is a chance that the I/O thread waits for free space because `--relay-log-space-limit` is exceeded, but the SQL thread has no relay log to purge and is unable to satisfy the I/O thread. This forces the I/O thread to ignore `--relay-log-space-limit` temporarily.

- `--replicate-do-db=db_name`

  The effects of this option depend on whether statement-based or row-based replication is in use.

  Statement-based replication. Tell the slave to restrict replication to statements where the default database (that is, the one selected by `USE`) is *`db_name`*. To specify more than one database, use this option multiple times, once for each database; however, doing so does *not* replicate cross-database statements such as `UPDATE some_db.some_table SET foo='bar'` while a different database (or no database) is selected.

  Warning

  To specify multiple databases you *must* use multiple instances of this option. Because database names can contain commas, if you supply a comma separated list then the list will be treated as the name of a single database.

  An example of what does not work as you might expect when using statement-based replication: If the slave is started with `--replicate-do-db=sales` and you issue the following statements on the master, the `UPDATE` statement is *not* replicated:

```
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

  The main reason for this “check just the default database” behavior is that it is difficult from the statement alone to know whether it should be replicated (for example, if you are using multiple-table `DELETE` statements or multiple-table `UPDATE` statements that act across multiple databases). It is also faster to check only the default database rather than all databases if there is no need.

  Row-based replication. Tells the slave to restrict replication to database *`db_name`*. Only tables belonging to *`db_name`* are changed; the current database has no effect on this. For example, suppose that the slave is started with `--replicate-do-db=sales` and row-based replication is in effect, and then the following statements are run on the master:

```
USE prices;
UPDATE sales.february SET amount=amount+100;
```

  The `february` table in the `sales` database on the slave is changed in accordance with the `UPDATE` statement; this occurs whether or not the `USE` statement was issued. However, issuing the following statements on the master has no effect on the slave when using row-based replication and `--replicate-do-db=sales`:

```
USE prices;
UPDATE prices.march SET amount=amount-25;
```

  Even if the statement `USE prices` were changed to `USE sales`, the `UPDATE` statement's effects would still not be replicated.

  Another important difference in how `--replicate-do-db` is handled in statement-based replication as opposed to row-based replication occurs with regard to statements that refer to multiple databases. Suppose the slave is started with `--replicate-do-db=db1`, and the following statements are executed on the master:

```
USE db1;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

  If you are using statement-based replication, then both tables are updated on the slave. However, when using row-based replication, only `table1` is affected on the slave; since `table2` is in a different database, `table2` on the slave is not changed by the `UPDATE`. Now suppose that, instead of the `USE db1` statement, a `USE db4` statement had been used:

```
USE db4;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

  In this case, the `UPDATE` statement would have no effect on the slave when using statement-based replication. However, if you are using row-based replication, the `UPDATE` would change `table1` on the slave, but not `table2` — in other words, only tables in the database named by `--replicate-do-db` are changed, and the choice of current database has no effect on this behavior.

  If you need cross-database updates to work, use `--replicate-wild-do-table=db_name.%` instead. See Section 4.3, "How Servers Evaluate Replication Rules".

> **Note**
>
> This option effects replication in the same manner that `--binlog-do-db` affects binary logging, and the affects of the replication format on how `--replicate-do-db` affects replication behavior are the same as those of the logging format on the behavior of `--binlog-do-db`.

- `--replicate-ignore-db=db_name`

  As with `--replicate-do-db`, the effects of this option depend on whether statement-based or row-based replication is in use.

  Statement-based replication. Tells the slave to not replicate any statement where the default database (that is, the one selected by `USE`) is *`db_name`*.

  Row-based replication. Tells the slave not to update any tables in the database *`db_name`*. The current database has no effect.

  When using statement-based replication, the following example does not work as you might expect. Suppose that the slave is started with `--replicate-ignore-db=sales` and you issue the following statements on the master:

```
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

  The `UPDATE` statement *is* replicated in such a case because `--replicate-ignore-db` applies only to the default database (determined by the `USE` statement). Because the `sales` database was specified explicitly in the statement, the statement has not been filtered. However, when using row-based replication, the `UPDATE` statement's effects are *not* propagated to the slave, and the slave's copy of the `sales.january` table is unchanged; in this instance, `--replicate-ignore-db=sales` causes *all* changes made to tables in the master's copy of the `sales` database to be ignored by the slave.

  To specify more than one database to ignore, use this option multiple times, once for each database. Because database names can contain commas, if you supply a comma separated list then the list will be treated as the name of a single database.

  You should not use this option if you are using cross-database updates and you do not want these updates to be replicated. See Section 4.3, "How Servers Evaluate Replication Rules".

  If you need cross-database updates to work, use `--replicate-wild-ignore-table=db_name.%` instead. See Section 4.3, "How Servers Evaluate Replication Rules".

> **Note**
>
> This option effects replication in the same manner that `--binlog-ignore-db` affects binary logging, and the affects of the replication format on how `--replicate-ignore-db` affects replication behavior are the same as those of the logging format on the behavior of `--binlog-ignore-db`.

- `--replicate-do-table=db_name.tbl_name`

  Tells the slave thread to restrict replication to the specified table. To specify more than one table, use this option multiple times, once for each table. This works for cross-database updates, in contrast to `--replicate-do-db`. See Section 4.3, "How Servers Evaluate Replication Rules".

- `--replicate-ignore-table=db_name.tbl_name`

  Tells the slave thread to not replicate any statement that updates the specified table, even if any other tables might be updated by the same statement. To specify more than one table to ignore, use this option multiple times, once for each table. This works for cross-database updates, in contrast to `--replicate-ignore-db`. See Section 4.3, "How Servers Evaluate Replication Rules".

- `--replicate-rewrite-db=from_name->to_name`

  Tells the slave to translate the default database (that is, the one selected by `USE`) to *`to_name`* if it was *`from_name`* on the master. Only statements involving tables are affected (not statements such as `CREATE DATABASE`, `DROP DATABASE`, and `ALTER DATABASE`), and only if *`from_name`* is the default database on the master. This does not work for cross-database updates. To specify multiple rewrites, use this option multiple times. The server uses the first one with a *`from_name`* value that matches. The database name translation is done *before* the `--replicate-*` rules are tested.

  If you use this option on the command line and the ">" character is special to your command interpreter, quote the option value. For example:

```
shell> mysqld --replicate-rewrite-db="olddb->newdb"
```

- `--replicate-same-server-id`

  To be used on slave servers. Usually you should use the default setting of 0, to prevent infinite loops caused by circular replication. If set to 1, the slave does not skip events having its own server ID. Normally, this is useful only in rare configurations. Cannot be set to 1 if `--log-slave-updates` is used. By default, the slave I/O thread does not write binary log events to the relay log if they have the slave's server ID (this optimization helps save disk usage). If you want to use `--replicate-same-server-id`, be sure to start the slave with this option before you make the slave read its own events that you want the slave SQL thread to execute.

- `--replicate-wild-do-table=`*`db_name.tbl_name`*

  Tells the slave thread to restrict replication to statements where any of the updated tables match the specified database and table name patterns. Patterns can contain the “`%`” and “`_`” wildcard characters, which have the same meaning as for the `LIKE` pattern-matching operator. To specify more than one table, use this option multiple times, once for each table. This works for cross-database updates. See Section 4.3, “How Servers Evaluate Replication Rules”.

  Example: `--replicate-wild-do-table=foo%.bar%` replicates only updates that use a table where the database name starts with `foo` and the table name starts with `bar`.

  If the table name pattern is `%`, it matches any table name and the option also applies to database-level statements (`CREATE DATABASE`, `DROP DATABASE`, and `ALTER DATABASE`). For example, if you use `--replicate-wild-do-table=foo%.%`, database-level statements are replicated if the database name matches the pattern `foo%`.

  To include literal wildcard characters in the database or table name patterns, escape them with a backslash. For example, to replicate all tables of a database that is named `my_own%db`, but not replicate tables from the `my1ownAABCdb` database, you should escape the “`_`” and “`%`” characters like this: `--replicate-wild-do-table=my\_own\%db`. If you're using the option on the command line, you might need to double the backslashes or quote the option value, depending on your command interpreter. For example, with the `bash` shell, you would need to type `--replicate-wild-do-table=my\\_own\\%db`.

- `--replicate-wild-ignore-table=`*`db_name.tbl_name`*

  Tells the slave thread not to replicate a statement where any table matches the given wildcard pattern. To specify more than one table to ignore, use this option multiple times, once for each table. This works for cross-database updates. See Section 4.3, “How Servers Evaluate Replication Rules”.

  Example: `--replicate-wild-ignore-table=foo%.bar%` does not replicate updates that use a table where the database name starts with `foo` and the table name starts with `bar`.

  For information about how matching works, see the description of the `--replicate-wild-do-table` option. The rules for including literal wildcard characters in the option value are the same as for `--replicate-wild-ignore-table` as well.

- `--report-host=`*`host_name`*

  The host name or IP number of the slave to be reported to the master during slave registration. This value appears in the output of `SHOW SLAVE HOSTS` on the master server. Leave the value unset if you do not want the slave to register itself with the master. Note that it is not sufficient for the master to simply read the IP number of the slave from the TCP/IP socket after the slave connects. Due to NAT and other routing issues, that IP may not be valid for connecting to the slave from the master or other hosts.

- `--report-password=`*`password`*

  The account password of the slave to be reported to the master during slave registration. This value appears in the output of `SHOW SLAVE HOSTS` on the master server if the `--show-slave-auth-info` option is given.

- `--report-port=`*`slave_port_num`*

  The TCP/IP port number for connecting to the slave, to be reported to the master during slave registration. Set this only if the slave is listening on a non-default port or if you have a special tunnel from the master or other clients to the slave. If you are not sure, do not use this option.

- `--report-user=`*`user_name`*

  The account user name of the slave to be reported to the master during slave registration. This value appears in the output of `SHOW SLAVE HOSTS` on the master server if the `--show-slave-auth-info` option is given.

- `--show-slave-auth-info`

  Display slave user names and passwords in the output of `SHOW SLAVE HOSTS` on the master server for slaves started with the `--report-user` and `--report-password` options.

- `--skip-slave-start`

  Tells the slave server not to start the slave threads when the server starts. To start the threads later, use a `START SLAVE` statement.

- `--slave_compressed_protocol={0|1}`

  If this option is set to 1, use compression for the slave/master protocol if both the slave and the master support it. The default is 0 (no compression).

- `--slave-load-tmpdir=`*`file_name`*

  The name of the directory where the slave creates temporary files. This option is by default equal to the value of the `tmpdir` system variable. When the slave SQL thread replicates a `LOAD DATA INFILE` statement, it extracts the file to be loaded from the relay log into temporary files, and then loads these into the table. If the file loaded on the master is huge, the temporary files on the slave are huge, too. Therefore, it might be advisable to use this option to tell the slave to put temporary files in a directory located in some file system that has a lot of available space. In that case, the relay logs are huge as well, so you might also want to use the `--relay-log` option to place the relay logs in that file system.

  The directory specified by this option should be located in a disk-based file system (not a memory-based file system) because the temporary files used to replicate `LOAD DATA INFILE` must survive machine restarts. The directory also should not be one that is cleared by the operating system during the system startup process.

- `--slave-net-timeout=`*`seconds`*

  The number of seconds to wait for more data from the master before the slave considers the connection broken, aborts the read, and tries to reconnect. The first retry occurs immediately after the timeout. The interval between retries is controlled by the `MASTER_CONNECT_RETRY` option for the `CHANGE MASTER TO` statement, and the number of reconnection attempts is limited by the `--master-retry-count` option. The default is 3600 seconds (one hour).

- `--slave-skip-errors=[`*`err_code1`*`,`*`err_code2`*`,...|all]`

  Normally, replication stops when an error occurs on the slave. This gives you the opportunity to resolve the inconsistency in the data manually. This option tells the slave SQL thread to continue replication when a statement returns any of the errors listed in the option value.

  Do not use this option unless you fully understand why you are getting errors. If there are no bugs in your replication setup and client programs, and no bugs in MySQL itself, an error that stops replication should never occur. Indiscriminate use of this option results in slaves becoming hopelessly out of synchrony with the master, with you having no idea why this has occurred.

  > **Note**
  >
  > Prior to MySQL 6.0.12, this option had no effect with row-based logging. (Bug#39393)

  For error codes, you should use the numbers provided by the error message in your slave error log and in the output of `SHOW SLAVE STATUS`. Errors, Error Codes, and Common Problems, lists server error codes.

  You can also (but should not) use the very non-recommended value of `all` to cause the slave to ignore all error messages and keeps going regardless of what happens. Needless to say, if you use `all`, there are no guarantees regarding the integrity of your data. Please do not complain (or file bug reports) in this case if the slave's data is not anywhere close to what it is on the master. *You have been warned*.

  Examples:

```
--slave-skip-errors=1062,1053
--slave-skip-errors=all
```

- `sql_slave_skip_counter`

Variable Name	`sql_slave_skip_counter`	
Variable Scope	Global	
Dynamic Variable	Yes	
Value Set	**Type**	`numeric`

The number of events from the master that a slave server should skip.

Important

If skipping the number of events specified by setting this variable would cause the slave to begin in the middle of an event group, the slave continues to skip until it finds the beginning of the next event group and begins from that point. See `SET GLOBAL SQL_SLAVE_SKIP_COUNTER` Syntax, for more information.

- `--abort-slave-event-count`

Command Line Format	`--abort-slave-event-count=#`	
Config File Format	`abort-slave-event-count`	
Value Set	**Type**	`numeric`
	Default	`0`
	Min Value	`0`

When this option is set to some positive integer *`value`* other than 0 (the default) it affects replication behavior as follows: After the slave SQL thread has started, *`value`* log events are allowed to be executed; after that, the slave SQL thread does not receive any more events, just as if the network connection from the master were cut. The slave thread continues to run, and the output from `SHOW SLAVE STATUS` displays `Yes` in both the `Slave_IO_Running` and the `Slave_SQL_Running` columns, but no further events are read from the relay log.

This option is used internally by the MySQL test suite for replication testing and debugging. It is not intended for use in a production setting.

- `--disconnect-slave-event-count`

Command Line Format	`--disconnect-slave-event-count=#`	
Config File Format	`disconnect-slave-event-count`	
Value Set	**Type**	`numeric`
	Default	`0`

This option is used internally by the MySQL test suite for replication testing and debugging.

Obsolete options. *The following options are removed in MySQL 6.0. If you attempt to start `mysqld` with any of these options in MySQL 6.0, the server aborts with an `UNKNOWN VARIABLE` error.* To set the replication parameters formerly associated with these options, you must use the `CHANGE MASTER TO ...` statement (see `CHANGE MASTER TO` Syntax).

The options affected are shown in this list:

- `--master-host`
- `--master-user`
- `--master-password`
- `--master-port`
- `--master-connect-retry`
- `--master-ssl`
- `--master-ssl-ca`
- `--master-ssl-capath`
- `--master-ssl-cert`
- `--master-ssl-cipher`
- `--master-ssl-key`

System variables used on replication slaves. The following system variables are used for controlling replication slave servers.

Those that can be set are specified using `SET`. Server options used with replication slaves are listed earlier in this section.

- `init_slave`

Command Line Format	`--init-slave=name`	
Config File Format	`init_slave`	
Option Sets Variable	Yes, `init_slave`	
Variable Name	`init_slave`	
Variable Scope	Global	
Dynamic Variable	Yes	
Value Set	**Type**	`string`

  This variable is similar to `init_connect`, but is a string to be executed by a slave server each time the SQL thread starts. The format of the string is the same as for the `init_connect` variable.

  Note

  The SQL thread sends an acknowledgement to the client before `init_slave` is executed. Therefore, it is not guaranteed that `init_slave` has been executed when `START SLAVE` returns. See `START SLAVE` Syntax, for more information.

- `rpl_recovery_rank`

  This variable is unused.

- `relay_log_recovery`

  Enables automatic relay log recovery immediately following server startup, which means that the replication slave discards all unprocessed relay logs and retrieves them from the replication master. This should be used following a crash on the replication slave to insure that no possibly corrupted relay logs are processed. The default value is 0 (disabled). This global variable can be changed dynamically, or by starting the slave with the `--relay-log-recovery` option.

- `sync_master_info`

Version Introduced	6.0.11	
Command Line Format	`--sync-master-info=#`	
Config File Format	`sync-master-info`	
Variable Name	`sync_master_info`	
Variable Scope	Global	
Dynamic Variable	Yes	
Value Set (>= 6.0.11)	**Platform Bit Size**	`64`
	Type	`numeric`
	Default	`0`
	Range	`0-18446744073709547520`

  If the value of this variable is greater than 0, a replication slave synchronizes its `master.info` file to disk (using `fdatasync()`) after every `sync_master_info` transactions. The default value of `sync_relay_log_info` is 0 (recommended in most situations), which does not force any synchronization to disk by the MySQL server — in this case, the server relies on the operating system to flush the `master.info` file's contents from time to time as for any other file.

  This variable was introduced in MySQL 6.0.11.

- `sync_relay_log`

Version Introduced	6.0.10
Command Line Format	`--sync-relay-log=#`
Config File Format	`sync-relay-log`
Variable Name	`sync_relay_log`

Variable Scope	Global	
Dynamic Variable	Yes	
Value Set (>= 6.0.10)	**Platform Bit Size**	`64`
	Type	`numeric`
	Default	`0`
	Range	`0-18446744073709547520`

If the value of this variable is greater than 0, the MySQL server synchronizes its relay log to disk (using `fdatasync()`) after every `sync_relay_log` writes to the relay log. There is one write to the relay log per statement if autocommit is enabled, and one write per transaction otherwise. The default value of `sync_relay_log` is 0, which does no synchronizing to disk — in this case, the server relies on the operating system to flush the relay log's contents from time to time as for any other file. A value of 1 is the safest choice, because in the event of a crash you lose at most one statement or transaction from the relay log. However, it is also the slowest choice (unless the disk has a battery-backed cache, which makes synchronization very fast).

This variable was introduced in MySQL 6.0.10.

- `sync_relay_log_info`

Version Introduced	6.0.11	
Command Line Format	`--sync-relay-log-info=#`	
Config File Format	`sync-relay-log-info`	
Variable Name	`sync_relay_log_info`	
Variable Scope	Global	
Dynamic Variable	Yes	
Value Set (>= 6.0.11)	**Platform Bit Size**	`64`
	Type	`numeric`
	Default	`0`
	Range	`0-18446744073709547520`

If the value of this variable is greater than 0, a replication slave synchronizes its `relay-log.info` file to disk (using `fdatasync()`) after every `sync_relay_log_info` transactions. A value of 1 is the generally the best choice. The default value of `sync_relay_log_info` is 0, which does not force any synchronization to disk by the MySQL server — in this case, the server relies on the operating system to flush the `relay-log.info` file's contents from time to time as for any other file.

This variable was introduced in MySQL 6.0.11.

- `slave_compressed_protocol`

Command Line Format	`--slave_compressed_protocol`	
Config File Format	`slave_compressed_protocol`	
Option Sets Variable	Yes, `slave_compressed_protocol`	
Variable Name	`slave_compressed_protocol`	
Variable Scope	Global	
Dynamic Variable	Yes	
Value Set	**Type**	`boolean`
	Default	`FALSE`

Whether to use compression of the slave/master protocol if both the slave and the master support it.

- `slave_exec_mode`

Version Introduced	6.0.5
Variable Name	`slave_exec_mode`

Variable Scope	Global	
Dynamic Variable	Yes	
Value Set	**Type**	`enumeration`
	Default	`STRICT`
	Valid Values	`IDEMPOTENT`, `STRICT`

Controls whether `IDEMPOTENT` or `STRICT` mode is used in replication conflict resolution and error checking. `IDEMPOTENT` mode causes suppression of duplicate-key and no-key-found errors. Beginning with MySQL 6.0.5, this mode should be employed in multi-master replication, circular replication, and some other special replication scenarios. `STRICT` mode is the default, and is suitable for most other cases.

- `slave_load_tmpdir`

Command Line Format	`--slave-load-tmpdir=name`	
Config File Format	`slave-load-tmpdir`	
Option Sets Variable	Yes, `slave_load_tmpdir`	
Variable Name	`slave_load_tmpdir`	
Variable Scope	Global	
Dynamic Variable	No	
Value Set	**Type**	`filename`
	Default	`/tmp`

The name of the directory where the slave creates temporary files for replicating `LOAD DATA INFILE` statements.

- `slave_net_timeout`

Command Line Format	`--slave-net-timeout=#`	
Config File Format	`slave-net-timeout`	
Option Sets Variable	Yes, `slave_net_timeout`	
Variable Name	`slave_net_timeout`	
Variable Scope	Global	
Dynamic Variable	Yes	
Value Set	**Type**	`numeric`
	Default	`3600`
	Min Value	`1`

The number of seconds to wait for more data from a master/slave connection before aborting the read. This timeout applies only to TCP/IP connections, not to connections made via Unix socket files, named pipes, or shared memory.

- `slave_skip_errors`

Command Line Format	`--slave-skip-errors=name`
Config File Format	`slave-skip-errors`
Option Sets Variable	Yes, `slave_skip_errors`
Variable Name	`slave_skip_errors`
Variable Scope	Global
Dynamic Variable	No

Normally, replication stops when an error occurs on the slave. This gives you the opportunity to resolve the inconsistency in the data manually. This variable tells the slave SQL thread to continue replication when a statement returns any of the errors listed in the variable value.

- `slave_transaction_retries`

Command Line Format	`--slave_transaction_retries=#`	
Config File Format	`slave_transaction_retries`	
Option Sets Variable	Yes, `slave_transaction_retries`	
Variable Name	`slave_transaction_retries`	
Variable Scope	Global	
Dynamic Variable	Yes	
Value Set	**Platform Bit Size**	`32`
	Type	`numeric`
	Default	`10`
	Range	`0-4294967295`
Value Set	**Platform Bit Size**	`64`
	Type	`numeric`
	Default	`10`
	Range	`0-18446744073709547520`

If a replication slave SQL thread fails to execute a transaction because of an `InnoDB` deadlock or because the transaction's execution time exceeded `InnoDB`'s `innodb_lock_wait_timeout`, it automatically retries `slave_transaction_retries` times before stopping with an error. The default value is 10.

1.3.4. Binary Log Options and Variables

You can use the `mysqld` options and system variables that are described in this section to affect the operation of the binary log as well as to control which statements are written to the binary log. For additional information about the binary log, see The Binary Log. For additional information about using MySQL server options and system variables, see Server Command Options, and Server System Variables.

Startup options used with binary logging. The following list describes startup options for enabling and configuring the binary log. Many of these options can be reset while the server is running by using the `CHANGE MASTER TO` statement. Others, can be set only when the slave server starts. System variables used with binary logging are discussed later in this section.

- `--binlog-row-event-max-size=N`

Command Line Format	`--binlog-row-event-max-size=#`	
Config File Format	`binlog-row-event-max-size`	
Value Set	**Platform Bit Size**	`32`
	Type	`numeric`
	Default	`1024`
	Range	`256-4294967295`
Value Set	**Platform Bit Size**	`64`
	Type	`numeric`
	Default	`1024`
	Range	`256-18446744073709547520`

Specify the maximum size of a row-based binary log event, in bytes. Rows are grouped into events smaller than this size if possible. The value should be a multiple of 256. The default is 1024. See Section 1.2, "Replication Formats".

- `--log-bin[=base_name]`

Command Line Format	`--log-bin`
Config File Format	`log-bin`
Variable Name	`log_bin`

Variable Scope	Global	
Dynamic Variable	No	
Value Set	**Type**	filename
	Default	OFF

Enable binary logging. The server logs all statements that change data to the binary log, which is used for backup and replication. See The Binary Log.

The option value, if given, is the basename for the log sequence. The server creates binary log files in sequence by adding a numeric suffix to the basename. It is recommended that you specify a basename (see Additional Known Issues, for the reason). Otherwise, MySQL uses *host_name*-bin as the basename.

- `--log-bin-index[=`*file_name*`]`

Command Line Format	--log-bin-index=name	
Config File Format	log-bin-index	
Value Set	**Type**	filename
	Default	OFF

The index file for binary log file names. See The Binary Log. If you omit the file name, and if you didn't specify one with `--log-bin`, MySQL uses *host_name*-bin.index as the file name.

- **Statement selection options.** The options in the following list affect which statements are written to the binary log, and thus sent by a replication master server to its slaves.

  - `--binlog-do-db=`*db_name*

    This option affects binary logging in the same manner that `--replicate-do-db` affects replication.

    The effects of this option depend on whether the statement-based or row-based logging format is in use, in the same way that the effects of `--replicate-do-db` depend on whether statement-based or row-based replication is in use.

    Statement-based logging. Only those statements where the default database (that is, the one selected by `USE`) is *db_name* are written to the binary log. To specify more than one database, use this option multiple times, once for each database; however, doing so does *not* cause cross-database statements such as `UPDATE` *some_db.some_table* `SET foo='bar'` to be logged while a different database (or no database) is selected.

    Warning

    To specify multiple databases you *must* use multiple instances of this option. Because database names can contain commas, if you supply a comma separated list then the list will be treated as the name of a single database.

    An example of what does not work as you might expect when using statement-based logging: If the server is started with `--binlog-do-db=sales` and you issue the following statements, the `UPDATE` statement is *not* logged:

```
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

    The main reason for this “just check the default database” behavior is that it is difficult from the statement alone to know whether it should be replicated (for example, if you are using multiple-table `DELETE` statements or multiple-table `UPDATE` statements that act across multiple databases). It is also faster to check only the default database rather than all databases if there is no need.

    Row-based logging. Logging is restricted to database *db_name*. Only changes to tables belonging to *db_name* are logged; the current database has no effect on this. For example, suppose that the server is started with `--replicate-do-db=sales` and row-based logging is in effect, and then the following statements are executed:

```
USE prices;
UPDATE sales.february SET amount=amount+100;
```

    The `february` table in the `sales` database is changed in accordance with the `UPDATE` statement; this occurs whether or not the `USE` statement was issued. However, the following statements are not logged when using the row-based logging format and `--binlog-do-db=sales`:

```
USE prices;
UPDATE prices.march SET amount=amount-25;
```

Even if the statement `USE prices` were changed to `USE sales`, the `UPDATE` statement's effects would still not be written to the binary log.

Another important difference in how `--binlog-do-db` is handled when using the statement-based logging format as opposed to the row-based format occurs with regard to statements that refer to multiple databases. Suppose the server is started with `--binlog-do-db=db1`, and the following statements are executed:

```
USE db1;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

If you are using statement-based logging, then the updates to both tables are written to the binary log. However, when using the row-based format, only the changes to `table1` logged; since `table2` is in a different database, it is not changed by the `UPDATE`. Now suppose that, instead of the `USE db1` statement, a `USE db4` statement had been used:

```
USE db4;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

In this case, the `UPDATE` statement would not be written to the binary log when using statement-based logging. However, if using row-based logging, the `UPDATE` would change `table1`, but not `table2` — in other words, only tables in the database named by `--binlog-do-db` are changed, and the choice of current database has no effect on this behavior.

- `--binlog-ignore-db=*db_name*`

  This option affects binary logging in the same manner that `--replicate-ignore-db` affects replication.

  The effects of this option depend on whether the statement-based or row-based logging format is in use, in the same way that the effects of `--replicate-ignore-db` depend on whether statement-based or row-based replication is in use.

  Statement-based logging. Tells the server to not log any statement where the default database (that is, the one selected by `USE`) is *`db_name`*.

  Row-based format. Tells the server not to log updates to any tables in the database *`db_name`*. The current database has no effect.

  When using statement-based logging, the following example does not work as you might expect. Suppose that the server is started with `--binlog-ignore-db=sales` and you issue the following statements:

  ```
  USE prices;
  UPDATE sales.january SET amount=amount+1000;
  ```

  The `UPDATE` statement *is* logged in such a case because `--binlog-ignore-db` applies only to the default database (determined by the `USE` statement). Because the `sales` database was specified explicitly in the statement, the statement has not been filtered. However, when using row-based logging, the `UPDATE` statement's effects are *not* written to the binary log, which means that no changes to the `sales.january` table are logged; in this instance, `--binlog-ignore-db=sales` causes *all* changes made to tables in the master's copy of the `sales` database to be ignored for purposes of binary logging.

  To specify more than one database to ignore, use this option multiple times, once for each database. Because database names can contain commas, if you supply a comma separated list then the list will be treated as the name of a single database.

  You should not use this option if you are using cross-database updates and you do not want these updates to be logged.

Additional server options that can be used to control logging also affect the binary log. For more information about these, see Server Command Options. For more information about how the options in the previous list are applied, see The Binary Log.

There are also options for slave servers that control which statements received from the master should be executed or ignored. For details, see Section 1.3.3, "Replication Slave Options and Variables".

- `--log-bin-trust-function-creators[={0|1}]`

Command Line Format	`--log-bin-trust-function-creators`	
Config File Format	`log-bin-trust-function-creators`	
Option Sets Variable	Yes, `log_bin_trust_function_creators`	
Variable Name	`log_bin_trust_function_creators`	
Variable Scope	Global	
Dynamic Variable	Yes	
Value Set	**Type**	`boolean`

	Default	`FALSE`

With no argument or an argument of 1, this option sets the `log_bin_trust_function_creators` system variable to 1. With an argument of 0, this option sets the system variable to 0. `log_bin_trust_function_creators` affects how MySQL enforces restrictions on stored function and trigger creation. See Binary Logging of Stored Programs.

Testing and debugging options. The following binary log options are used in replication testing and debugging. They are not intended for use in normal operations.

- `--max-binlog-dump-events`

Command Line Format	`--max-binlog-dump-events=#`	
Config File Format	`max-binlog-dump-events`	
Value Set	**Type**	`numeric`
	Default	`0`

  This option is used internally by the MySQL test suite for replication testing and debugging.

- `--sporadic-binlog-dump-fail`

Command Line Format	`--sporadic-binlog-dump-fail`	
Config File Format	`sporadic-binlog-dump-fail`	
Value Set	**Type**	`boolean`
	Default	`FALSE`

  This option is used internally by the MySQL test suite for replication testing and debugging.

System variables used with the binary log. The following system variables are used for controlling replication slave servers. Those that can be set are specified using `SET`. Server options used with replication slaves are listed earlier in this section.

- `binlog_cache_size`

Command Line Format	`--binlog_cache_size=#`	
Config File Format	`binlog_cache_size`	
Option Sets Variable	Yes, `binlog_cache_size`	
Variable Name	`binlog_cache_size`	
Variable Scope	Global	
Dynamic Variable	Yes	
Value Set	**Platform Bit Size**	`32`
	Type	`numeric`
	Default	`32768`
	Range	`4096-4294967295`
Value Set	**Platform Bit Size**	`64`
	Type	`numeric`
	Default	`32768`
	Range	`4096-18446744073709547520`

  The size of the cache to hold the SQL statements for the binary log during a transaction. A binary log cache is allocated for each client if the server supports any transactional storage engines and if the server has the binary log enabled (`--log-bin` option). If you often use large, multiple-statement transactions, you can increase this cache size to get more performance. The

Binlog_cache_use and Binlog_cache_disk_use status variables can be useful for tuning the size of this variable. See The Binary Log.

MySQL Enterprise
For recommendations on the optimum setting for binlog_cache_size subscribe to the MySQL Enterprise Monitor. For more information, see http://www.mysql.com/products/enterprise/advisors.html.

- binlog_format

Command Line Format	--binlog-format	
Config File Format	binlog-format	
Option Sets Variable	Yes, binlog_format	
Variable Name	binlog_format	
Variable Scope	Both	
Dynamic Variable	Yes	
Value Set	**Type**	enumeration
	Default	STATEMENT
	Valid Values	ROW, STATEMENT, MIXED

This variable sets the binary logging format, and can be any one of STATEMENT, ROW, or MIXED. binlog_format is set by the --binlog-format option at startup, or by the binlog_format variable at runtime.

You must have the SUPER privilege to set this variable, which (unlike with most system variables) is true as of MySQL 6.0.8 even for the session value. See Section 1.2, “Replication Formats”.

The rules governing when changing this variable takes effect and how long the effect lasts are the same as for other MySQL server system variables. See SET Syntax, for more information.

MIXED is used by default before MySQL 6.0.8; STATEMENT is the default beginning with MySQL 6.0.8.

If MIXED is specified, statement-based replication is used except for cases where only row-based replication is guaranteed to lead to proper results. For example, this happens when statements contain user-defined functions (UDF) or the UUID() function. An exception to this rule is that MIXED always uses statement-based replication for stored functions and triggers.

There are exceptions when you cannot switch the replication format at runtime:

- From within a stored function or a trigger.
- If the session is currently in row-based replication mode and has open temporary tables.

Trying to switch the format in those cases results in an error.

The binlog format affects the behavior of the following server options:

- --replicate-do-db
- --replicate-ignore-db
- --binlog-do-db
- --binlog-ignore-db

These effects are discussed in detail in the descriptions of the individual options.

- max_binlog_cache_size

Command Line Format	--max_binlog_cache_size=#	
Config File Format	max_binlog_cache_size	
Option Sets Variable	Yes, max_binlog_cache_size	
Variable Name	max_binlog_cache_size	
Variable Scope	Global	
Dynamic Variable	Yes	
Value Set	**Platform Bit Size**	32

	Type	numeric
	Default	4294967295
	Range	4096-4294967295
Value Set	**Platform Bit Size**	64
	Type	numeric
	Default	18446744073709547520
	Range	4096-18446744073709547520

If a multiple-statement transaction requires more than this many bytes of memory, the server generates a `MULTI-STATEMENT TRANSACTION REQUIRED MORE THAN 'MAX_BINLOG_CACHE_SIZE' BYTES OF STORAGE` error. The minimum value is 4096; the maximum and default values are 4GB on 32-bit platforms and 16 PB (petabytes) on 64-bit platforms.

- `max_binlog_size`

Command Line Format	`--max_binlog_size=#`	
Config File Format	`max_binlog_size`	
Option Sets Variable	Yes, `max_binlog_size`	
Variable Name	`max_binlog_size`	
Variable Scope	Global	
Dynamic Variable	Yes	
Value Set	**Type**	numeric
	Default	1073741824
	Min Value	4096

If a write to the binary log causes the current log file size to exceed the value of this variable, the server rotates the binary logs (closes the current file and opens the next one). You cannot set this variable to more than 1GB or to less than 4096 bytes. The default value is 1GB.

A transaction is written in one chunk to the binary log, so it is never split between several binary logs. Therefore, if you have big transactions, you might see binary logs larger than `max_binlog_size`.

If `max_relay_log_size` is 0, the value of `max_binlog_size` applies to relay logs as well.

- `sync_binlog`

Command Line Format	`--sync-binlog=#`	
Config File Format	`sync-binlog`	
Option Sets Variable	Yes, `sync_binlog`	
Variable Name	`sync_binlog`	
Variable Scope	Global	
Dynamic Variable	Yes	
Value Set	**Platform Bit Size**	32
	Type	numeric
	Default	0
	Range	0-4294967295
Value Set	**Platform Bit Size**	64
	Type	numeric
	Default	0
	Range	0-18446744073709547520

If the value of this variable is greater than 0, the MySQL server synchronizes its binary log to disk (using `fdatasync()`)

after every sync_binlog writes to the binary log. There is one write to the binary log per statement if autocommit is enabled, and one write per transaction otherwise. The default value of sync_binlog is 0, which does no synchronizing to disk — in this case, the server relies on the operating system to flush the binary log's contents from to time as for any other file. A value of 1 is the safest choice, because in the event of a crash you lose at most one statement or transaction from the binary log. However, it is also the slowest choice (unless the disk has a battery-backed cache, which makes synchronization very fast).

1.4. Common Replication Administration Tasks

Once replication has been started it should execute without requiring much regular administration. Depending on your replication environment, you will want to check the replication status of each slave either periodically, daily, or even more frequently.

MySQL Enterprise
For regular reports regarding the status of your slaves, subscribe to the MySQL Enterprise Monitor. For more information, see http://www.mysql.com/products/enterprise/advisors.html.

1.4.1. Checking Replication Status

The most common task when managing a replication process is to ensure that replication is taking place and that there have been no errors between the slave and the master.

The primary statement for this is SHOW SLAVE STATUS which you must execute on each slave:

```
mysql> SHOW SLAVE STATUS\G
*************************** 1. row ***************************
             Slave_IO_State: Waiting for master to send event
                Master_Host: master1
                Master_User: root
                Master_Port: 3306
              Connect_Retry: 60
            Master_Log_File: mysql-bin.000004
        Read_Master_Log_Pos: 931
             Relay_Log_File: slave1-relay-bin.000056
              Relay_Log_Pos: 950
      Relay_Master_Log_File: mysql-bin.000004
           Slave_IO_Running: Yes
          Slave_SQL_Running: Yes
            Replicate_Do_DB:
        Replicate_Ignore_DB:
         Replicate_Do_Table:
     Replicate_Ignore_Table:
    Replicate_Wild_Do_Table:
Replicate_Wild_Ignore_Table:
                 Last_Errno: 0
                 Last_Error:
               Skip_Counter: 0
        Exec_Master_Log_Pos: 931
            Relay_Log_Space: 1365
            Until_Condition: None
             Until_Log_File:
              Until_Log_Pos: 0
         Master_SSL_Allowed: No
         Master_SSL_CA_File:
         Master_SSL_CA_Path:
            Master_SSL_Cert:
          Master_SSL_Cipher:
             Master_SSL_Key:
      Seconds_Behind_Master: 0
1 row in set (0.01 sec)
```

The key fields from the status report to examine are:

- Slave_IO_State — indicates the current status of the slave. See Replication Slave I/O Thread States, and Replication Slave SQL Thread States, for more information.
- Slave_IO_Running — shows whether the IO thread for the reading the master's binary log is running.
- Slave_SQL_Running — shows whether the SQL thread for the executing events in the relay log is running.
- Last_Error — shows the last error registered when processing the relay log. Ideally this should be blank, indicating no errors.
- Seconds_Behind_Master — shows the number of seconds that the slave SQL thread is behind processing the master binary log. A high number (or an increasing one) can indicate that the slave is unable to cope with the large number of statements from the master.

  A value of 0 for Seconds_Behind_Master can usually be interpreted as meaning that the slave has caught up with the master, but there are some cases where this is not strictly true. For example, this can occur if the network connection between master and slave is broken but the slave I/O thread has not yet noticed this — that is, `slave_net_timeout` has not yet elapsed.

It is also possible that transient values for `Seconds_Behind_Master` may not reflect the situation accurately. When the slave SQL thread has caught up on I/O, `Seconds_Behind_Master` displays 0; but when the slave I/O thread is still queuing up a new event, `Seconds_Behind_Master` may show a large value until the SQL thread finishes executing the new event. This is especially likely when the events have old timestamps; in such cases, if you execute `SHOW SLAVE STATUS` several times in a relatively short peiod, you may see this value change back and forth repeatedly between 0 and a relatively large value.

On the master, you can check the status of slaves by examining the list of running processes. Slaves execute the `Binlog Dump` command:

```
mysql> SHOW PROCESSLIST \G;
*************************** 4. row ***************************
     Id: 10
   User: root
   Host: slave1:58371
     db: NULL
Command: Binlog Dump
   Time: 777
  State: Has sent all binlog to slave; waiting for binlog to be updated
   Info: NULL
```

Because it is the slave that drives the core of the replication process, very little information is available in this report.

If you have used the `--report-host` option, then the `SHOW SLAVE HOSTS` statement will show basic information about connected slaves:

```
mysql> SHOW SLAVE HOSTS;
+-----------+--------+------+-------------------+-----------+
| Server_id | Host   | Port | Rpl_recovery_rank | Master_id |
+-----------+--------+------+-------------------+-----------+
|        10 | slave1 | 3306 |                 0 |         1 |
+-----------+--------+------+-------------------+-----------+
1 row in set (0.00 sec)
```

The output includes the ID of the slave server, the value of the `--report-host` option, the connecting port, master ID and the priority of the slave for receiving binary log updates.

1.4.2. Pausing Replication on the Slave

You can stop and start the replication of statements on the slave using the `STOP SLAVE` and `START SLAVE` statements.

To stop execution of the binary log from the master, use `STOP SLAVE`:

```
mysql> STOP SLAVE;
```

When execution is stopped, the slave does not read the binary log from the master (the `IO_THREAD`) and stops processing events from the relay log that have not yet been executed (the `SQL_THREAD`). You can pause either the IO or SQL threads individually by specifying the thread type. For example:

```
mysql> STOP SLAVE IO_THREAD;
```

Stopping the SQL thread can be useful if you want to perform a backup or other task on a slave that only processes events from the master. The IO thread will continue to be read from the master, but not executed, which will make it easier for the slave to catch up when you start slave operations again.

Stopping the IO thread will allow the statements in the relay log to be executed up until the point where the relay log has ceased to receive new events. Using this option can be useful when you want to pause execution to allow the slave to catch up with events from the master, when you want to perform administration on the slave but also ensure you have the latest updates to a specific point. This method can also be used to pause execution on the slave while you conduct administration on the master while ensuring that there is not a massive backlog of events to be executed when replication is started again.

To start execution again, use the `START SLAVE` statement:

```
mysql> START SLAVE;
```

If necessary, you can start either the `IO_THREAD` or `SQL_THREAD` threads individually.

Chapter 2. Replication Solutions

Replication can be used in many different environments for a range of purposes. In this section you will find general notes and advice on using replication for specific solution types.

For information on using replication in a backup environment, including notes on the setup, backup procedure, and files to back up, see Section 2.1, “Using Replication for Backups”.

For advice and tips on using different storage engines on the master and slaves, see Section 2.2, “Using Replication with Different Master and Slave Storage Engines”.

Using replication as a scale-out solution requires some changes in the logic and operation of applications that use the solution. See Section 2.3, “Using Replication for Scale-Out”.

For performance or data distribution reasons you may want to replicate different databases to different replication slaves. See Section 2.4, “Replicating Different Databases to Different Slaves”

As the number of replication slaves increases, the load on the master can increase (because of the need to replicate the binary log to each slave) and lead to a reduction in performance of the master. For tips on improving your replication performance, including using a single secondary server as an replication master, see Section 2.5, “Improving Replication Performance”.

For guidance on switching masters, or converting slaves into masters as part of an emergency failover solution, see Section 2.6, “Switching Masters During Failover”.

To secure your replication communication you can encrypt the communication channel by using SSL to exchange data. Step-by-step instructions can be found in Section 2.8, “Setting Up Replication Using SSL”.

2.1. Using Replication for Backups

You can use replication as a backup solution by replicating data from the master to a slave, and then backing up the data slave. Because the slave can be paused and shut down without affecting the running operation of the master you can produce an effective snapshot of 'live' data that would otherwise require a shutdown of the master database.

How you back up the database will depend on the size of the database and whether you are backing up only the data, or the data and the replication slave state so that you can rebuild the slave in the event of failure. There are therefore two choices:

If you are using replication as a solution to enable you to back up the data on the master, and the size of your database is not too large, then the `mysqldump` tool may be suitable. See Section 2.1.1, “Backing Up a Slave Using `mysqldump`”.

For larger databases, where `mysqldump` would be impractical or inefficient, you can back up the raw data files instead. Using the raw data files option also means that you can back up the binary and relay logs that will enable you to recreate the slave in the event of a slave failure. For more information, see Section 2.1.2, “Backing Up Raw Data from a Slave”.

Another backup strategy, which can be used for either master or slave servers, is to put the server in a read-only state. The backup is performed against the read-only server, which then is changed back to its usual read/write operational status. See Section 2.1.3, “Backing Up a Master or Slave by Making It Read Only”.

2.1.1. Backing Up a Slave Using `mysqldump`

Using `mysqldump` to create a copy of the database enables you to capture all of the data in the database in a format that allows the information to be imported into another instance of MySQL. Because the format of the information is SQL statements the file can easily be distributed and applied to running servers in the event that you need access to the data in an emergency. However, if the size of your data set is very large then `mysqldump` may be impractical.

When using `mysqldump` you should stop the slave before starting the dump process to ensure that the dump contains a consistent set of data:

1. Stop the slave from processing requests. You can either stop the slave completely using `mysqladmin`:

   ```
   shell> mysqladmin stop-slave
   ```

   Alternatively, you can stop processing the relay log files by stopping the replication SQL thread. Using this method will allow the binary log data to be transferred. Within busy replication environments this may speed up the catch-up process when you start the slave processing again:

   ```
   shell> mysql -e 'STOP SLAVE SQL_THREAD;'
   ```

2. Run mysqldump to dump your databases. You may either select databases to be dumped, or dump all databases. For more information, see mysqldump. For example, to dump all databases:

   ```
   shell> mysqldump --all-databases >fulldb.dump
   ```

3. Once the dump has completed, start slave operations again:

   ```
   shell> mysqladmin start-slave
   ```

In the preceding example you may want to add login credentials (user name, password) to the commands, and bundle the process up into a script that you can run automatically each day.

If you use this approach, make sure you monitor the slave replication process to ensure that the time taken to run the backup in this way is not affecting the slave's ability to keep up with events from the master. See Section 1.4.1, "Checking Replication Status". If the slave is unable to keep up you may want to add another server and distribute the backup process. For an example of how to configure this scenario, see Section 2.4, "Replicating Different Databases to Different Slaves".

2.1.2. Backing Up Raw Data from a Slave

To guarantee the integrity of the files that are copied, backing up the raw data files on your MySQL replication slave should take place while your slave server is shut down. If the MySQL server is still running then background tasks, particularly with storage engines with background processes such as InnoDB, may still be updating the database files. With InnoDB, these problems should be resolved during crash recovery, but since the slave server can be shut down during the backup process without affecting the execution of the master it makes sense to take advantage of this facility.

To shut down the server and back up the files:

1. Shut down the slave MySQL server:

   ```
   shell> mysqladmin shutdown
   ```

2. Copy the data files. You can use any suitable copying or archive utility, including cp, tar or WinZip:

   ```
   shell> tar cf /tmp/dbbackup.tar ./data
   ```

3. Start up the mysqld process again:

   ```
   shell> mysqld_safe &
   ```

   Under Windows:

   ```
   C:\> "C:\Program Files\MySQL\MySQL Server 6.0\bin\mysqld"
   ```

Normally you should back up the entire data folder for the slave MySQL server. If you want to be able to restore the data and operate as a slave (for example, in the event of failure of the slave), then when you back up the slave's data, you should back up the slave status files, master.info and relay-log.info, along with the relay log files. These files are needed to resume replication after you restore the slave's data.

If you lose the relay logs but still have the relay-log.info file, you can check it to determine how far the SQL thread has executed in the master binary logs. Then you can use CHANGE MASTER TO with the MASTER_LOG_FILE and MASTER_LOG_POS options to tell the slave to re-read the binary logs from that point. Of course, this requires that the binary logs still exist on the master server.

If your slave is subject to replicating LOAD DATA INFILE statements, you should also back up any SQL_LOAD-* files that exist in the directory that the slave uses for this purpose. The slave needs these files to resume replication of any interrupted LOAD DATA INFILE operations. The directory location is specified using the --slave-load-tmpdir option. If this option is not specified, the directory location is the value of the tmpdir system variable.

2.1.3. Backing Up a Master or Slave by Making It Read Only

It is possible to back up either master or slave servers in a replication setup by acquiring a global read lock and manipulating the read_only system variable to change the read-only state of the server to be backed up:

1. Make the server read-only, so that it processes only retrievals and blocks updates
2. Perform the backup
3. Change the server back to its normal read/write state

The following instructions describe how to do this for a master server and for a slave server.

> **Note**
>
> The instructions in this section place the server to be backed up in a state that is safe for backup methods that get the data from the server, such as `mysqldump` (see `mysqldump`). You should not attempt to use these instructions to make a binary backup by copying files directly because the server may still have modified data cached in memory and not flushed to disk.

For both scenarios discussed here, suppose that you have the following replication setup:

- A master server M1
- A slave server S1 that has M1 as its master
- A client C1 connected to M1
- A client C2 connected to S1

Scenario 1: Backup with a Read-Only Master

Put the master M1 in a read-only state by executing these statements on it:

```
FLUSH TABLES WITH READ LOCK;
SET GLOBAL read_only = ON;
```

While M1 is in a read-only state, the following properties are true:

- Requests for updates sent by C1 to M1 will fail because the server is in read-only mode
- Requests for retrievals sent by C1 to M1 will succeed
- Making a backup on M1 is safe
- Making a backup on S1 is not safe: this server is still running, and might be processing the binary log or update requests coming from client C2 (S1 might not be in a read-only state)

While M1 is read only, perform the backup. For example, you can use `mysqldump`.

After the backup on M1 has been done, restore M1 to its normal operational state by executing these statements:

```
SET GLOBAL read_only = OFF;
UNLOCK TABLES;
```

Although performing the backup on M1 is safe (as far as the backup is concerned), it is not optimal because clients of M1 are blocked from executing updates.

This strategy also applies to backing up a single server in a non-replication setting.

Scenario 2: Backup with a Read-Only Slave

Put the slave S1 in a read-only state by executing these statements on it:

```
FLUSH TABLES WITH READ LOCK;
SET GLOBAL read_only = ON;
```

While S1 is in a read-only state, the following properties are true:

- The master M1 will continue to operate

- Making a backup on the master is not safe
- The slave S1 is stopped
- Making a backup on the slave S1 is safe

These properties provide the basis for a popular backup scenario: Having one slave busy performing a backup for a while is not a problem because it does not affect the entire network, and the system is still running during the backup. (For example, clients can still perform updates on the master server.)

While S1 is read only, perform the backup.

After the backup on S1 has been done, restore S1 to its normal operational state by executing these statements:

```
SET GLOBAL read_only = OFF;
UNLOCK TABLES;
```

After the slave is restored to normal operation, it again synchronizes to the master by catching up with any outstanding updates in the binary log from the master.

In either scenario, the statements to acquire the global read lock and manipulate the `read_only` variable are performed on the server to be backed up and do not propagate to any slaves of that server.

2.2. Using Replication with Different Master and Slave Storage Engines

The replication process does not care if the source table on the master and the replicated table on the slave use different engine types. In fact, the system variable `storage_engine` is not replicated.

This provides a number of advantages in the replication process in that you can take advantage of different engine types for different replication scenarios. For example, in a typical scaleout scenario (see Section 2.3, “Using Replication for Scale-Out”), you want to use `InnoDB` tables on the master to take advantage of the transactional functionality, but use `MyISAM` on the slaves where transaction support is not required because the data is only read. When using replication in a data logging environment you may want to use the `Archive` storage engine on the slave.

Setting up different engines on the master and slave depends on how you set up the initial replication process:

- If you used `mysqldump` to create the database snapshot on your master then you could edit the dump text to change the engine type used on each table.

  Another alternative for `mysqldump` is to disable engine types that you do not want to use on the slave before using the dump to build the data on the slave. For example, you can add the `--skip-innodb` option on your slave to disable the `InnoDB` engine. If a specific engine does not exist, MySQL will use the default engine type, usually `MyISAM`. If you want to disable further engines in this way, you may want to consider building a special binary to be used on the slave that only supports the engines you want.

- If you are using raw data files for the population of the slave, you will be unable to change the initial table format. Instead, use `ALTER TABLE` to change the table types after the slave has been started.

- For new master/slave replication setups where there are currently no tables on the master, avoid specifying the engine type when creating new tables.

If you are already running a replication solution and want to convert your existing tables to another engine type, follow these steps:

1. Stop the slave from running replication updates:

   ```
   mysql> STOP SLAVE;
   ```

   This will enable you to change engine types without interruptions.

2. Execute an `ALTER TABLE ... Engine='`*`enginetype`*`'` for each table where you want to change the engine type.

3. Start the slave replication process again:

   ```
   mysql> START SLAVE;
   ```

Although the `storage_engine` variable is not replicated, be aware that `CREATE TABLE` and `ALTER TABLE` statements that include the engine specification will be correctly replicated to the slave. For example, if you have a CSV table and you execute:

```
mysql> ALTER TABLE csvtable Engine='MyISAM';
```

The above statement will be replicated to the slave and the engine type on the slave will be converted to `MyISAM`, even if you have previously changed the table type on the slave to an engine other than CSV. If you want to retain engine differences on the master and slave, you should be careful to use the `storage_engine` variable on the master when creating a new table. For example, instead of:

```
mysql> CREATE TABLE tablea (columna int) Engine=MyISAM;
```

Use this format:

```
mysql> SET storage_engine=MyISAM;
mysql> CREATE TABLE tablea (columna int);
```

When replicated, the `storage_engine` variable will be ignored, and the `CREATE TABLE` statement will be executed with the slave's default engine type.

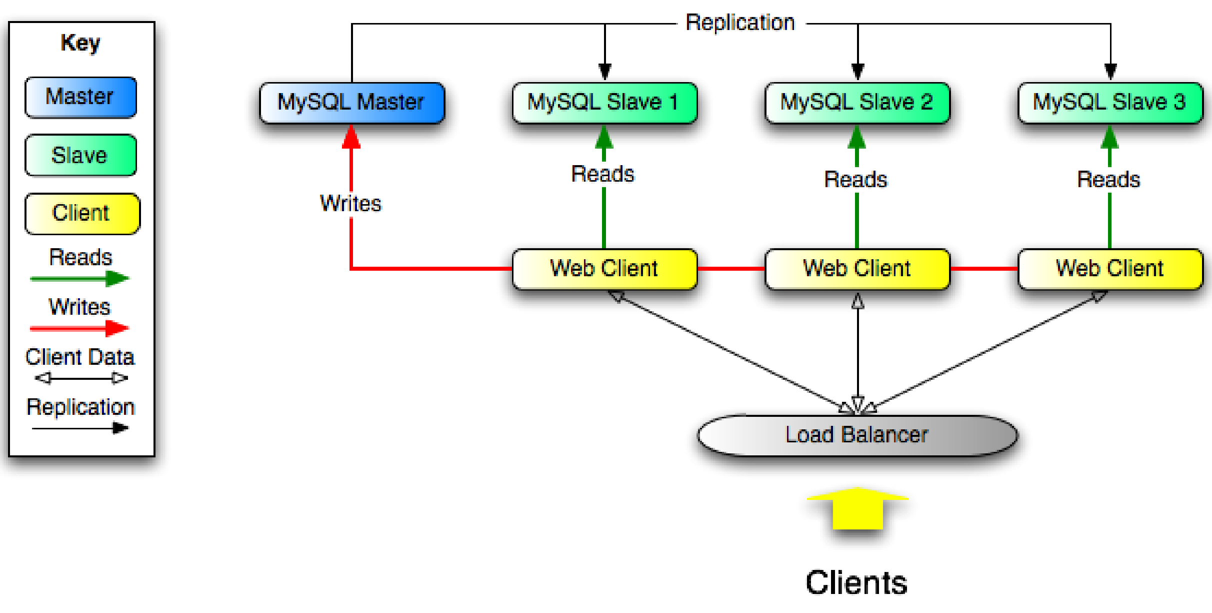
2.3. Using Replication for Scale-Out

You can use replication as a scale-out solution, i.e. where you want to split up the load of database queries across multiple database servers, within some reasonable limitations.

Because replication works from the distribution of one master to one or more slaves, using replication for scaleout works best in an environment where you have a high number of reads and low number of writes/updates. Most websites fit into this category, where users are browsing the website, reading articles, posts, or viewing products. Updates only occur during session management, or when making a purchase or adding a comment/message to a forum.

Replication in this situation enables you to distribute the reads over the replication slaves, while still allowing your web servers to communicate with the replication master when a write is required. You can see a sample replication layout for this scenario in Figure 2.1, "Using replication to improve the performance during scaleout".

Figure 2.1. Using replication to improve the performance during scaleout



If the part of your code that is responsible for database access has been properly abstracted/modularized, converting it to run with a replicated setup should be very smooth and easy. Change the implementation of your database access to send all writes to the master, and to send reads to either the master or a slave. If your code does not have this level of abstraction, setting up a replicated system gives you the opportunity and motivation to clean it up. Start by creating a wrapper library or module that implements the following functions:

- `safe_writer_connect()`
- `safe_reader_connect()`
- `safe_reader_statement()`
- `safe_writer_statement()`

`safe_` in each function name means that the function takes care of handling all error conditions. You can use different names for the functions. The important thing is to have a unified interface for connecting for reads, connecting for writes, doing a read, and doing a write.

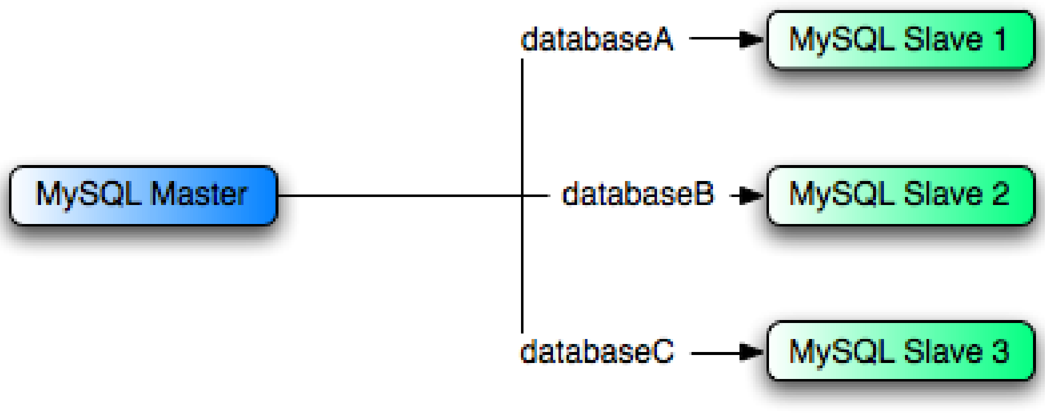
Then convert your client code to use the wrapper library. This may be a painful and scary process at first, but it pays off in the long run. All applications that use the approach just described are able to take advantage of a master/slave configuration, even one involving multiple slaves. The code is much easier to maintain, and adding troubleshooting options is trivial. You need modify only one or two functions; for example, to log how long each statement took, or which statement among those issued gave you an error.

If you have written a lot of code, you may want to automate the conversion task by using the `replace` utility that comes with standard MySQL distributions, or write your own conversion script. Ideally, your code uses consistent programming style conventions. If not, then you are probably better off rewriting it anyway, or at least going through and manually regularizing it to use a consistent style.

2.4. Replicating Different Databases to Different Slaves

There may be situations where you have a single master and want to replicate different databases to different slaves. For example, you may want to distribute different sales data to different departments to help spread the load during data analysis. A sample of this layout is shown in Figure 2.2, “Using replication to replicate databases to separate replication slaves”.

Figure 2.2. Using replication to replicate databases to separate replication slaves



You can achieve this separation by configuring the master and slaves as normal, and then limiting the binary log statements that each slave processes by using the `--replicate-wild-do-table` configuration option on each slave.

> **Important**
>
> You should *not* use `--replicate-do-db` for this purpose when using statement-based replication, since statement-based replication causes this option's affects to vary according to the database that is currently selected. This applies to mixed-format replication as well, since this allows some updates to be replicated using the statement-based format.
>
> However, it should be to use `--replicate-do-db` for this purpose if you are using row-based replication only, since in this case the currently-selected database has no effect on the option's operation.

For example, to support the separation as shown in Figure 2.2, “Using replication to replicate databases to separate replication slaves”, you should configure each replication slave as follows, before executing `START SLAVE`:

- Replication slave 1 should use `--replicate-wild-do-table=databaseA.%`.

- Replication slave 2 should use `--replicate-wild-do-table=databaseB.%`.
- Replication slave 3 should use `--replicate-wild-do-table=databaseC.%`.

If you have data that needs to be synchronized to the slaves before replication starts, you have a number of choices:

- Synchronize all the data to each slave, and delete the databases, tables, or both that you do not want to keep.
- Use `mysqldump` to create a separate dump file for each database and load the appropriate dump file on each slave.
- Use a raw data file dump and include only the specific files and databases that you need for each slave.

  Note

  This does not work with `InnoDB` databases unless you use `innodb_file_per_table`.

Each slave in this configuration receives the entire binary log from the master, but executes only those events from the binary log that apply to the databases and tables included by the `--replicate-wild-do-table` option in effect on that slave.

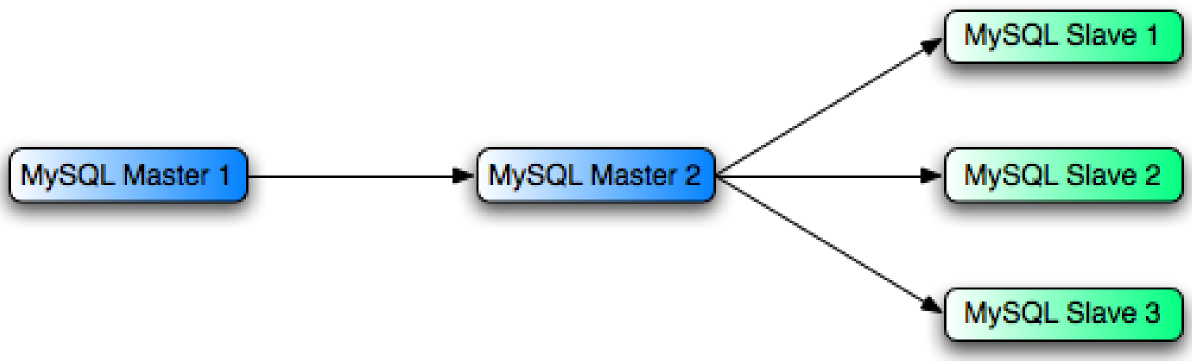
2.5. Improving Replication Performance

As the number of slaves connecting to a master increases, the load, although minimal, also increases, as each slave uses up a client connection to the master. Also, as each slave must receive a full copy of the master binary log, the network load on the master may also increase and start to create a bottleneck.

If you are using a large number of slaves connected to one master, and that master is also busy processing requests (for example, as part of a scaleout solution), then you may want to improve the performance of the replication process.

One way to improve the performance of the replication process is to create a deeper replication structure that enables the master to replicate to only one slave, and for the remaining slaves to connect to this primary slave for their individual replication requirements. A sample of this structure is shown in Figure 2.3, “Using an additional replication host to improve performance”.

Figure 2.3. Using an additional replication host to improve performance



For this to work, you must configure the MySQL instances as follows:

- Master 1 is the primary master where all changes and updates are written to the database. Binary logging should be enabled on this machine.
- Master 2 is the slave to the Master 1 that provides the replication functionality to the remainder of the slaves in the replication structure. Master 2 is the only machine allowed to connect to Master 1. Master 2 also has binary logging enabled, and the `--log-slave-updates` option so that replication instructions from Master 1 are also written to Master 2's binary log so that they can then be replicated to the true slaves.
- Slave 1, Slave 2, and Slave 3 act as slaves to Master 2, and replicate the information from Master 2, which is really the data logged on Master 1.

The above solution reduces the client load and the network interface load on the primary master, which should improve the overall performance of the primary master when used as a direct database solution.

If your slaves are having trouble keeping up with the replication process on the master then there are a number of options available:

- If possible, you should put the relay logs and the data files on different physical drives. To do this, use the `--relay-log` option to specify the location of the relay log.
- If the slaves are significantly slower than the master, then you may want to divide up the responsibility for replicating different databases to different slaves. See Section 2.4, “Replicating Different Databases to Different Slaves”.
- If your master makes use of transactions and you are not concerned about transaction support on your slaves, then use `MyISAM` or another non-transactional engine. See Section 2.2, “Using Replication with Different Master and Slave Storage Engines”.
- If your slaves are not acting as masters, and you have a potential solution in place to ensure that you can bring up a master in the event of failure, then you can switch off `--log-slave-updates`. This prevents 'dumb' slaves from also logging events they have executed into their own binary log.

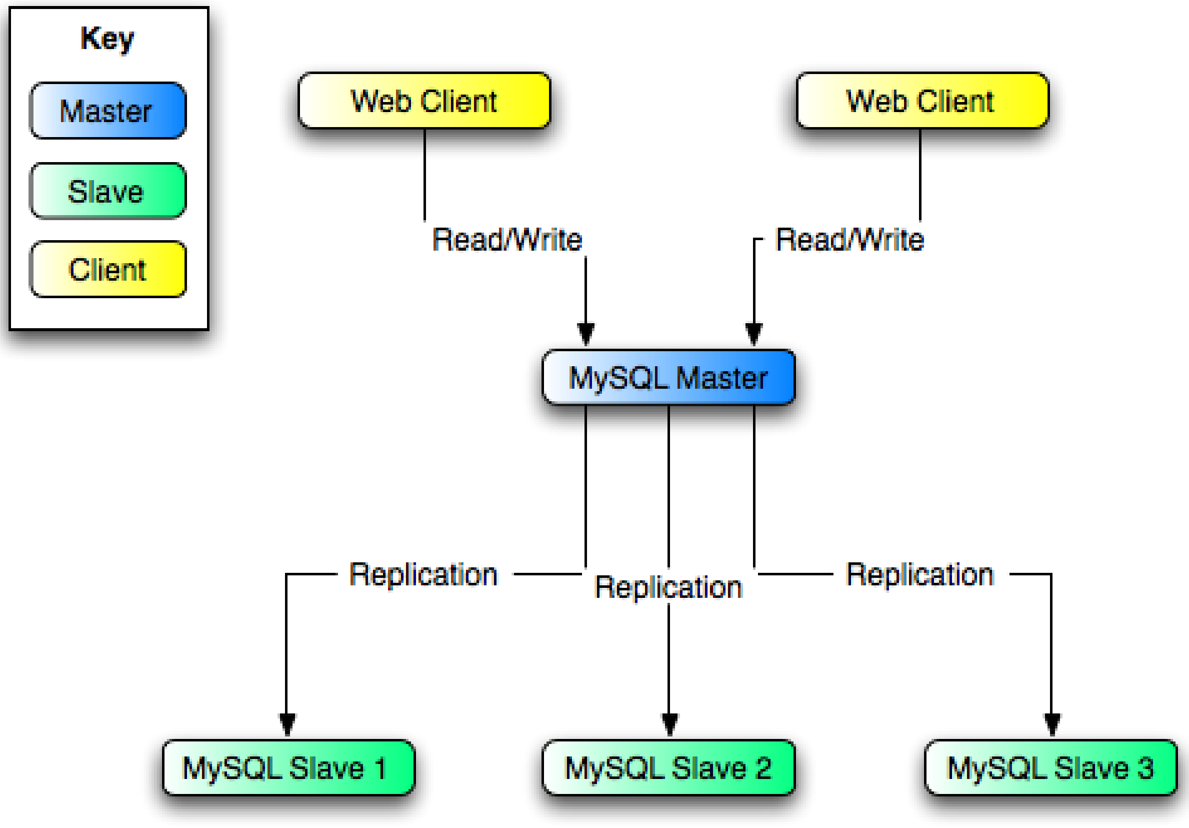
2.6. Switching Masters During Failover

There is currently no official solution for providing failover between master and slaves in the event of a failure. With the currently available features, you would have to set up a master and a slave (or several slaves), and to write a script that monitors the master to check whether it is up. Then instruct your applications and the slaves to change master in case of failure.

Remember that you can tell a slave to change its master at any time, using the `CHANGE MASTER TO` statement. The slave will not check whether the databases on the master are compatible with the slave, it will just start executing events from the specified log and position on the new master. In a failover situation all the servers in the group are probably executing the same events from the same binary log, so changing the source of the events should not affect the database structure or integrity providing you are careful.

Run your slaves with the `--log-bin` option and without `--log-slave-updates`. In this way, the slave is ready to become a master as soon as you issue `STOP SLAVE`; `RESET MASTER`, and `CHANGE MASTER TO` statement on the other slaves. For example, assume that you have the structure shown in Figure 2.4, “Redundancy using replication, initial structure”.

Figure 2.4. Redundancy using replication, initial structure



In this diagram, the `MySQL Master` holds the master database, the `MySQL Slave` computers are replication slaves, and the `Web Client` machines are issuing database reads and writes. Web clients that issue only reads (and would normally be connected to the slaves) are not shown, as they do not need to switch to a new server in the event of failure. For a more detailed example of a read/write scaleout replication structure, see Section 2.3, “Using Replication for Scale-Out”.

Each MySQL Slave (`Slave 1`, `Slave 2`, and `Slave 3`) are slaves running with `--log-bin` and without `--log-slave-updates`. Because updates received by a slave from the master are not logged in the binary log unless `--log-slave-updates` is specified, the binary log on each slave is empty initially. If for some reason `MySQL Master` becomes unavailable, you can pick one of the slaves to become the new master. For example, if you pick `Slave 1`, all `Web Clients` should be redirected to `Slave 1`, which will log updates to its binary log. `Slave 2` and `Slave 3` should then replicate from `Slave 1`.

The reason for running the slave without `--log-slave-updates` is to prevent slaves from receiving updates twice in case you cause one of the slaves to become the new master. Suppose that `Slave 1` has `--log-slave-updates` enabled. Then it will write updates that it receives from `Master` to its own binary log. When `Slave 2` changes from `Master` to `Slave 1` as its master, it may receive updates from `Slave 1` that it has already received from `Master`

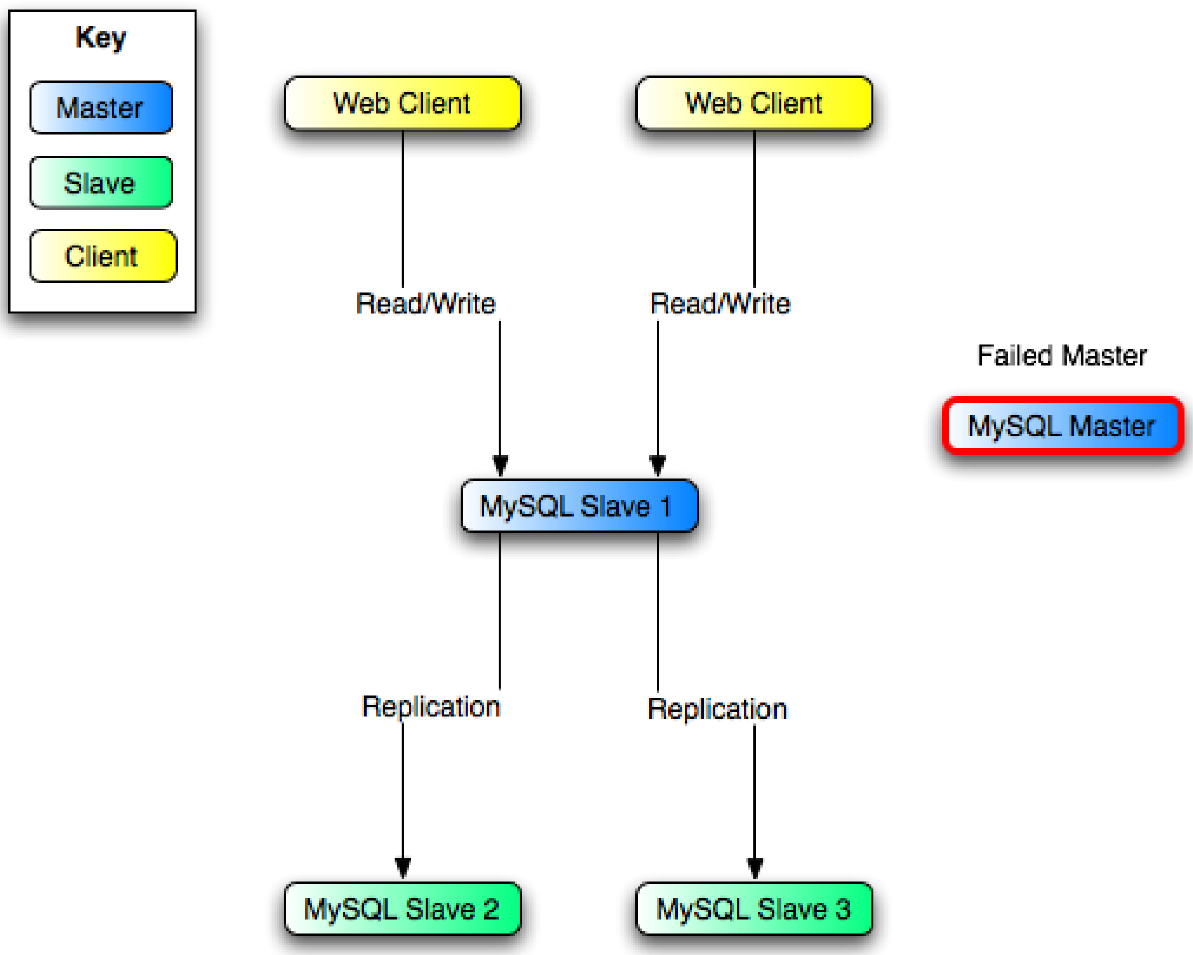
Make sure that all slaves have processed any statements in their relay log. On each slave, issue `STOP SLAVE IO_THREAD`, then check the output of `SHOW PROCESSLIST` until you see `Has read all relay log`. When this is true for all slaves, they can be reconfigured to the new setup. On the slave `Slave 1` being promoted to become the master, issue `STOP SLAVE` and `RESET MASTER`.

On the other slaves `Slave 2` and `Slave 3`, use `STOP SLAVE` and `CHANGE MASTER TO MASTER_HOST='Slave1'` (where `'Slave1'` represents the real host name of `Slave 1`). To use `CHANGE MASTER TO`, add all information about how to connect to `Slave 1` from `Slave 2` or `Slave 3` (*`user`*, *`password`*, *`port`*). In `CHANGE MASTER TO`, there is no need to specify the name of `Slave 1`'s binary log or binary log position to read from: We know it is the first binary log and position 4, which are the defaults for `CHANGE MASTER TO`. Finally, use `START SLAVE` on `Slave 2` and `Slave 3`.

Once the new replication is in place, you will then need to instruct each `Web Client` to direct their statements to `Slave 1`. From that point on, all updates statements sent by `Web Client` to `Slave 1` are written to the binary log of `Slave 1`, which then contains every update statement sent to `Slave 1` since `Master` died.

The resulting server structure is shown in Figure 2.5, “Redundancy using replication, after master failure”.

Figure 2.5. Redundancy using replication, after master failure



When `Master` is up again, you must issue on it the same `CHANGE MASTER TO` as that issued on `Slave 2` and `Slave 3`, so that `Master` becomes a slave of `S1` and picks up each `Web Client` writes that it missed while it was down.

To make `Master` a master again (because it is the most powerful machine, for example), use the preceding procedure as if `Slave 1` was unavailable and `Master` was to be the new master. During this procedure, do not forget to run `RESET MASTER` on `Master` before making `Slave 1`, `Slave 2`, and `Slave 3` slaves of `Master`. Otherwise, they may pick up old `Web Client` writes from before the point at which `Master` became unavailable.

Note that there is no synchronization between the different slaves to a master. Some slaves might be ahead of others. This means that the concept outlined in the previous example might not work. In practice, however, the relay logs of different slaves will most likely not be far behind the master, so it would work, anyway (but there is no guarantee).

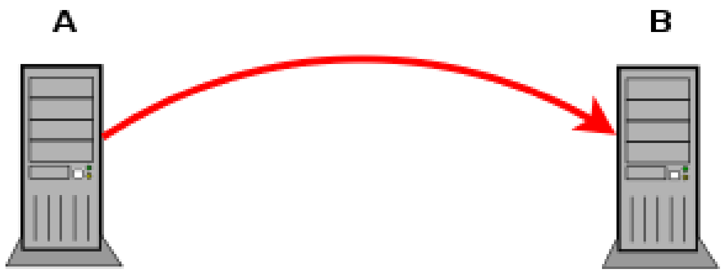
A good way to keep your applications informed as to the location of the master is by having a dynamic DNS entry for the master. With `bind` you can use `nsupdate` to dynamically update your DNS.

2.7. Upgrading Multi-Master Replication

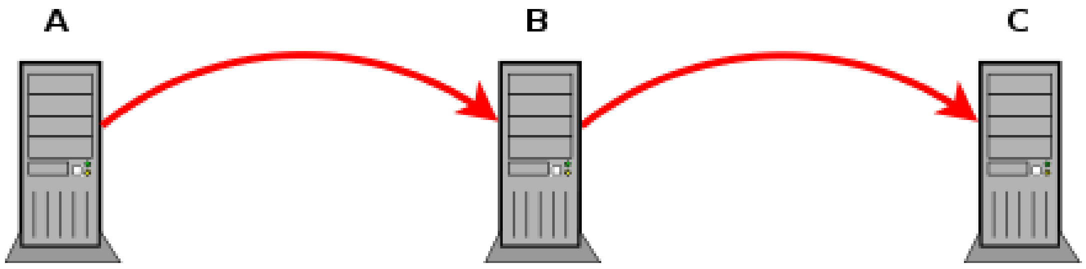
This section discusses how to upgrade the MySQL server software on several machines in a multi-master replication setup from an older version to a newer version of the software without taking the entire system offline. The procedure outlined here is intended to be illustrative and not necessarily to be followed exactly as written in all possible scenarios.

There are two sorts of configurations for replication involving multiple masters:

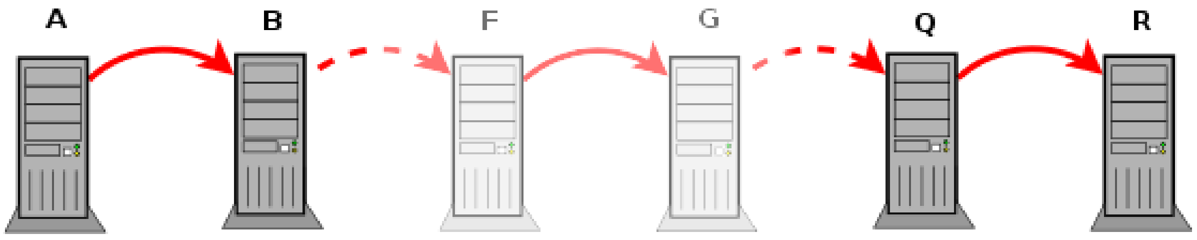
- **Linear replication.** In this type of setup, one or more masters replicates to a single slave. The simplest linear replication topology is shown here, where a single master A replicates to a single slave B:



Of greater interest are cases where we actually have multiple masters, such as when we have a chain of MySQL servers, some of which are acting as both masters and slaves. The following diagram depicts server A replicating to B, which in turn replicates to C; here, B acts as both a master and a slave:

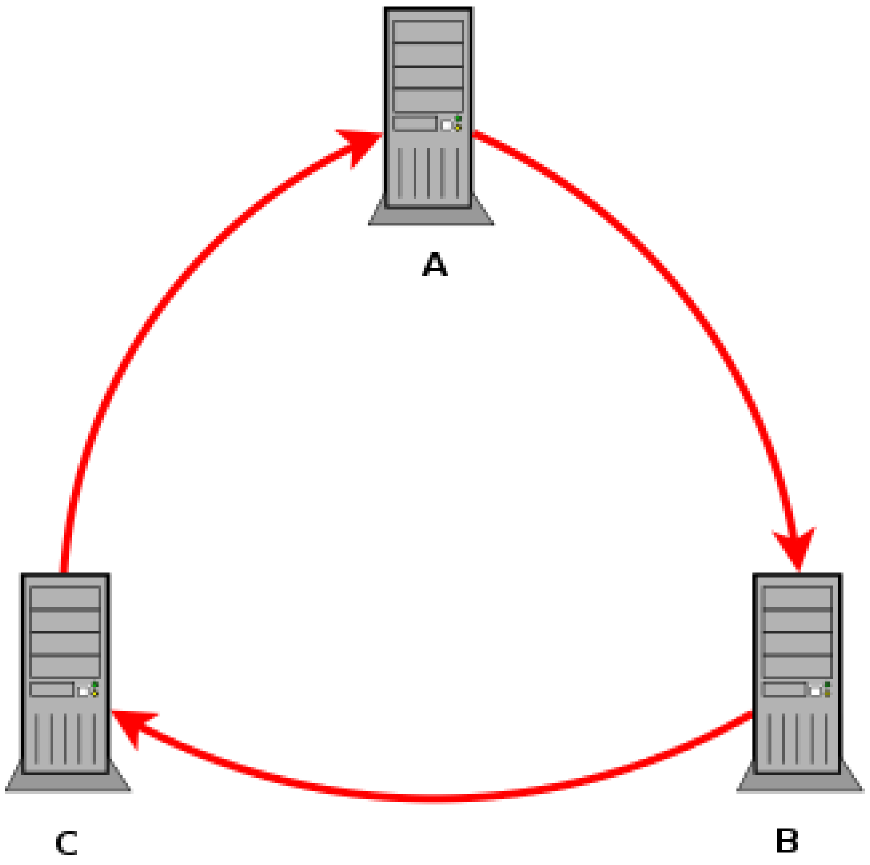


In this case, the procedure for performing a software upgrade can be developed from the simple principle “upgrade the slave first, then the master”. In other words, we should start by upgrading the server that acts only as a slave (C), then upgrading its master (B), and so on, until we reach the server acting as a master only (A), upgrade it, and so complete the process. This can easily be extended to cover an arbitrary number of MySQL servers, as shown here:



- **Circular replication.** In a circular replication setup, *each* MySQL server acts as both a master and a slave; thus, there is no “last” server which we can use as a starting point to apply “upgrade the slave first, then the master”. We therefore require a different approach to performing the upgrade, and it is for this reason that the rest of this section is devoted to a discussion of upgrading the MySQL server software on several hosts configured in a circular replication setup.

Basic scenario. Assume that we have three servers, A, B, and C, running MySQL version 6.0, replicating in a circle, as shown in this diagram:



Our objective is to upgrade, in turn, all three machines from one MySQL version (for example, MySQL 5.1) to a newer MySQL version (such as MySQL 6.0) without taking the system as a whole out of production. We start with server C, which acts as a slave of server B and a master to server A.

To upgrade this server, we need to perform the following steps:

1. **Stop C.** On C, execute the statement

   ```
   STOP SLAVE;
   ```

2. **Create a "marker" event on B.** Execute a statement on B that generates an event which is easily identified. For this example, we assume that there is no existing table named `marker` in the `test` database, and perform the following statements to create it:

   ```
   USE test;
   CREATE TABLE marker1 (col INT);
   ```

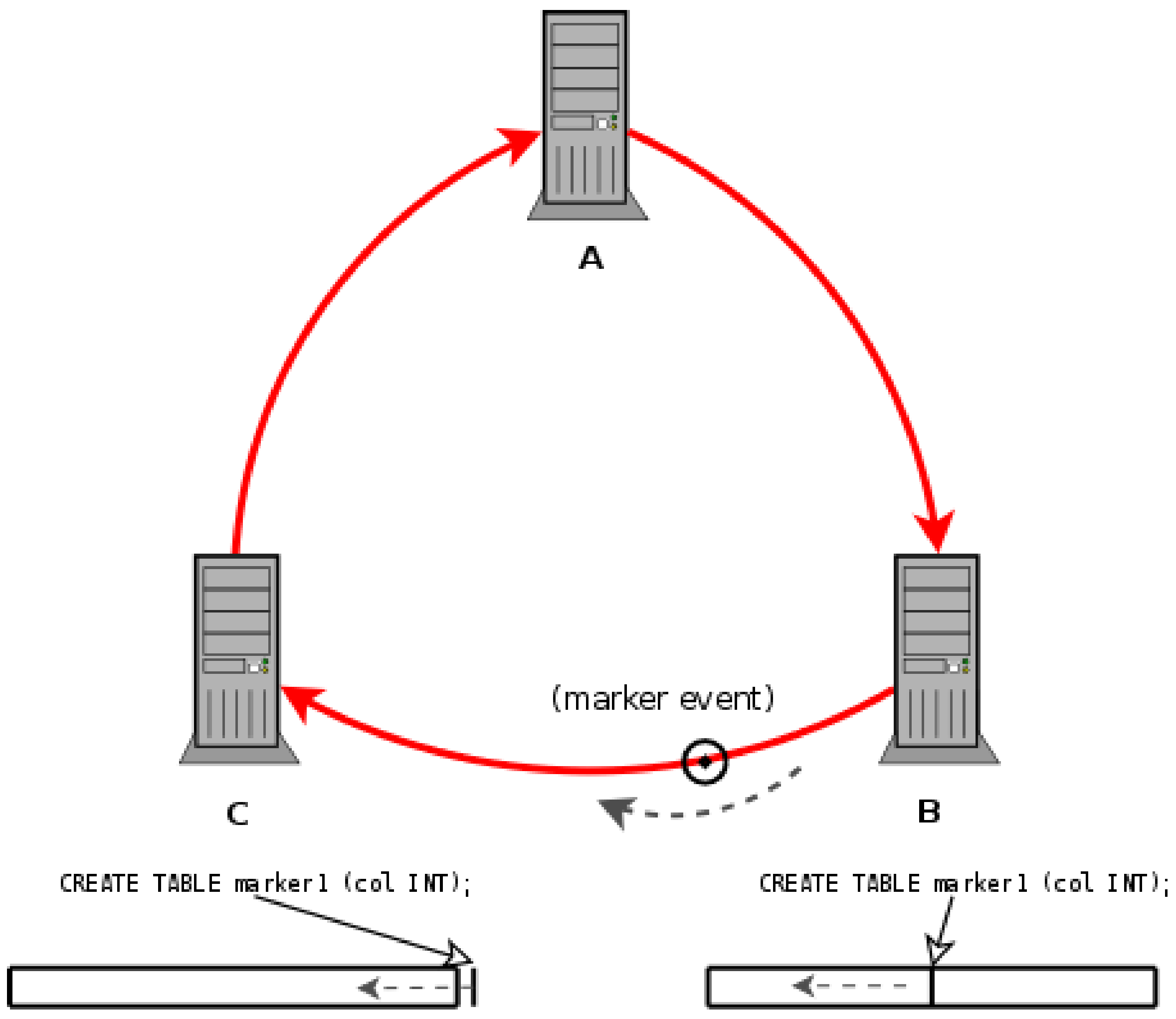
   The table schema is completely arbitrary; in fact, the statement is itself completely arbitrary. The only requirement is that we use an SQL statement that is unique and easily identifiable for use as the "marker".

3. **Find the position of the marker in the binary log.** This can be done by executing `SHOW BINLOG EVENTS` on B, then checking the `Info` column in the output for an event containing the "marker" statement. Note the values of the `Log_name` and `Pos` columns, which are needed for the next step, where we refer to these values as *`fileB`* and *`posB`*, respectively.

4. **Allow C to catch up to the marker.** Execute the following statements on C:

   ```
   START SLAVE UNTIL
       MASTER_LOG_FILE=fileB,
       MASTER_LOG_POS=posB;
   SELECT MASTER_POS_WAIT(fileB, posB);
   ```

   This causes C to execute any remaining events sent from B up to the point where the "marker" statement was issued, and then to stop. The place of the marker in the sequence of events flowing from B to C is illustrated here:


A
(marker event)
C
B
CREATE TABLE marker1 (col INT);
CREATE TABLE marker1 (col INT);

5. **Take server C offline.** Ensure that no further actions capable of updating the binary log can be taken on C:

   - Redirect any clients using C to A or B. This is best handled in application code. Additionally, you may wish to use the `SHOW PROCESSLIST` and `KILL` statements, as the MySQL `root` user or as another user with the `SUPER` privilege, to terminate any remaining client processes other than the one you are using to perform tasks on C relating to the software upgrade.

     You can prevent any application clients from reconnecting to C by executing the following statement as MySQL `root` (or another user having the `SUPER` privilege):

     ```
     SET @@GLOBAL.MAX_CONNECTIONS = 1;
     ```

     Once this has been done, only a single client, having the `SUPER` privilege, may connect to C. This works because `max_connections + 1` clients are allowed to connect to the server, with one of these connections being reserved for a client having the `SUPER` privilege. Therefore, when `max_connections` is equal to 1, and no other clients are connected, a maximum of 1 client *not* having `SUPER` may connect. However, a client not having the `SUPER` privilege cannot use the extra connection. This means that, when `max_connections` is `1` and a client having `SUPER` is already connected, no non-`SUPER` clients may connect to the server.

   - Force all tables to be read-only by executing the following statement:

     ```
     SET @@GLOBAL.READ_ONLY = ON;
     ```

     As an alternative, you can use the following statement, which is equivalent to the previous one:

```
SET @@GLOBAL.READ_ONLY = 1;
```

This places the server into “read-only” mode, which prevents any accidental changes to tables on C.

- Stop the MySQL Event Scheduler on server C by executing the following statement:

  ```
  SET @@GLOBAL.EVENT_SCHEDULER = OFF;
  ```

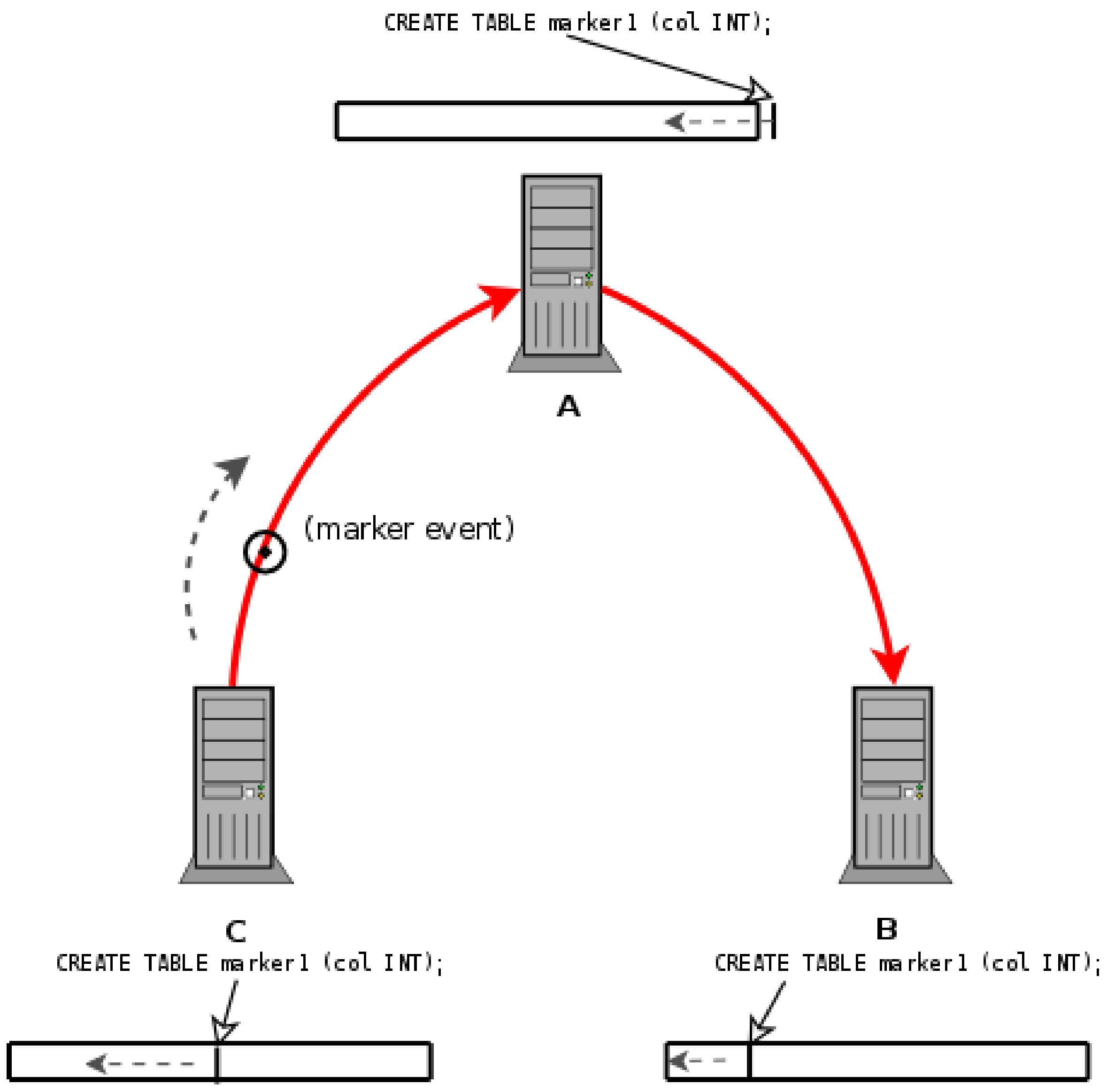
  This is necessary since the Event Scheduler can perform actions that result in writes to the binary log, which could cause the binary log on C to diverge from the binary logs on the other servers in unexpected ways.

6. **Find the end of the last binary log on C.** This can be accomplished by executing `SHOW MASTER STATUS` on C and noting the values shown in the `File` and `Position` columns of the output, which we show as *`fileC`* and *`posC`*, respectively, in the next step.

7. **Stop and synchronize slave A.** Execute `STOP SLAVE` on A. Then perform the following statements:

   ```
   START SLAVE UNTIL
       MASTER_LOG_FILE=fileC,
       MASTER_LOG_POS=posC;
   SELECT MASTER_POS_WAIT(fileC, posC);
   ```

   This causes any remaining unprocessed events up the marker event on C to be executed on A, and causes A to stop once this has been done. The propagation of the marker from server C to server A is shown here:


CREATE TABLE marker1 (col INT);
A
(marker event)
C
CREATE TABLE marker1 (col INT);
B
CREATE TABLE marker1 (col INT);

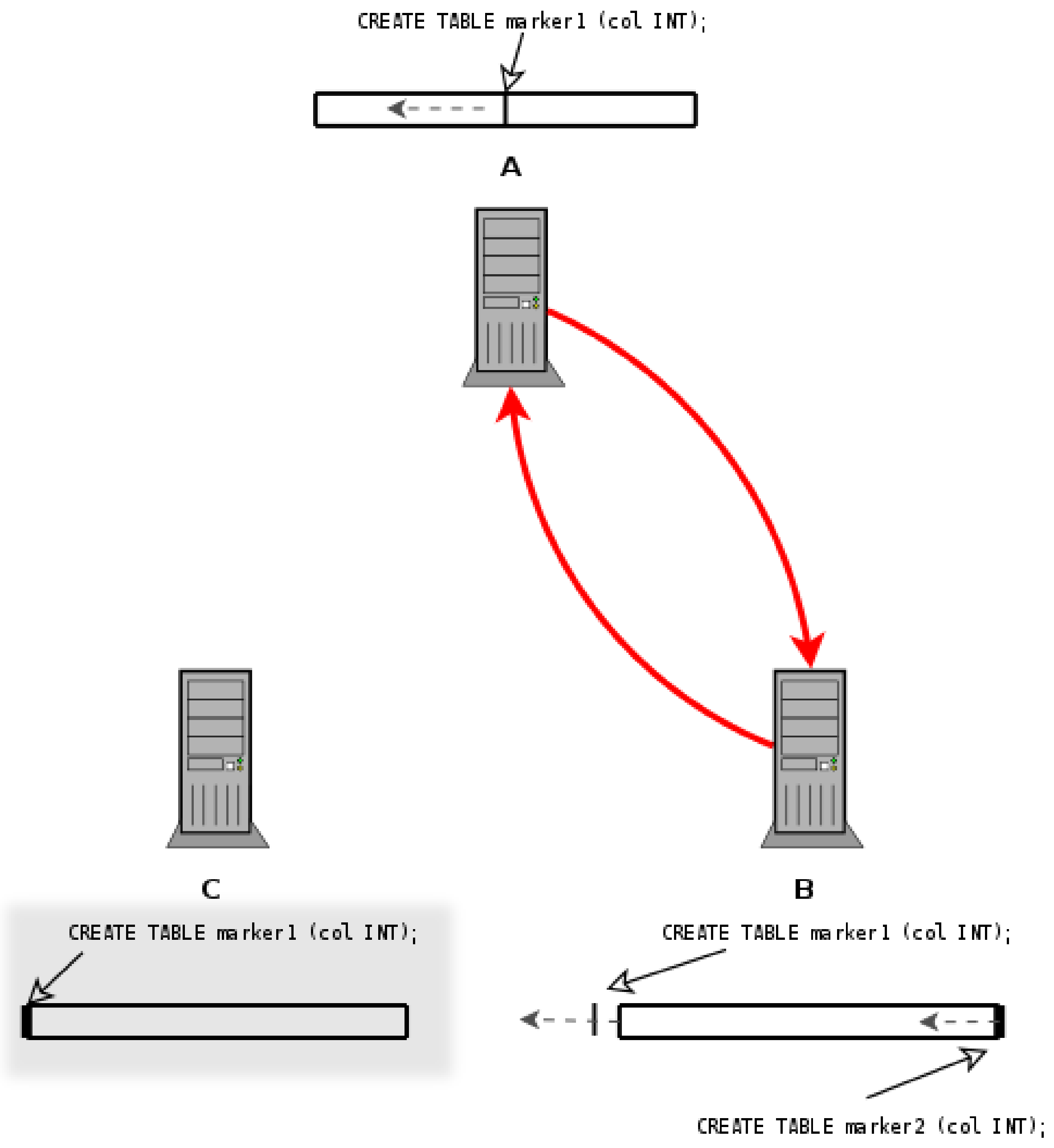
This is not the same marker as the previous one — in fact, the best “marker” to use here is the end of C's binary log.

8. **Start replication from B to A.** You can cause A to replicate from B instead of from C by issuing the following 2 statements on server A:

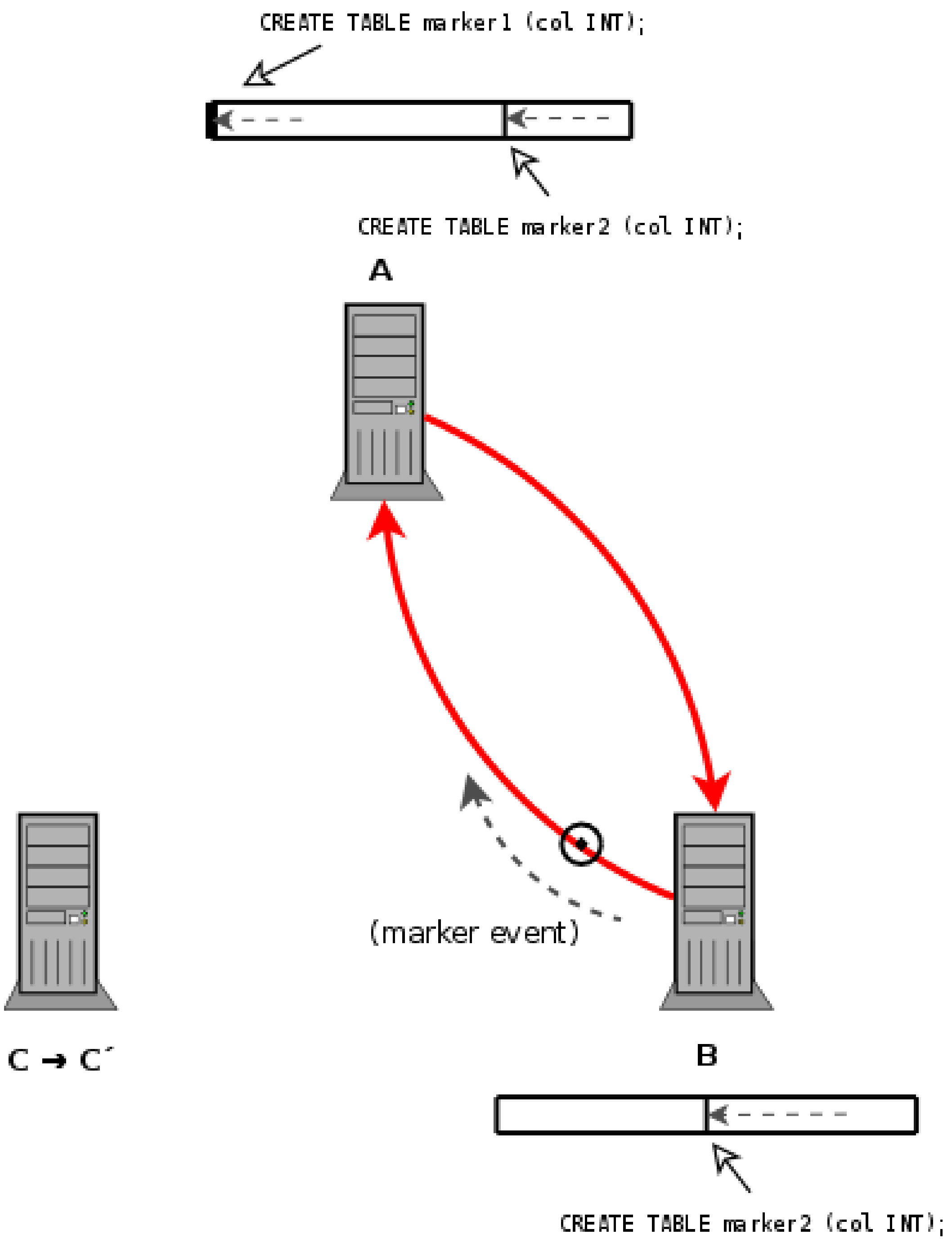
```
CHANGE MASTER TO
    MASTER_HOST=hostB,
    MASTER_LOG_FILE=fileB,
    MASTER_LOG_POS=posB;
START SLAVE;
```

In the first of these statements, `hostB` represents the host name or IP address for server B; `fileB` and `posB` are the same as determined for these values earlier

C is now isolated from the other two servers, which are now replicating to each other, as shown here:


CREATE TABLE marker1 (col INT);
A
C
CREATE TABLE marker1 (col INT);
B
CREATE TABLE marker1 (col INT);
CREATE TABLE marker2 (col INT);

9. **Upgrade C to C'.** Shut down C, and upgrade the MySQL software on C from version X to version Y:


CREATE TABLE marker1 (col INT);
CREATE TABLE marker2 (col INT);
A
(marker event)
C → C'
B
CREATE TABLE marker2 (col INT);

We refer to the upgraded server C as *C'*.

For general information about performing upgrades, see the *Upgrading MySQL* section of the *MySQL Manual* corresponding to the versions from which and to which you are upgrading.

10. **Start C' in offline mode.** Start server C', insuring that all its tables are in read-only mode, and that no MySQL clients (with the exception of a single connection from a superuser account) can connect to it. You can do this by starting `mysqld` with the options `--read_only --max_connections=1`. (For more information about these options, see Server System Variables.)

11. **Stop replicating from B to A.** Stop sending events from B to A, and ensure that A has executed all events sent to it from B:

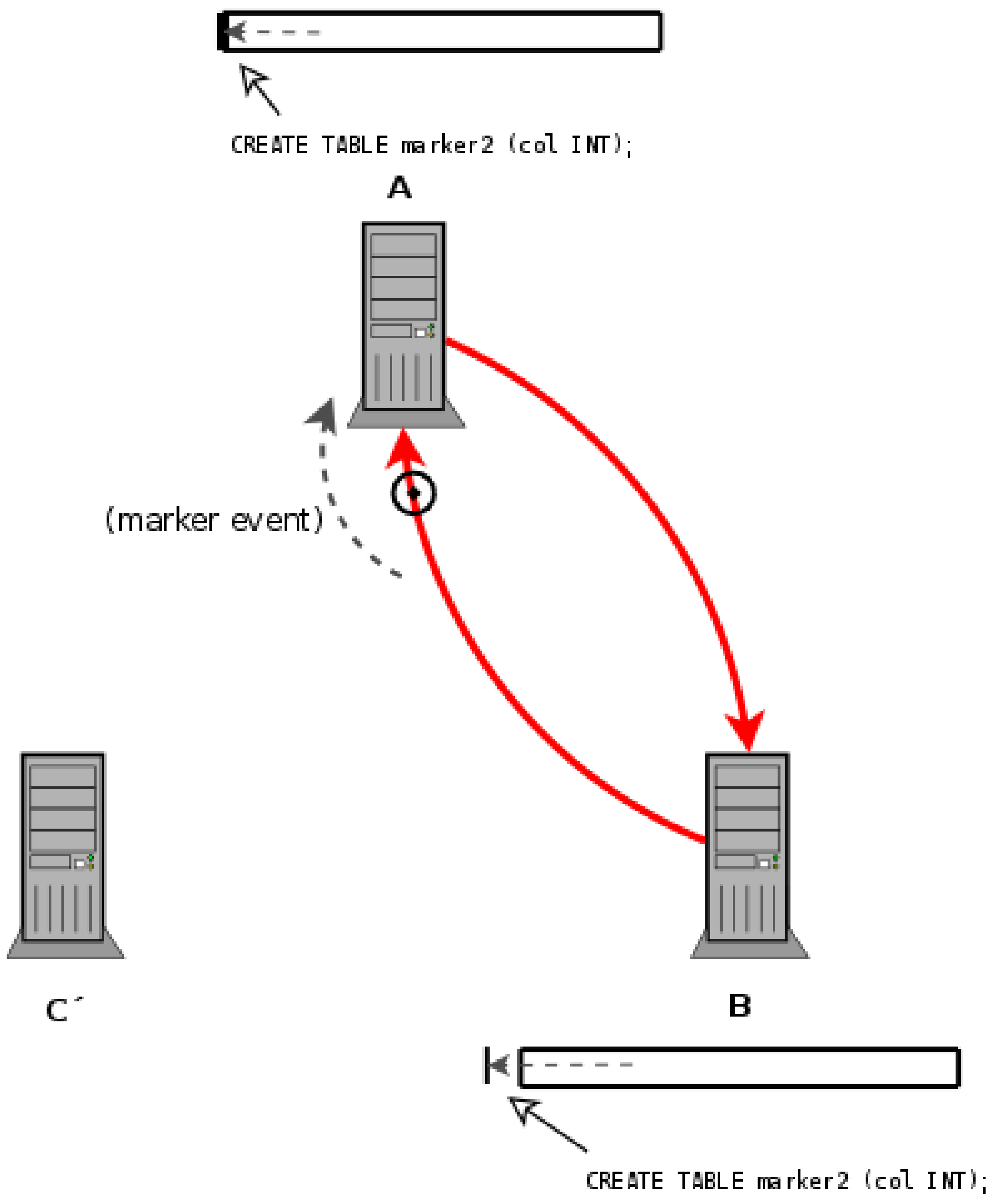
- Issue a `STOP SLAVE` on A
- Issue a marker statement on B, such as this one:

  ```
  CREATE TABLE test.marker2 (col INT);
  ```

  As with the previous marker statement, the type and any other aspects of the statement are completely arbitrary; the only requirement is that the statement must be uniquely identifiable.
- Use `SHOW BINLOG EVENTS` on B to find the binary log file and position where the marker event was recorded, as described previously. We use *`fileB'`* and *`posB'`* to denote these in the next item.
- Start server A and synchronize it with B by issuing the following statements on A:

  ```
  START SLAVE UNTIL
      MASTER_LOG_FILE=fileB',
      MASTER_LOG_POS=posB';
  SELECT MASTER_POS_WAIT(fileB', posB');
  ```

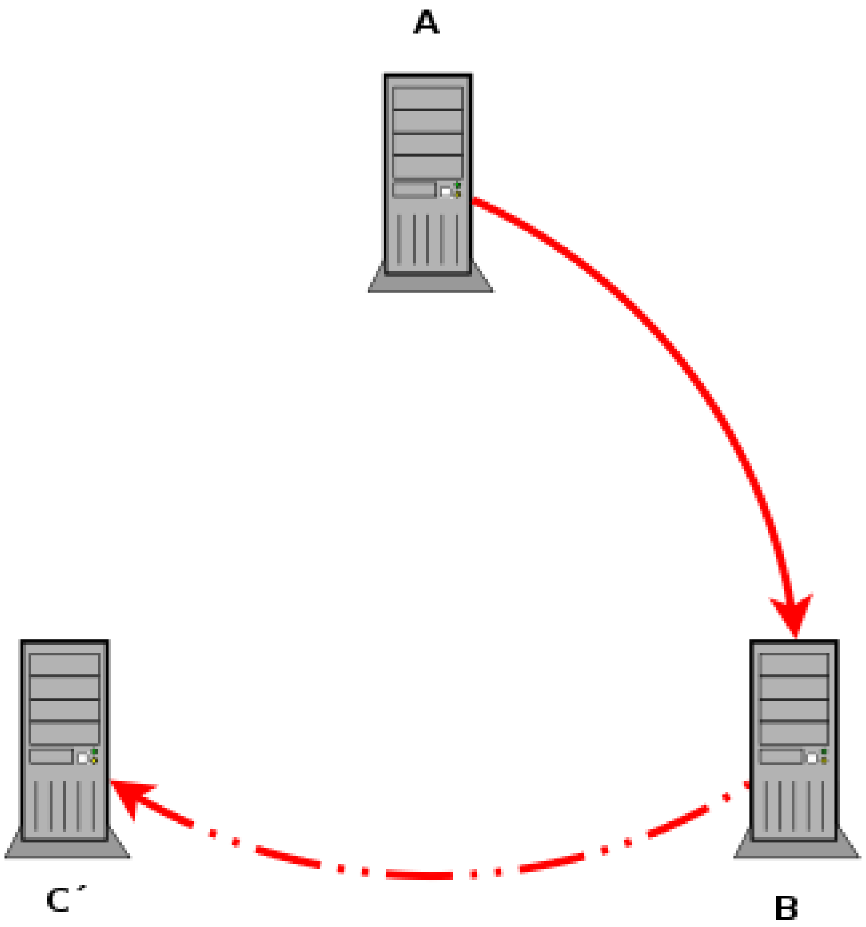
  Once A has executed all events up to and including the second marker event, it stops, as shown here:


CREATE TABLE marker2 (col INT);
A
(marker event)
C´
B
CREATE TABLE marker2 (col INT);

12. **Start replicating from B to C'.** Start sending events from B to C' and executing them on C' (indicated by the dotted line in the next diagram), ensuring that the first event not sent to A is the first event sent to C'. You can do this by issuing the following statements on C':

    ```
    SET @@GLOBAL.READ_ONLY = OFF;
    CHANGE MASTER TO
        MASTER_HOST=hostB,
        MASTER_LOG_FILE=fileB',
        MASTER_LOG_POS=posB';
    START SLAVE;
    ```

    Replication now occurs as shown here:



13. **Start replicating from C' to A.** This can be done as follows:

    - Locate the file and position of the second marker event in the binary log on server C'. This can be found by issuing `SHOW BINLOG EVENTS` on C' as previously described.

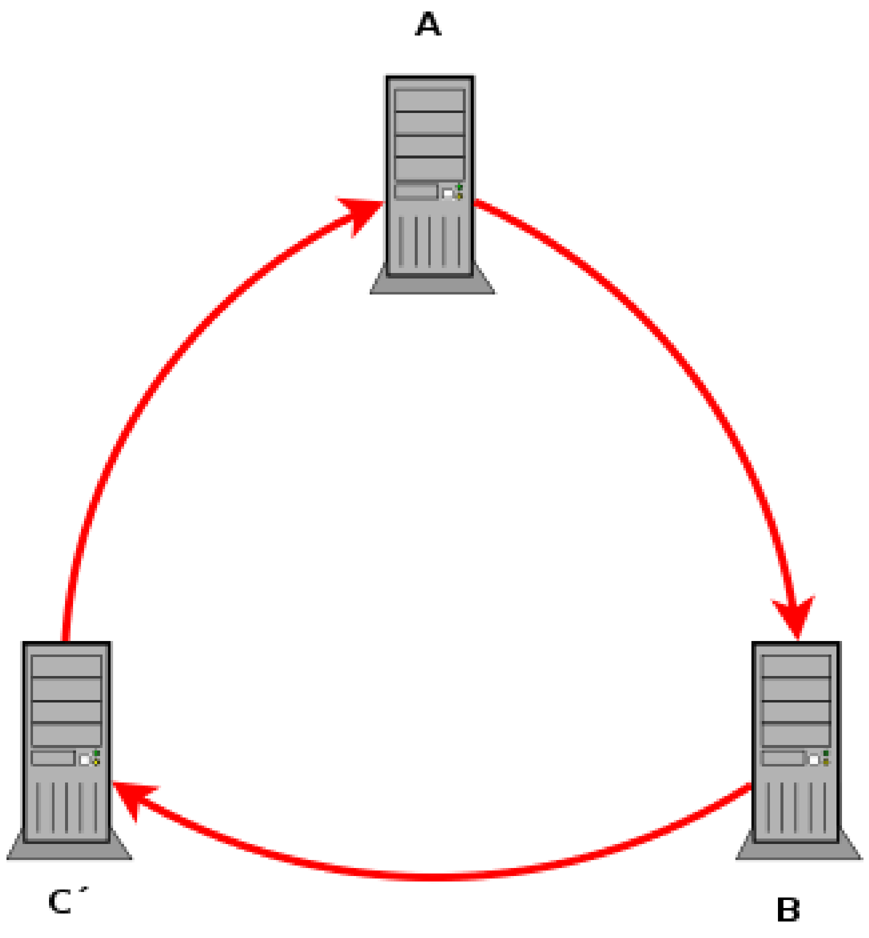
      We denote the file and position within this file as *`fileC'`* and *`posC'`*, respectively.

    - Start replication on A from this point by issuing the following statements, where *`hostC'`* represents the host name or IP address of server C', and *`fileC'`* and *`posC'`* are defined as stated in the previous item:

      ```
      CHANGE MASTER TO
          MASTER_HOST=hostC',
          MASTER_LOG_FILE=fileC',
          MASTER_LOG_POS=posC';
      START SLAVE;
      ```

14. **Return server C to online status.** This can be done by setting `@@GLOBAL.MAX_CONNECTIONS` to an appropriate value greater than `1`, thereby once again permitting regular clients not having the `SUPER` privilege to connect.

At this point, the original replication topology has been restored, and all is as before, except that server C running MySQL version X has been upgrade to C' running MySQL version Y, as shown here:



You can now complete the software upgrade process by repeating the steps shown previously for servers A and B, each in turn.

2.8. Setting Up Replication Using SSL

Setting up replication using an SSL connection is similar to setting up a server and client using SSL. You will need to obtain (or create) a suitable security certificate that you can use on the master, and a similar certificate (from the same certificate authority) on each slave.

To use SSL for encrypting the transfer of the binary log required during replication you must first set up the master to support SSL network connections. If the master does not support SSL connections (because it has not been compiled or configured for SSL), then replication through an SSL connection will not be possible.

For more information on setting up a server and client for SSL connectivity, see Using SSL Connections.

To enable SSL on the master you will need to create or obtain suitable certificates and then add the following configuration options to the master's configuration within the `mysqld` section:

```
ssl-ca=cacert.pem
ssl-cert=server-cert.pem
ssl-key=server-key.pem
```

> **Note**
>
> You should use full path to specify the location of your certificate files.

The options are as follows:

- `ssl-ca` identifies the Certificate Authority (CA) certificate.

- `ssl-cert` identifies the server public key. This can be sent to the client and authenticated against the CA certificate that it has.
- `ssl-key` identifies the server private key.

On the slave, you have two options available for setting the SSL information. You can either add the slaves certificates to the `client` section of the slave configuration file, or you can explicitly specify the SSL information using the `CHANGE MASTER TO` statement.

Using the former option, add the following lines to the `client` section of the slave configuration file:

```
[client]
ssl-ca=cacert.pem
ssl-cert=server-cert.pem
ssl-key=server-key.pem
```

Restart the slave server, using the `--skip-slave` to prevent the slave from connecting to the master. Use `CHANGE MASTER TO` to specify the master configuration, using the `master_ssl` option to enable SSL connectivity:

```
mysql> CHANGE MASTER TO \
    MASTER_HOST='master_hostname', \
    MASTER_USER='replicate', \
    MASTER_PASSWORD='password', \
    MASTER_SSL=1;
```

To specify the SSL certificate options during the `CHANGE MASTER TO` command, append the SSL options:

```
CHANGE MASTER TO \
      MASTER_HOST='master_hostname', \
      MASTER_USER='replicate', \
      MASTER_PASSWORD='password', \
      MASTER_SSL=1, \
      MASTER_SSL_CA = 'ca_file_name', \
      MASTER_SSL_CAPATH = 'ca_directory_name', \
      MASTER_SSL_CERT = 'cert_file_name', \
      MASTER_SSL_KEY = 'key_file_name';
```

Once the master information has been updated, start the slave replication process:

```
mysql> START SLAVE;
```

You can use the `SHOW SLAVE STATUS` to confirm that SSL connection has been completed.

For more information on the `CHANGE MASTER TO` syntax, see `CHANGE MASTER TO` Syntax.

If you want to enforce SSL connections to be used during replication, then create a user with the `REPLICATION SLAVE` privilege and use the `REQUIRE_SSL` option for that user. For example:

```
mysql> GRANT REPLICATION SLAVE ON *.*
    -> TO 'repl'@'%.mydomain.com' IDENTIFIED BY 'slavepass' REQUIRE SSL;
```

2.9. Semisynchronous Replication

MySQL 6.0 supports an interface to semisynchronous replication in addition to the built-in asynchronous replication. This section discusses what semisynchronous replication is and how it works. The following sections cover the adminstrative interface to semisynchronous replication and how to install, configure, and monitor it.

MySQL replication by default is asynchronous. The master writes events to its binary log but does not know whether or when a slave has retrieved and processed them. With asynchronous replication, if the master crashes, transactions that it has committed might not have been transmitted to any slave. Consequently, failover from master to slave in this case may result in failover to a server that is missing transactions relative to the master.

As of MySQL 6.0.8, semisynchronous replication can be used instead:

- A slave indicates whether it is semisynchronous-capable when it connects to the master.
- If semisynchronous replication is enabled on the master side and there is at least one semisynchronous slave, a thread that performs a transaction commit on the master blocks after the commit is done and waits until at least one semisynchronous slave acknowledges that it has received all events for the transaction, or until a timeout occurs.

- The slave acknowledges receipt of a transaction's events only after the events have been written to its relay log and flushed to disk.
- If a timeout occurs without any slave having acknowledged the transaction, the master reverts to asynchronous replication. When at least one semisynchronous slave catches up, the master returns to semisynchronous replication.
- Semisynchronous replication must be enabled on both the master and slave sides. If semisynchronous replication is disabled on the master, or enabled on the master but on no slaves, the master uses asynchronous replication.

While the master is blocking (waiting for acknowledgment from a slave after having performed a commit), it does not return to the session that performed the transaction. When the block ends, the master returns to the session, which then can proceed to execute other statements. At this point, the transaction has committed on the master side, and receipt of its events has been acknowledged by at least one slave.

Blocking also occurs after rollbacks that are written to the binary log, which occurs when a transaction that modifies non-transactional tables is rolled back. The rolled-back transaction is logged even though it has no effect for transactional tables because the modifications to the non-transactional tables cannot be rolled back and must be sent to slaves.

For statements that do not occur in transactional context (that is, when no transaction has been started with `START TRANSACTION` or `SET autocommit = 0`), autocommit is enabled and each statement commits implicitly. With semisynchronous replication, the master blocks after committing each such statement, just as it does for explicit transaction commits.

To understand what the “semi” in “semisynchronous replication” means, compare it with asynchronous and fully synchronous replication:

- With asynchronous replication, the master writes events to its binary log and slaves request them when they are ready. There is no guarantee that any event will ever reach any slave.
- With fully synchronous replication, when a master commits a transaction, all slaves also will have committed the transaction before the master returns to the session that performed the transaction. The drawback of this is that there might be a lot of delay to complete a transaction.
- Semisynchronous replication falls between asynchronous and fully synchronous replication. The master waits after commit only until at least one slave has received and logged the events. It does not wait for all slaves to acknowledge receipt, and it requires only receipt, not that the events have been fully executed and committed on the slave side.

Compared to asynchronous replication, semisynchronous replication provides improved data integrity. When a commit returns successfully, it is known that the data exists in at least two places (on the master and at least one slave). If the master commits but a crash occurs while the master is waiting for acknowledgment from a slave, it is possible that the transaction may not have reached any slave.

Semisynchronous replication does have some performance impact because commits are slower due to the need to wait for slaves. This is the tradeoff for increased data integrity. The amount of slowdown is at least the TCP/IP roundtrip time to send the commit to the slave and wait for the acknowledgment of receipt by the slave. This means that semisynchronous replication works best for close servers communicating over fast networks, and worst for distant servers communicating over slow networks.

2.9.1. Semisynchronous Replication Administrative Interface

The administrative interface to semisynchronous replication has several components:

- Two plugins implement semisynchronous capability. There is one plugin for the master side and one for the slave side.
- System variables control plugin behavior:
  - `rpl_semi_sync_master_enabled`

    Controls whether semisynchronous replication is enabled on the master. To enable or disable the plugin, set this variable to 1 or 0, respectively. The default is 1.
  - `rpl_semi_sync_master_timeout`

    A value in seconds that controls how long the master waits on a commit for acknowledgment from a slave before timing out and reverting to asynchronous replication. The default value is 10 seconds.
  - `rpl_semi_sync_slave_enabled`

    Similar to `rpl_semi_sync_master_enabled`, but controls the slave plugin.

- Status variables enable semisynchronous replication monitoring:
  - `Rpl_semi_sync_master_clients`

    The number of semisynchronous slaves.
  - `Rpl_semi_sync_master_status`

    Whether semisynchronous replication currently is operational on the master. The value is 1 if the plugin has been enabled and a commit acknowledgment has not occurred. It is 0 if the plugin is not enabled or the master has fallen back to asynchronous replication due to commit acknowledgment timeout.
  - `Rpl_semi_sync_master_no_tx`

    The number of commits that were not acknowledged successfully by a slave.
  - `Rpl_semi_sync_master_yes_tx`

    The number of commits that were acknowledged successfully by a slave.
  - `Rpl_semi_sync_slave_status`

    Whether semisynchronous replication currently is operational on the slave. This is 1 if the plugin has been enabled and the slave I/O thread is running, 0 otherwise.

The system and status variables are available only if the appropriate master or slave plugin has been installed with `INSTALL PLUGIN`.

2.9.2. Semisynchronous Replication Installation and Configuration

Semisynchronous replication is implemented using plugins, so the plugins must be installed into the server to make them available. After a plugin has been installed, you control it by means of the system variables associated with it. These system variables are unavailable until the associated plugin has been installed.

To use semisynchronous replication, the following requirements must be satisfied:

- MySQL 6.0.8 or higher must be installed.
- The capability of installing plugins requires a MySQL server that supports dynamic loading. To verify this, check that the value of the `have_dynamic_loading` system variable is `YES`. Binary distributions should support dynamic loading. If you compile MySQL from source, do not configure the source distribution with the `--with-mysqld-ldflags=-all-static` option.
- Replication must already be working. For information on creating a master/slave relationship, see Section 1.1, "How to Set Up Replication".

To set up semisynchronous replication, use the following instructions. The `INSTALL PLUGIN`, `SET GLOBAL`, `STOP SLAVE`, and `START SLAVE` statements mentioned here require the `SUPER` privilege.

Obtain the semisynchronous replication plugins. They are not included with MySQL distributions. Instead, they are distributed as a separate component. The initial preview release may be obtained from http://downloads.mysql.com/forge/replication_preview.

Currently, the plugins are available only for Linux. Other platforms are is not yet supported.

Unpack the component distribution, which contains files for the master side and the slave side.

Install the component files in the plugin directory of the appropriate server. Install the `libsemisync_master*` files in the plugin directory of the master server. Install the `libsemisync_slave*` files in the plugin directory of each slave server. The location of the plugin directory is available as the value of the server's `plugin_dir` system variable.

To load the plugins, use the `INSTALL PLUGIN` statement on the master and on each slave that is to be semisynchronous.

On the master:

```
mysql> INSTALL PLUGIN rpl_semi_sync_master SONAME 'libsemisync_master.so';
```

On each slave:

```
mysql> INSTALL PLUGIN rpl_semi_sync_slave SONAME 'libsemisync_slave.so';
```

The preceding commands use a plugin file name suffix of `.so`. A different suffix might apply on your system. If you are not sure about the plugin file name, look for the plugins in the server's plugin directory.

To see which plugins are installed, use the `SHOW PLUGINS` statement, or query the `INFORMATION_SCHEMA.PLUGINS` table.

After a semisynchronous replication plugin has been installed, it is enabled by default. The plugins must be enabled both on the master side and the slave side to enable semisynchronous replication. If only one side is enabled, replication will be asynchronous.

To control an installed plugin, set the appropriate system variables. You can set these variables at runtime using `SET GLOBAL`, or at server startup on the command line or in an option file.

At runtime, these master-side system variables are available:

```
mysql> SET GLOBAL rpl_semi_sync_master_enabled = {0|1};
mysql> SET GLOBAL rpl_semi_sync_master_timeout = N;
```

On the slave side, this system variable is available:

```
mysql> SET GLOBAL rpl_semi_sync_slave_enabled = {0|1};
```

For `rpl_semi_sync_master_enabled` or `rpl_semi_sync_slave_enabled`, the value should be 1 to enable semisynchronous replication or 0 to disable it. By default, these variables are set to 1.

For `rpl_semi_sync_master_timeout`, the value *`N`* is given in seconds. The default value is 10.

If you enable semisynchronous replication on a slave at runtime, you must also start the slave I/O thread (stopping it first if it is already running) to cause the slave to connect to the master and register as a semisynchronous slave:

```
mysql> STOP SLAVE IO_THREAD; START SLAVE IO_THREAD;
```

If the I/O thread is already running and you do not restart it, the slave continues to use asynchronous replication.

At server startup, the variables that control semisynchronous replication can be set as command-line options or in an option file. A setting listed in an option file takes effect each time the server starts. For example, you can set the variables in `my.cnf` files on the master and slave sides as follows.

On the master:

```
[mysqld]
rpl_semi_sync_master_enabled=1
rpl_semi_sync_master_timeout=10
```

On each slave:

```
[mysqld]
rpl_semi_sync_slave_enabled=1
```

2.9.3. Semisynchronous Replication Monitoring

The plugins for the semisynchronous replication capability expose several system and status variables that you can examine to determine its configuration and operational state.

The system variable reflect how semisynchronous replication is configured. To check their values, use `SHOW VARIABLES`:

```
mysql> SHOW VARIABLES LIKE 'rpl_semi_sync%';
```

The status variables enable you to monitor the operation of semisynchronous replication. To check their values, use `SHOW STATUS`:

```
mysql> SHOW STATUS LIKE 'Rpl_semi_sync%';
```

When the master switches between asynchronous or semisynchronous replication due to commit-blocking timeout or a slave catching up, it sets the value of the `Rpl_semi_sync_master_status` status variable appropriately. Automatic fallback from semisynchronous to asynchronous replication on the master means that it is possible for the `rpl_semi_sync_master_enabled` system variable to have a value of 1 on the master side even when semisynchronous replication is in fact not operational at the moment. You can monitor the `Rpl_semi_sync_master_status` status variable to determine whether the master currently is using asynchronous or semisynchronous replication.

To see how many semisynchronous slaves are connected, check `Rpl_semi_sync_master_clients`.

The number of commits that have been acknowledged successfully or unsucessfully by slaves are indicated by the `Rpl_semi_sync_master_yes_tx` and `Rpl_semi_sync_master_no_tx` variables.

On the slave side, `Rpl_semi_sync_slave_status` indicates whether semisynchronous replication currently is operational.

Chapter 3. Replication Notes and Tips

3.1. Replication Features and Issues

The following sections provide information about what is supported and what is not in MySQL replication, and about specific issues and situations that may occur when replicating certain statements.

Statement-based replication depends on compatibility at the SQL level between the master and slave. In others, successful SBR requires that any SQL features used be supported by both the master and the slave servers. For example, if you use a feature on the master server that is available only in MySQL 6.0 (or later), you cannot replicate to a slave that uses MySQL 5.1 (or earlier).

Such incompatibilities also can occur within a release series when using pre-production releases of MySQL. For example, the `SLEEP()` function is available beginning with MySQL 5.0.12. If you use this function on the master, you cannot replicate to a slave that uses MySQL 5.0.11 or earlier.

For this reason, we recommend that you use Generally Available (GA) releases of MySQL for statement-based replication in a production setting, since we do not introduce new SQL statements or change their behavior within a given release series once that series reaches GA release status.

If you are planning to use statement-based replication between MySQL 6.0 and a previous MySQL release series, it is also a good idea to consult the edition of the *MySQL Reference Manual* corresponding to the earlier release series for information regarding the replication characteristics of that series.

With MySQL's classic statement-based replication, there may be issues with replicating stored routines or triggers. You can avoid these issues by using MySQL's row-based replication instead. For a detailed list of issues, see Binary Logging of Stored Programs. For more information about row-based replication, see Section 1.2, “Replication Formats”.

For additional information specific to replication and `InnoDB`, see `InnoDB` and MySQL Replication. For information relating to replication with MySQL Cluster, see MySQL Cluster Replication.

3.1.1. Replication and `AUTO_INCREMENT`

Statement-based replication of `AUTO_INCREMENT`, `LAST_INSERT_ID()`, and `TIMESTAMP` values is done correctly, subject to the following exceptions:

- An insert into an `AUTO_INCREMENT` column caused by a stored routine or trigger running on a master that uses MySQL 5.0.60 or earlier does not replicate correctly to a slave running MySQL 5.1.12 through 5.1.23 (inclusive). (Bug#33029)
- Table-level `AUTO_INCREMENT` option values were not replicated correctly prior to MySQL 6.0.10. (Bug#41986)
- Adding an `AUTO_INCREMENT` column to a table with `ALTER TABLE` might not produce the same ordering of the rows on the slave and the master. This occurs because the order in which the rows are numbered depends on the specific storage engine used for the table and the order in which the rows were inserted. If it is important to have the same order on the master and slave, the rows must be ordered before assigning an `AUTO_INCREMENT` number. Assuming that you want to add an `AUTO_INCREMENT` column to the table `t1`, the following statements produce a new table `t2` identical to `t1` but with an `AUTO_INCREMENT` column:

```
CREATE TABLE t2 LIKE t1;
ALTER TABLE t2 ADD id INT AUTO_INCREMENT PRIMARY KEY;
INSERT INTO t2 SELECT * FROM t1 ORDER BY col1, col2;
```

  This assumes that the table `t1` has columns `col1` and `col2`.

  Important

  To guarantee the same ordering on both master and slave, *all* columns of `t1` must be referenced in the `ORDER BY` clause.

  The instructions just given are subject to the limitations of `CREATE TABLE ... LIKE`: Foreign key definitions are ignored, as are the `DATA DIRECTORY` and `INDEX DIRECTORY` table options. If a table definition includes any of those characteristics, create `t2` using a `CREATE TABLE` statement that is identical to the one used to create `t1`, but with the addition of the `AUTO_INCREMENT` column.

  Regardless of the method used to create and populate the copy having the `AUTO_INCREMENT` column, the final step is to drop the original table and then rename the copy:

```
DROP t1;
ALTER TABLE t2 RENAME t1;
```

See also Problems with `ALTER TABLE`.

3.1.2. Replication and Character Sets

The following applies to replication between MySQL servers that use different character sets:

1. If the master uses MySQL 4.1, you must *always* use the same *global* character set and collation on the master and the slave, regardless of the MySQL version running on the slave. (These are controlled by the `--character-set-server` and `--collation-server` options.) Otherwise, you may get duplicate-key errors on the slave, because a key that is unique in the master character set might not be unique in the slave character set. Note that this is not a cause for concern when master and slave are both MySQL 5.0 or later.

2. If the master is older than MySQL 4.1.3, the character set of any client should never be made different from its global value because this character set change is not known to the slave. In other words, clients should not use `SET NAMES`, `SET CHARACTER SET`, and so forth. If both the master and the slave are 4.1.3 or newer, clients can freely set session values for character set variables because these settings are written to the binary log and so are known to the slave. That is, clients can use `SET NAMES` or `SET CHARACTER SET` or can set variables such as `collation_client` or `collation_server`. However, clients are prevented from changing the *global* value of these variables; as stated previously, the master and slave must always have identical global character set values. This is true whether you are using statement-based or row-based replication.

3. If you have databases on the master with character sets that differ from the global `character_set_server` value, you should design your `CREATE TABLE` statements so that tables in those databases do not implicitly rely on the database default character set. A good workaround is to state the character set and collation explicitly in `CREATE TABLE` statements.

3.1.3. Replication of `CREATE TABLE ... SELECT` Statements

This section discusses the rules that are applied when a `CREATE TABLE ... SELECT` statement is replicated.

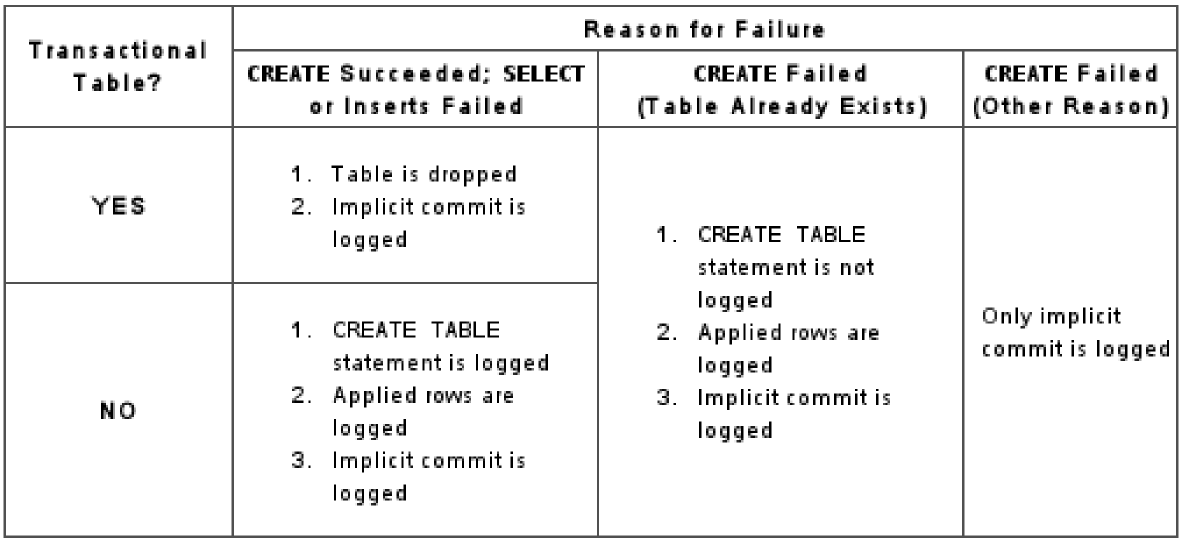
> **Note**
>
> `CREATE TABLE ... SELECT` always performs an implicit commit (Statements That Cause an Implicit Commit).

Statement succeeds. If the `CREATE TABLE ... SELECT` statement succeeds on the master, then it is replicated as follows:

- **`STATEMENT` or `MIXED` format.** The `CREATE TABLE ... SELECT` statement is itself replicated.
- **`ROW` format.** The statement is replicated as a `CREATE TABLE` statement followed by a series of `binwrite` events (that is, binary inserts).

Statement fails. The failure of a `CREATE TABLE ... SELECT` is handled according to the following criteria:

- **No `IF NOT EXISTS` option.** If the `CREATE TABLE ... SELECT` does not contain an `IF NOT EXISTS` option, then the statement has no effect. However, the implicit commit caused by the statement is logged. This is true regardless of the replication format, storage engine used, and the reason for which the statement failed.
- **Statement uses `IF NOT EXISTS`.** If the `CREATE TABLE ... SELECT` statement includes the `IF NOT EXISTS` option and fails, the failure is handled according to the replication format. If the row-based format is in use, the action taken depends additionally on whether or not the table to be created uses a transactional or non-transactional storage engine, and on the reason for the failure:
  - **`STATEMENT` or `MIXED` format.** When using statement-based or mixed-format replication, the `CREATE TABLE IF NOT EXISTS ... SELECT` is logged with an error.
  - **`ROW` format.** When row-based replication is used, failure of a `CREATE TABLE ... SELECT` that includes `IF NOT EXISTS` is handled differently depending on the reason for the failure, as shown in the following diagram:



Transactional Table?	Reason for Failure		
	CREATE Succeeded; SELECT or Inserts Failed	CREATE Failed (Table Already Exists)	CREATE Failed (Other Reason)
YES	1. Table is dropped 2. Implicit commit is logged	1. CREATE TABLE statement is not logged 2. Applied rows are logged 3. Implicit commit is logged	Only implicit commit is logged
NO	1. CREATE TABLE statement is logged 2. Applied rows are logged 3. Implicit commit is logged		

3.1.4. Replication with Differing Tables on Master and Slave

Source and target tables for replication do not have to be identical. A table on the master can have more or fewer columns than the slave's copy of the table. In addition — subject to certain conditions — corresponding table columns on the master and the slave can use different data types.

In all cases where the source and target tables do not have identical definitions, the following must be true in order for replication to work:

- You must be using row-based replication. (Using `MIXED` for the binary logging format does not work.)
- The database and table names must be the same on both the master and the slave.

Additional conditions are discussed (and examples provided) in the following two sections.

3.1.4.1. Replication with More Columns on Master or Slave

You can replicate a table from the master to the slave such that the master's copy of the table and the slave's copy of the table do not have the same number of columns, subject to the following conditions:

- Each “extra” column in the version of the table having more columns must have a default value.

  Note

  A column's default value is determined by a number of factors, including its type, whether it is defined with a `DEFAULT` option, whether it is declared as `NULL`, and the server SQL mode in effect at the time of its creation; see Data Type Default Values), for more information.

- Matching columns must be defined in the same order on both the master and the slave.
- Any additional columns must be defined following the matching columns.

In addition, when the slave's copy of the table has more columns than the master's copy, then each matching column must use the same data type.

Examples. The following examples illustrate some valid and invalid table definitions:

- **More columns on the master.** The following table definitions are valid:

```
master> CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
slave>  CREATE TABLE t1 (c1 INT, c2 INT);
```

  The following table definitions would raise Error 1532 (`ER_BINLOG_ROW_RBR_TO_SBR`) because the definitions of the columns common to both versions of the table are in a different order on the slave than they are on the master:

```
master> CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
slave>  CREATE TABLE t1 (c2 INT, c1 INT);
```

The following table definitions would also raise Error 1532, because the definition of the extra column on the master appears before the definitions of the columns common to both versions of the table:

```
master> CREATE TABLE t1 (c3 INT, c1 INT, c2 INT);
slave>  CREATE TABLE t1 (c1 INT, c2 INT);
```

- **More columns on the slave.** The following definitions replicate correctly:

  ```
  master> CREATE TABLE t1 (c1 INT, c2 INT);
  slave>  CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
  ```

  The following definitions raise Error 1532 because the columns common to both versions of the table are not defined in the same order on both the master and the slave:

  ```
  master> CREATE TABLE t1 (c1 INT, c2 INT);
  slave>  CREATE TABLE t1 (c2 INT, c1 INT, c3 INT);
  ```

  The following table definitions also raise Error 1532 because the definition for the extra column in the slave's version of the table appears before the definitions for the columns which are common to both versions of the table:

  ```
  master> CREATE TABLE t1 (c1 INT, c2 INT);
  slave>  CREATE TABLE t1 (c3 INT, c1 INT, c2 INT);
  ```

  The following table definitions fail, because the slave's version of the table has additional columns compared to the master's version, and the two versions of the table define column `c2` as a different data type.

  ```
  master> CREATE TABLE t1 (c1 INT, c2 BIGINT);
  slave>  CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
  ```

3.1.4.2. Replication of Columns Having Different Data Types

Corresponding columns on the master's and the slave's copies of the same table should have the same type. However, this is not always strictly enforced, as long as certain conditions are met. These conditions are listed here:

- The slave's copy of the table cannot contain more columns than the master's copy.

- For columns holding numeric data types, the sizes may differ, as long as the size of the slave's version of the column is equal or greater to the size of the master's version of the column. This is sometimes referred to as *attribute promotion*, because the data type of the master's version of the column is promoted to a type that is the same size or larger on the slave.

  Data type conversions currently supported by attribute promotion are shown in the following table, in which *`X`* and *`N`* both represent positive integers.

Original Data Type	**Promoted Data Type(s)**
`CHAR(X)`	`CHAR(X+N)`
`VARCHAR(X)`	`VARCHAR(X+N)`
`CHAR(X)`	`VARCHAR(X+N)`
`BINARY(X)`	`BINARY(X+N)`
`VARBINARY(X)`	`VARBINARY(X+N)`
`BINARY(X)`	`VARBINARY(X+N)`
`BIT(X)`	`BIT(X+N)`
`TINYINT`	`SMALLINT`, `MEDIUMINT`, `INT`, or `BIGINT`
`SMALLINT`	`MEDIUMINT`, `INT`, or `BIGINT`
`MEDIUMINT`	`INT` or `BIGINT`
`INT`	`BIGINT`

  Unsigned integer columns can be promoted to larger unsigned types; for example, a column declared as `TINYINT UNSIGNED` can be restored to a column declared as `SMALLINT UNSIGNED`, `MEDIUMINT UNSIGNED`, `INT UNSIGNED`, or `BIGINT UNSIGNED`. You cannot promote a signed column to an unsigned type, or an unsigned column to a signed type.

For columns holding numeric data types the sizes may differ, as long as the size of the slave's version of the column is equal or greater to the size of the master's version of the column. For example, the following table definitions are allowed:

```
master> CREATE TABLE t1 (c1 TINYINT, c2 INT);
slave>  CREATE TABLE t1 (c1 INT,     c2 INT);
```

The slave's versions of both columns `c1` and `c2` are the same size as or larger than the master's versions of these columns. However, the following definitions would fail:

```
master> CREATE TABLE t1 (c1 INT, c2 FLOAT(8,3));
slave>  CREATE TABLE t1 (c1 INT, c2 FLOAT(7,3));
```

In this case, Error 1532 would be raised because the master's copy of column `c2` is larger than its counterpart on the slave — that is, the master's copy of `c2` on the master can hold more digits than the slave's copy of the column.

- There is no conversion between integer (`TINYINT`, `SMALLINT`, `MEDIUMINT`, and so on) and non-integer (`FLOAT`, `DOUBLE`, `DECIMAL`, and so on) numeric data types, and so the following definitions would fail with Error 1532:

  ```
  master> CREATE TABLE t1 (c1 INT, c2 FLOAT(8,3));
  slave>  CREATE TABLE t1 (c1 INT, c2 BIGINT);
  ```

  A column using a non-integer numeric data type must always have the same definition on both the master and the slave.

- For columns storing `CHAR` and `BINARY` data, the size of the slave's copy of the column must be equal to or greater than the size of the master's copy. For example, the following table definitions would replicate successfully:

  ```
  master> CREATE TABLE t1 (c1 INT, c2 CHAR(30));
  slave>  CREATE TABLE t1 (c1 INT, c2 CHAR(50));
  ```

  If the size of the master's version of the column is greater than that of the slave's version of the column, replication fails with Error 1532.

- The replication process can convert freely between `BINARY`, `VARBINARY`, `CHAR` and `VARCHAR` columns, as long as the slave's version of the column is the same size as or larger than the master's version. For example, the following table definitions can be used successfully:

  ```
  master> CREATE TABLE t1 (c1 INT, c2 VARBINARY(30));
  slave>  CREATE TABLE t1 (c1 INT, c2 CHAR(30));
  ```

  Note

  Since replication is currently not supported between different character sets, it is sufficient when comparing sizes of columns containing character data to count the number of characters rather than the number of bytes.

- Attribute promotion can be used with both statement-based and row-based replication, and is not dependent on the storage engine used by either the master or the slave.

3.1.5. Replication and `DIRECTORY` Table Options

If a `DATA DIRECTORY` or `INDEX DIRECTORY` table option is used in a `CREATE TABLE` statement on the master server, the table option is also used on the slave. This can cause problems if no corresponding directory exists in the slave host file system or if it exists but is not accessible to the slave server. This can be overridden by using the `NO_DIR_IN_CREATE` server SQL mode on the slave, which causes the slave to ignore the `DATA DIRECTORY` and `INDEX DIRECTORY` table options when replicating `CREATE TABLE` statements. The result is that `MyISAM` data and index files are created in the table's database directory.

For more information, see Server SQL Modes.

3.1.6. Replication of `DROP ... IF EXISTS` Statements

The statements `DROP DATABASE IF EXISTS`, `DROP TABLE IF EXISTS`, and `DROP VIEW IF EXISTS` are always replicated, even if the database, table, or view to be dropped does not exist on the master. This is to ensure that the object to be dropped no longer exists on either the master or the slave, once the slave has caught up with the master.

Beginning with MySQL 6.0.12, the statements `DROP PROCEDURE IF EXISTS` and `DROP FUNCTION IF EXISTS` are also replicated, even if the procedure or function to be dropped does not exist on the master. (Bug#13684)

3.1.7. Replication of Invoked Features

Replication of invoked features such as scheduled events, user-defined functions (UDFs), stored routines (including both stored procedures and stored functions), and triggers provides the following characteristics:

- The effects of the feature are always replicated.
- The following statements are replicated using statement-based replication:
  - `CREATE EVENT`
  - `ALTER EVENT`
  - `DROP EVENT`
  - `CREATE PROCEDURE`
  - `DROP PROCEDURE`
  - `CREATE FUNCTION`
  - `DROP FUNCTION`
  - `CREATE TRIGGER`
  - `DROP TRIGGER`

  However, the *effects* of features created, modified, or dropped using these statements are replicated using row-based replication.

  > **Note**
  >
  > Attempting to replicate invoked features using statement-based replication produces the warning `STATEMENT IS NOT SAFE TO LOG IN STATEMENT FORMAT`. For example, trying to replicate a UDF with statement-based replication generates this warning because it currently cannot be determined by the MySQL server whether the UDF is deterministic. If you are absolutely certain that the invoked feature's effects are deterministic, you can safely disregard such warnings.
  >
  > In a future MySQL release, we may implement ways for users to indicate that such features are deterministic, so that they can be recognized by the server as “safe” for statement-based replication. (Bug#34597)

- In the case of `CREATE EVENT` and `ALTER EVENT`:
  - The status of the event is set to `SLAVESIDE_DISABLED` on the slave regardless of the state specified (this does not apply to `DROP EVENT`).
  - The master on which the event was created is identified on the slave by its server ID. The `ORIGINATOR` column in `INFORMATION_SCHEMA.EVENTS` and the `originator` column in `mysql.event` store this information. (See The `INFORMATION_SCHEMA EVENTS` Table, and `SHOW EVENTS` Syntax.)
- The feature implementation resides on the slave in a renewable state so that if the master fails, the slave can be used as the master without loss of event processing.

To determine whether there are any scheduled events on a MySQL server that were created on a different server (that was acting as a replication master), use `SHOW EVENTS`, like this:

```
SHOW EVENTS
    WHERE STATUS = 'SLAVESIDE_DISABLED';
```

Alternatively, you might wish to query the `INFORMATION_SCHEMA.EVENTS` table as shown here:

```
SELECT EVENT_SCHEMA, EVENT_NAME, ORIGINATOR
    FROM INFORMATION_SCHEMA.EVENTS
    WHERE STATUS = 'SLAVESIDE_DISABLED';
```

When promoting a replication slave having such events to a replication master, use the following query to enable the events:

```
UPDATE mysql.event
    SET STATUS = 'ENABLED'
    WHERE STATUS = 'SLAVESIDE_DISABLED';
```

If more than one master was involved in creating events on this slave, and you wish to enable events that were created only on a given master having the server ID *`master_id`*, use the following query instead:

```
UPDATE mysql.event
    SET STATUS = 'ENABLED'
    WHERE ORIGINATOR = master_id
    AND STATUS = 'SLAVESIDE_DISABLED';
```

Important

Before executing either of the previous two UPDATE statements, you should disable the Event Scheduler on the slave (using SET GLOBAL EVENT_SCHEDULER = OFF;), run the UPDATE, restart the server, then re-enable the Event Scheduler afterwards (using SET GLOBAL EVENT_SCHEDULER = ON;).

If you later demote the new master back to being a replication slave, you must disable manually all events enabled by the UPDATE statement. You can do this by storing in a separate table the event names from the SELECT statement shown previously, or using an UPDATE statement to rename the events with a common prefix to identify them, as shown in this example:

```
UPDATE mysql.event
    SET name = CONCAT('replicated_', name)
    WHERE status = 'SLAVESIDE_DISABLED';
```

When demoting this server back to being a replication slave, you can then rename and disable the events like this:

```
UPDATE mysql.event
    SET name = REPLACE(name, 'replicated_', ''),
        status = 'SLAVESIDE_DISABLED'
    WHERE INSTR(name, 'replicated_') = 1;
```

3.1.8. Replication with Floating-Point Values

With statement-based replication, values are converted from decimal to binary. Because conversions between decimal and binary representations of them may be approximate, comparisons involving floating-point values are inexact. This is true for operations that use floating-point values explicitly, or that use values that are converted to floating-point implicitly. Comparisons of floating-point values might yield different results on master and slave servers due to differences in computer architecture, the compiler used to build MySQL, and so forth. See Type Conversion in Expression Evaluation, and Problems with Floating-Point Comparisons.

3.1.9. Replication and FLUSH

Some forms of the FLUSH statement are not logged because they could cause problems if replicated to a slave: FLUSH LOGS, FLUSH MASTER, FLUSH SLAVE, and FLUSH TABLES WITH READ LOCK. For a syntax example, see FLUSH Syntax. The FLUSH TABLES, ANALYZE TABLE, OPTIMIZE TABLE, and REPAIR TABLE statements are written to the binary log and thus replicated to slaves. This is not normally a problem because these statements do not modify table data.

However, this behavior can cause difficulties under certain circumstances. If you replicate the privilege tables in the mysql database and update those tables directly without using GRANT, you must issue a FLUSH PRIVILEGES on the slaves to put the new privileges into effect. In addition, if you use FLUSH TABLES when renaming a MyISAM table that is part of a MERGE table, you must issue FLUSH TABLES manually on the slaves. These statements are written to the binary log unless you specify NO_WRITE_TO_BINLOG or its alias LOCAL.

3.1.10. Replication and System Functions

Certain functions do not replicate well under some conditions:

- The USER(), CURRENT_USER(), UUID(), VERSION(), and LOAD_FILE() functions are replicated without change and thus do not work reliably on the slave unless row-based replication is enabled. This is also true for CURRENT_USER. (See Section 1.2, “Replication Formats”.)

  Beginning with MySQL 6.0.4, USER(), CURRENT_USER(), and CURRENT_USER are automatically replicated using row-based replication when using MIXED mode, and generate a warning in STATEMENT mode. (Bug#28086)

- For NOW(), the binary log includes the timestamp and replicates correctly.

  Unlike NOW(), the SYSDATE() function is not replication-safe because it is not affected by SET TIMESTAMP statements in the binary log and is non-deterministic if statement-based logging is used. This is not a problem if row-based logging is used. Another option is to start the server with the --sysdate-is-now option to cause SYSDATE() to be an alias for NOW().

- *The following restriction applies to statement-based replication only, not to row-based replication.* The GET_LOCK(), RELEASE_LOCK(), IS_FREE_LOCK(), and IS_USED_LOCK() functions that handle user-level locks are replicated without the slave knowing the concurrency context on master. Therefore, these functions should not be used to insert into a master's table because the content on the slave would differ. (For example, do not issue a statement such as INSERT INTO mytable VALUES(GET_LOCK(...)).)

As a workaround for the preceding limitations when statement-based replication is in effect, you can use the strategy of saving the problematic function result in a user variable and referring to the variable in a later statement. For example, the following single-row INSERT is problematic due to the reference to the UUID() function:

```
INSERT INTO t VALUES(UUID());
```

To work around the problem, do this instead:

```
SET @my_uuid = UUID();
INSERT INTO t VALUES(@my_uuid);
```

That sequence of statements replicates because the value of @my_uuid is stored in the binary log as a user-variable event prior to the INSERT statement and is available for use in the INSERT.

The same idea applies to multiple-row inserts, but is more cumbersome to use. For a two-row insert, you can do this:

```
SET @my_uuid1 = UUID(); @my_uuid2 = UUID();
INSERT INTO t VALUES(@my_uuid1),(@my_uuid2);
```

However, if the number of rows is large or unknown, the workaround is difficult or impracticable. For example, you cannot convert the following statement to one in which a given individual user variable is associated with each row:

```
INSERT INTO t2 SELECT UUID(), * FROM t1;
```

Within a stored function, RAND() replicates correctly as long as it is invoked only once during the execution of the function. (You can consider the function execution timestamp and random number seed as implicit inputs that are identical on the master and slave.)

The FOUND_ROWS() and ROW_COUNT() functions are not replicated reliably using statement-based replication. A workaround is to store the result of the function call in a user variable, and then use that in the INSERT statement. For example, if you wish to store the result in a table named mytable, you might normally do so like this:

```
SELECT SQL_CALC_FOUND_ROWS FROM mytable LIMIT 1;
INSERT INTO mytable VALUES( FOUND_ROWS() );
```

However, if you are replicating mytable, then you should use SELECT INTO, and then store the variable in the table, like this:

```
SELECT SQL_CALC_FOUND_ROWS INTO @found_rows FROM mytable LIMIT 1;
INSERT INTO mytable VALUES(@found_rows);
```

In this way, the user variable is replicated as part of the context, and applied on the slave correctly.

Beginning with MySQL 6.0.4, these functions are automatically replicated using row-based replication when using MIXED mode, and generate a warning in STATEMENT mode. (Bug#12092, Bug#30244)

3.1.11. Replication and LIMIT

Statement-based replication of LIMIT clauses in DELETE, UPDATE, and INSERT ... SELECT statements is unsafe since the order of the rows affected is not defined. (Such statements can be replicated correctly when using STATEMENT mode only if they also contain an ORDER BY clause.) Beginning with MySQL 6.0.5, when such a statement (without ORDER BY) is encountered:

- When using STATEMENT mode, a warning that the statement is not safe for statement-based replication is now issued.

  Currently, when using STATEMENT mode, warnings are issued for DML statements containing LIMIT even when they also have an ORDER BY clause (and so are made deterministic). This is a known issue which we are working to resolve in a future MySQL release. (Bug#42851)

- When using MIXED mode, the statement is now automatically replicated using row-based mode.

3.1.12. Replication and LOAD DATA

The LOAD DATA statement is not replicated correctly to a slave running MySQL 5.1 or later from a master running MySQL 4.0 or earlier.

When using statement-based replication, the LOAD DATA INFILE statement's CONCURRENT option is not replicated; that is, LOAD DATA CONCURRENT INFILE is replicated as LOAD DATA INFILE, and LOAD DATA CONCURRENT LOCAL INFILE is replicated as LOAD DATA LOCAL INFILE. The CONCURRENT option *is* replicated when using row-based replication. (Bug#34628)

3.1.13. Replication and the Slow Query Log

Prior to MySQL 6.0.11, replication slaves did not write replicated queries to the slow query log, even if the same queries were written to the slow query log on the master. (Bug#23300)

3.1.14. Replication During a Master Crash

A crash on the master side can result in the master's binary log having a final position less than the most recent position read by the slave, due to the master's binary log file not being flushed. This can cause the slave not to be able to replicate when the master comes back up. Setting `sync_binlog=1` in the master `my.cnf` file helps to minimize this problem because it causes the master to flush its binary log more frequently.

3.1.15. Replication During a Master Shutdown

It is safe to shut down a master server and restart it later. When a slave loses its connection to the master, the slave tries to reconnect immediately and retries periodically if that fails. The default is to retry every 60 seconds. This may be changed with the `CHANGE MASTER TO` statement. A slave also is able to deal with network connectivity outages. However, the slave notices the network outage only after receiving no data from the master for `slave_net_timeout` seconds. If your outages are short, you may want to decrease `slave_net_timeout`. See Server System Variables.

3.1.16. Replication with `MEMORY` Tables

When a server shuts down and restarts, its `MEMORY` tables become empty. The master replicates this effect to slaves as follows: The first time that the master uses each `MEMORY` table after startup, it logs an event that notifies the slaves that the table needs to be emptied by writing a `DELETE` statement for that table to the binary log. See The `MEMORY` (`HEAP`) Storage Engine, for more information about `MEMORY` tables.

3.1.17. Replication of the System `mysql` Database

Data modification statements made to tables in the `mysql` database are replicated according to the value of `binlog_format`; if this value is `MIXED`, then these statement are replicated using the row-based format. However, statements that would normally update this information indirectly — such `GRANT`, `REVOKE`, and statements manipulating triggers, stored routines, and views — are replicated to slaves using statement-based replication.

3.1.18. Replication and the Query Optimizer

It is possible for the data on the master and slave to become different if a statement is designed in such a way that the data modification is non-deterministic; that is, left up the query optimizer. (This is in general not a good practice, even outside of replication.) Examples of non-deterministic statements include `DELETE` or `UPDATE` statements that use `LIMIT` with no `ORDER BY` clause; see Section 3.1.11, “Replication and `LIMIT`”, for a detailed discussion of these.

3.1.19. Replication and Reserved Words

You can encounter problems when you are attempting to replicate from an older master to a newer slave and you make use of identifiers on the master that are reserved words in the newer MySQL version running on the slave. An example of this is using a table column named `current_user` on a 4.0 master that is replicating to a 4.1 or higher slave, because `CURRENT_USER` is a reserved word beginning in MySQL 4.1. Replication can fail in such cases with Error 1064 `You have an error in your SQL syntax...`, *even if a database or table named using the reserved word or a table having a column named using the reserved word is excluded from replication*. This is due to the fact that each SQL statement must be parsed by the slave prior to execution, so that the slave knows which database object or objects would be effected by the statement; only after the statement is parsed can the slave apply any filtering rules defined by `--replicate-do-db`, `--replicate-do-table`, `--replicate-ignore-db`, and `--replicate-ignore-table`.

To work around the problem of database, table, or column names on the master which would be regarded as reserved words by the slave, do one of the following:

- Use one or more `ALTER TABLE` statements on the master to change the names of any database objects where these names would be considered reserved words on the slave, and change any SQL statements that use the old names to use the new names instead.
- In any SQL statements using these database object names, set the names off using backtick characters (`` ` ``).

For listings of reserved words by MySQL version, see Reserved Words, in the *MySQL Server Version Reference*.

3.1.20. Slave Errors during Replication

If a statement on a slave produces an error, the slave SQL thread terminates, and the slave writes a message to its error log. You should then connect to the slave manually and determine the cause of the problem. (`SHOW SLAVE STATUS` is useful for this.)

Then fix the problem (for example, you might need to create a non-existent table) and run `START SLAVE`.

> **MySQL Enterprise**
> For instant notification when a slave thread terminates subscribe to the MySQL Enterprise Monitor. For more information, see http://www.mysql.com/products/enterprise/advisors.html.

3.1.21. Replication during a Slave Shutdown

Shutting down the slave (cleanly) is also safe because it keeps track of where it left off. Unclean shutdowns might produce problems, especially if the disk cache was not flushed to disk before the system went down. Your system fault tolerance is greatly increased if you have a good uninterruptible power supply. Unclean shutdowns of the master may cause inconsistencies between the content of tables and the binary log in master.

3.1.22. Replication and Temporary Tables

This item does not apply when row-based replication is in use because in that case temporary tables are not replicated (see Section 1.2, “Replication Formats”).

Safe shutdown of slaves when using temporary tables. Temporary tables are replicated except in the case where you shut down the slave server (not just the slave threads) and you have replicated temporary tables that are used in updates that have not yet been executed on the slave. If you shut down the slave server, the temporary tables needed by those updates are no longer available when the slave is restarted. To avoid this problem, do not shut down the slave while it has temporary tables open. Instead, use the following procedure:

1. Issue a `STOP SLAVE SQL_THREAD` statement.
2. Use `SHOW STATUS` to check the value of the `Slave_open_temp_tables` variable.
3. If the value is 0, issue a `mysqladmin shutdown` command to stop the slave.
4. If the value is not 0, restart the slave SQL thread with `START SLAVE SQL_THREAD`.
5. Repeat the procedure later until the `Slave_open_temp_tables` variable is 0 and you can stop the slave.

Temporary tables and replication options. By default, all temporary tables are replicated; this happens whether or not there are any matching `--replicate-do-db`, `--replicate-do-table`, or `--replicate-wild-do-table` options in effect. However, the `--replicate-ignore-table` and `--replicate-wild-ignore-table` options are honored for temporary tables.

A recommended practice when using statement-based or mixed-format replication is to designate a prefix for exclusive use in naming temporary tables that you do not want replicated, then employ a matching `--replicate-wild-ignore-table` option. For example, you might give all such tables names beginning with `norep_` (such as `norep_tablea`, `norep_tableb`, and so on), then use `--replicate-wild-ignore-table=norep_` to prevent the replication of these tables.

3.1.23. Replication Retries and Timeouts

The global system variable `slave_transaction_retries` affects replication as follows: If the replication slave SQL thread fails to execute a transaction because of an `InnoDB` deadlock or because it exceeded the `InnoDB` `innodb_lock_wait_timeout` value, the transaction is automatically retried `slave_transaction_retries` times before stopping with an error. The default value is 10. The total retry count can be seen in the output of `SHOW STATUS`; see Server Status Variables.

3.1.24. Replication and Time Zones

If the master uses MySQL 4.1, the same system time zone should be set for both master and slave. Otherwise some statements will not be replicated properly, such as statements that use the `NOW()` or `FROM_UNIXTIME()` functions. You can set the time zone in which MySQL server runs by using the `--timezone=`*`timezone_name`* option of the `mysqld_safe` script or by setting the `TZ` environment variable. Both master and slave should also have the same default connection time zone setting; that is, the `--default-time-zone` parameter should have the same value for both master and slave. Note that this is not necessary when the master is MySQL 5.0 or later.

`CONVERT_TZ(...,...,@@session.time_zone)` is properly replicated only if both master and slave are running MySQL 5.0.4 or newer.

3.1.25. Replication and Transactions

It is possible to replicate transactional tables on the master using non-transactional tables on the slave. For example, you can replicate an `InnoDB` master table as a `MyISAM` slave table. However, if you do this, there are problems if the slave is stopped in the middle of a `BEGIN`/`COMMIT` block because the slave restarts at the beginning of the `BEGIN` block.

Beginning with MySQL 6.0.10, it is also safe to replicate transactions from `MyISAM` tables on the master to transactional tables — such as tables that use the `InnoDB` storage engine — on the slave. In such cases (beginning with MySQL 6.0.10), an `AUTOCOMMIT=1` statement issued on the master is replicated, thus enforcing `AUTOCOMMIT` mode on the slave.

Mixing transactional and non-transactional statements within the same transaction. The semantics of mixing non-transactional and transactional tables in a transaction in the first statement of a transaction changed in MySQL 6.0.10. Previously, if the first statement in a transaction contained non-transactional changes, the statement was written directly to the binary log, in an attempt to mimic the non-transactional behavior of the statement. Beginning with MySQL 6.0.10, any statement appearing after a `BEGIN` is always considered part of the transaction and cached. This means that non-transactional changes do not propagate to the slave until the transaction is committed and thus written to the binary log. In addition (also beginning with MySQL 5.1.31), if `AUTOMCOMMIT` is set to 0, any statement appearing immediately following a `COMMIT` is handled in the same way.

Previously, a statement was considered non-transactional if it changed a non-transactional table. This behavior had the following subtle but non-trivial consequences:

- A statement containing only non-transactional changes was written immediately to the binary log (sometime referred to as “write-ahead”).
- A statement containing only transactional changes was always cached while waiting for the transaction to be committed.
- A statement containing a mix of transactional and non-transactional changes (that is, a statement updating both transaction and non-transactional tables) could lead to mismatched tables on the master and the slave.

In situations where transactions mix updates to transactional and non-transactional tables, the order of statements in the binary log is correct, and all needed statements are written to the binary log even in case of a `ROLLBACK`. However, when a second connection updates the non-transactional table before the first connection's transaction is complete, statements can be logged out of order, because the second connection's update is written immediately after it is performed, regardless of the state of the transaction being performed by the first connection.

Due to the non-transactional nature of `MyISAM` tables, it is possible to have a statement that only partially updates a table and returns an error code. This can happen, for example, on a multiple-row insert that has one row violating a key constraint, or if a long update statement is killed after updating some of the rows. If that happens on the master, the slave thread exits and waits for the database administrator to decide what to do about it unless the error code is legitimate and execution of the statement results in the same error code on the slave. If this error code validation behavior is not desirable, some or all errors can be masked out (ignored) with the `--slave-skip-errors` option.

> **Caution**
>
> You should avoid transactions that update both transactional and non-transactional tables in a replication environment.

When the storage engine type of the slave is non-transactional, transactions on the master that mix updates of transactional and non-transactional tables should be avoided because they can cause inconsistency of the data between the master's transactional table and the slave's non-transactional table. That is, such transactions can lead to master storage engine-specific behavior with the possible effect of replication going out of synchrony. MySQL does not issue a warning about this currently, so extra care should be taken when replicating transactional tables from the master to non-transactional ones on the slaves.

3.1.26. Replication and Triggers

Triggers are not executed on the slave under row-based replication. However, they are executed on the slave under statement-based replication. Instead, when using row-based replication, the changes caused by executing the trigger on the master are applied on the slave.

This behavior is by design. The reason for this is that, if both the master and the slave applied the changes from the master and, in addition, the trigger causing these changes were applied on the slave, the changes would in effect be applied twice on the slave, leading to different data on the master and the slave.

If you wish for triggers to execute on both the master and the slave — perhaps because you have different triggers on the master and slave — then you must use statement-based replication. However, it is not necessary to use statement-based replication exclusively if you want to enable slave-side triggers; it is sufficient in such cases to switch to statement-based replication only for those statements where you want this effect, and to use row-based replication the rest of the time.

Before MySQL 6.0.10, a trigger that was defined on a transactional table but that updated a non-transactional tables could cause updates on the transactional table to be replicated before they were actually committed on the master, and not be rolled back correctly on the slave if they were rolled back on the master. (Bug#40116) See also Section 3.1.25, “Replication and Transactions”.

3.1.27. Replication and `TRUNCATE`

`TRUNCATE` is normally regarded as a DML statement, and so would be expected to be logged and replicated using row-based format when the binary logging mode is `ROW` or `MIXED`. However this caused issues when logging or replicating, in `STATEMENT` or `MIXED` mode, tables that used transactional storage engines such as `InnoDB` when the transaction isolation level was `READ COMMITTED` or `READ UNCOMMITTED`, which precludes statement-based logging.

Beginning with MySQL 6.0.10, `TRUNCATE` is treated for purposes of logging and replication as DDL rather than DML so that it can be logged and replicated as a statement. However, the effects of the statement as applicable to `InnoDB` and other transactional tables on replication slaves still follow the rules described in `TRUNCATE` Syntax governing such tables. (Bug#36763)

3.1.28. Replication and Variables

The `foreign_key_checks`, `unique_checks`, and `sql_auto_is_null` variables are all replicated.

`sql_mode` is also replicated except for the `NO_DIR_IN_CREATE` mode. However, when `mysqlbinlog` parses a `SET @@sql_mode = value` statement, the full *`value`*, including `NO_DIR_IN_CREATE`, is passed to the receiving server.

The `storage_engine` system variable is not replicated, which is a good thing for replication between different storage engines.

Session variables are not replicated properly when used in statements that update tables. For example, `SET MAX_JOIN_SIZE=1000` followed by `INSERT INTO mytable VALUES(@@MAX_JOIN_SIZE)` will not insert the same data on the master and the slave. This does not apply to the common sequence of `SET TIME_ZONE=...` followed by `INSERT INTO mytable VALUES(CONVERT_TZ(...,...,@@time_zone))`.

Replication of session variables is not a problem when row-based replication is being used. See Section 1.2, “Replication Formats”.

3.1.29. Replication and Views

Views are always replicated to slaves. Views are filtered by their own name, not by the tables they refer to. This means that a view can be replicated to the slave even if the view contains a table that would normally be filtered out by `replication-ignore-table` rules. Care should therefore be taken to ensure that views do not replicate table data that would normally be filtered for security reasons.

3.2. Replication Compatibility Between MySQL Versions

MySQL supports replication from one major version to the next higher major version. For example, you can replicate from a master running MySQL 4.1 to a slave running MySQL 5.0, from a master running MySQL 5.0 to a slave running MySQL 5.1, from a master running MySQL 5.1 to a slave running MySQL 6.0, and so on.

In some cases, it is also possible to replicate between a master and a slave that is more than one major version newer than the master. However, there are known issues with trying to replicate from a master running MySQL 4.1 or earlier to a slave running MySQL 5.1 or later. To work around such problems, you can insert one or more MySQL servers running intermediate versions between the two; for example, rather than replicating directly from a MySQL 4.1 master to a MySQL 6.0 slave, it is possible to replicate from a MySQL 4.1 server to a MySQL 5.0 server, and then from the MySQL 5.0 server to a MySQL 5.1 server, and finally from the MySQL 5.1 server to a MySQL 6.0 server.

> **Important**
>
> We strongly recommend using the most recent release available within a given MySQL major version because replication (and other) capabilities are continually being improved. We also recommend upgrading masters and slaves that use alpha or beta releases of a major version of MySQL to GA (production) releases when these become available for that major version.

Replication from newer masters to older slaves may be possible, but is generally not supported. This is due to a number of factors:

- **Binary log format changes.** The binary log format can change between major releases. While we attempt to maintain backward compatibility, this is not always possible. For example, the binary log format implemented in MySQL 5.0 changed considerably from that used in previous versions, especially with regard to handling of character sets, `LOAD DATA INFILE`, and time zones. This means that replication from a MySQL 5.0 (or later) master to a MySQL 4.1 (or earlier) slave is generally not supported.

  This also has significant implications for upgrading replication servers; see Section 3.3, “Upgrading a Replication Setup”, for more information.

- **Use of row-based replication.** You cannot replicate using row-based replication from any MySQL 6.0 or later master to a slave running MySQL 5.1.4 or earlier, since MySQL versions prior to 5.1.5 do not support RBR.

For more information about row-based replication, see Section 1.2, “Replication Formats”.

- **SQL incompatiblities.** You cannot replicate from a newer master to an older slave using statement-based replication if the statements to be replicated use SQL features available on the master but not on the slave.

  However, if both the master and the slave support row-based replication, and there are no data definition statements to be replicated that depend on SQL features found on the master but not on the slave, then you can use row-based replication to replicate the effects of data modification statements even if the DDL run on the master is not supported on the slave.

For more information on potential replication issues, see Section 3.1, “Replication Features and Issues”.

3.3. Upgrading a Replication Setup

When you upgrade servers that participate in a replication setup, the procedure for upgrading depends on the current server versions and the version to which you are upgrading.

This section applies to upgrading replication from older versions of MySQL to MySQL 6.0. A 4.0 server should be 4.0.3 or newer.

When you upgrade a master to 6.0 from an earlier MySQL release series, you should first ensure that all the slaves of this master are using the same 6.0.x release. If this is not the case, you should first upgrade the slaves. To upgrade each slave, shut it down, upgrade it to the appropriate 6.0.x version, restart it, and restart replication. The 6.0 slave is able to read the old relay logs written prior to the upgrade and to execute the statements they contain. Relay logs created by the slave after the upgrade are in 6.0 format.

After the slaves have been upgraded, shut down the master, upgrade it to the same 6.0.x release as the slaves, and restart it. The 6.0 master is able to read the old binary logs written prior to the upgrade and to send them to the 6.0 slaves. The slaves recognize the old format and handle it properly. Binary logs created by the master following the upgrade are in 6.0 format. These too are recognized by the 6.0 slaves.

In other words, there are no measures to take when upgrading to MySQL 6.0, except that the slaves must be MySQL 6.0 before you can upgrade the master to 6.0. Note that downgrading from 6.0 to older versions does not work so simply: You must ensure that any 6.0 binary logs or relay logs have been fully processed, so that you can remove them before proceeding with the downgrade.

Downgrading a replication setup to a previous version cannot be done once you have switched from statement-based to row-based replication, and after the first row-based statement has been written to the binlog. See Section 1.2, “Replication Formats”.

3.4. Replication FAQ

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Questions

- 3.4.1: Does the slave need to be connected to the master all the time?
- 3.4.2: Do I have to enable networking on my master to enable replication?
- 3.4.3: How do I know how late a slave is compared to the master? In other words, how do I know the date of the last statement replicated by the slave?
- 3.4.4: How do I force the master to block updates until the slave catches up?
- 3.4.5: What issues should I be aware of when setting up two-way replication?
- 3.4.6: How can I use replication to improve performance of my system?
- 3.4.7: What should I do to prepare client code in my own applications to use performance-enhancing replication?
- 3.4.8: When and how much can MySQL replication improve the performance of my system?
- 3.4.9: How can I use replication to provide redundancy or high availability?
- 3.4.10: How do I tell whether a master server is using statement-based or row-based binary logging format?
- 3.4.11: How do I tell a slave to use row-based replication?
- 3.4.12: How do I prevent `GRANT` and `REVOKE` statements from replicating to slave machines?

- 3.4.13: Does replication work on mixed operating systems (for example, the master runs on Linux while slaves run on Mac OS X and Windows)?
- 3.4.14: Does replication work on mixed hardware architectures (for example, the master runs on a 64-bit machine while slaves run on 32-bit machines)?

Questions and Answers

3.4.1: Does the slave need to be connected to the master all the time?

No, it does not. The slave can go down or stay disconnected for hours or even days, and then reconnect and catch up on updates. For example, you can set up a master/slave relationship over a dial-up link where the link is up only sporadically and for short periods of time. The implication of this is that, at any given time, the slave is not guaranteed to be in sync with the master unless you take some special measures.

To ensure that this is the case, you must not remove binary logs from the master, where the information has not been replicated to the slaves. Asynchronous replication can only work if the slave is able to read the binary log from the last point in the binary logs where it had read the replication statements.

3.4.2: Do I have to enable networking on my master to enable replication?

Networking must be enabled on the master. If networking is not enabled, then the slave is unable to connect to the master and transfer the binary log. Check that the `skip-networking` option has not been enabled in your configuration file.

3.4.3: How do I know how late a slave is compared to the master? In other words, how do I know the date of the last statement replicated by the slave?

You can read the `Seconds_Behind_Master` column in `SHOW SLAVE STATUS`. See Section 4.1, "Replication Implementation Details".

When the slave SQL thread executes an event read from the master, it modifies its own time to the event timestamp. (This is why `TIMESTAMP` is well replicated.) In the `Time` column in the output of `SHOW PROCESSLIST`, the number of seconds displayed for the slave SQL thread is the number of seconds between the timestamp of the last replicated event and the real time of the slave machine. You can use this to determine the date of the last replicated event. Note that if your slave has been disconnected from the master for one hour, and then reconnects, you may immediately see `Time` values like 3600 for the slave SQL thread in `SHOW PROCESSLIST`. This is because the slave is executing statements that are one hour old.

3.4.4: How do I force the master to block updates until the slave catches up?

Use the following procedure:

1. On the master, execute these statements:

   ```
   mysql> FLUSH TABLES WITH READ LOCK;
   mysql> SHOW MASTER STATUS;
   ```

   Record the replication coordinates (the log file name and offset) from the output of the `SHOW` statement.

2. On the slave, issue the following statement, where the arguments to the `MASTER_POS_WAIT()` function are the replication coordinate values obtained in the previous step:

   ```
   mysql> SELECT MASTER_POS_WAIT('log_name', log_offset);
   ```

   The `SELECT` statement blocks until the slave reaches the specified log file and offset. At that point, the slave is in synchrony with the master and the statement returns.

3. On the master, issue the following statement to allow the master to begin processing updates again:

   ```
   mysql> UNLOCK TABLES;
   ```

3.4.5: What issues should I be aware of when setting up two-way replication?

MySQL replication currently does not support any locking protocol between master and slave to guarantee the atomicity of a distributed (cross-server) update. In other words, it is possible for client A to make an update to co-master 1, and in the meantime, before it propagates to co-master 2, client B could make an update to co-master 2 that makes the update of client A work differently than it did on co-master 1. Thus, when the update of client A makes it to co-master 2, it produces tables that are different from what you have on co-master 1, even after all the updates from co-master 2 have also propagated. This means that you should not chain two servers together in a two-way replication relationship unless you are sure that your updates can safely happen in any order, or unless you take care of mis-ordered updates somehow in the client code.

You should also realize that two-way replication actually does not improve performance very much (if at all) as far as updates are concerned. Each server must do the same number of updates, just as you would have a single server do. The only difference is that there is a little less lock contention, because the updates originating on another server are serialized in one slave thread. Even this benefit might be offset by network delays.

3.4.6: How can I use replication to improve performance of my system?

You should set up one server as the master and direct all writes to it. Then configure as many slaves as you have the budget and rackspace for, and distribute the reads among the master and the slaves. You can also start the slaves with the `--skip-innodb`, `--low-priority-updates`, and `--delay-key-write=ALL` options to get speed improvements on the slave end. In this case, the slave uses non-transactional `MyISAM` tables instead of `InnoDB` tables to get more speed by eliminating transactional overhead.

3.4.7: What should I do to prepare client code in my own applications to use performance-enhancing replication?

See the guide to using replication as a scale-out solution, Section 2.3, “Using Replication for Scale-Out”.

3.4.8: When and how much can MySQL replication improve the performance of my system?

MySQL replication is most beneficial for a system that processes frequent reads and infrequent writes. In theory, by using a single-master/multiple-slave setup, you can scale the system by adding more slaves until you either run out of network bandwidth, or your update load grows to the point that the master cannot handle it.

To determine how many slaves you can use before the added benefits begin to level out, and how much you can improve performance of your site, you need to know your query patterns, and to determine empirically by benchmarking the relationship between the throughput for reads (reads per second, or `reads`) and for writes (`writes`) on a typical master and a typical slave. The example here shows a rather simplified calculation of what you can get with replication for a hypothetical system.

Let's say that system load consists of 10% writes and 90% reads, and we have determined by benchmarking that `reads` is 1200 – 2 × `writes`. In other words, the system can do 1,200 reads per second with no writes, the average write is twice as slow as the average read, and the relationship is linear. Let us suppose that the master and each slave have the same capacity, and that we have one master and *N* slaves. Then we have for each server (master or slave):

`reads = 1200 – 2 × writes`

`reads = 9 × writes / (N + 1)` (reads are split, but writes go to all servers)

`9 × writes / (N + 1) + 2 × writes = 1200`

`writes = 1200 / (2 + 9/(N+1))`

The last equation indicates the maximum number of writes for *N* slaves, given a maximum possible read rate of 1,200 per minute and a ratio of nine reads per write.

This analysis yields the following conclusions:

- If *N* = 0 (which means we have no replication), our system can handle about 1200/11 = 109 writes per second.
- If *N* = 1, we get up to 184 writes per second.
- If *N* = 8, we get up to 400 writes per second.
- If *N* = 17, we get up to 480 writes per second.
- Eventually, as *N* approaches infinity (and our budget negative infinity), we can get very close to 600 writes per second, increasing system throughput about 5.5 times. However, with only eight servers, we increase it nearly four times.

Note that these computations assume infinite network bandwidth and neglect several other factors that could be significant on your system. In many cases, you may not be able to perform a computation similar to the one just shown that accurately predicts what will happen on your system if you add *N* replication slaves. However, answering the following questions should help you decide whether and by how much replication will improve the performance of your system:

- What is the read/write ratio on your system?
- How much more write load can one server handle if you reduce the reads?

- For how many slaves do you have bandwidth available on your network?

3.4.9: How can I use replication to provide redundancy or high availability?

How you implement redundancy is entirely dependent on your application and circumstances. High-availability solutions (with automatic failover) require active monitoring and either custom scripts or third party tools to provide the failover support from the original MySQL server to the slave.

To handle the process manually, you should be able to switch from a failed master to a pre-configured slave by altering your application to talk to the new server or by adjusting the DNS for the MySQL server from the failed server to the new server.

For more information and some example solutions, see Section 2.6, “Switching Masters During Failover”.

3.4.10: How do I tell whether a master server is using statement-based or row-based binary logging format?

Check the value of the `binlog_format` system variable:

```
mysql> SHOW VARIABLES LIKE 'binlog_format';
```

The value shown is one of `STATEMENT`, `ROW`, or `MIXED`. When `MIXED` mode is in use, row-based replication is preferred but replication switches automatically to statement-based format under certain conditions; see Mixed Binary Logging Format, for information about when this may occur.

3.4.11: How do I tell a slave to use row-based replication?

Slaves automatically know which format to use.

3.4.12: How do I prevent `GRANT` and `REVOKE` statements from replicating to slave machines?

Start the server with the `--replicate-wild-ignore-table=mysql.%` option.

3.4.13: Does replication work on mixed operating systems (for example, the master runs on Linux while slaves run on Mac OS X and Windows)?

Yes.

3.4.14: Does replication work on mixed hardware architectures (for example, the master runs on a 64-bit machine while slaves run on 32-bit machines)?

Yes.

3.5. Troubleshooting Replication

If you have followed the instructions, and your replication setup is not working, the first thing to do is *check the error log for messages*. Many users have lost time by not doing this soon enough after encountering problems.

If you cannot tell from the error log what the problem was, try the following techniques:

- Verify that the master has binary logging enabled by issuing a `SHOW MASTER STATUS` statement. If logging is enabled, `Position` is nonzero. If binary logging is not enabled, verify that you are running the master with the `--log-bin` and `--server-id` options.
- Verify that the slave is running. Use `SHOW SLAVE STATUS` to check whether the `Slave_IO_Running` and `Slave_SQL_Running` values are both `Yes`. If not, verify the options that were used when starting the slave server. For example, `--skip-slave-start` prevents the slave threads from starting until you issue a `START SLAVE` statement.
- If the slave is running, check whether it established a connection to the master. Use `SHOW PROCESSLIST`, find the I/O and SQL threads and check their `State` column to see what they display. See Section 4.1, “Replication Implementation Details”. If the I/O thread state says `Connecting to master`, check the following:
  - Verify the privileges for the user being used for replication on the master.
  - Check that the host name of the master is correct and that you are using the correct port to connect to the master. The port used for replication is the same as used for client network communication (the default is `3306`). For the host name, ensure that the name resolves to the correct IP address.
  - Check that networking on the master has not been disabled. Look for the `skip-networking` option in the configuration file. It should either be commented out or deleted entirely.

  - If the master has a firewall or IP filtering configuration, ensure that the network port being used for MySQL is not being filtered.

  - Check that you can reach the master by using `ping` or `traceroute`/`tracert` to reach the host.

- If the slave was running previously but has stopped, the reason usually is that some statement that succeeded on the master failed on the slave. This should never happen if you have taken a proper snapshot of the master, and never modified the data on the slave outside of the slave thread. If the slave stops unexpectedly, it is a bug or you have encountered one of the known replication limitations described in Section 3.1, "Replication Features and Issues". If it is a bug, see Section 3.6, "How to Report Replication Bugs or Problems", for instructions on how to report it.

- If a statement that succeeded on the master refuses to run on the slave, try the following procedure if it is not feasible to do a full database resynchronization by deleting the slave's databases and copying a new snapshot from the master:

  1. Determine whether the affected table on the slave is different from the master table. Try to understand how this happened. Then make the slave's table identical to the master's and run `START SLAVE`.

  2. If the preceding step does not work or does not apply, try to understand whether it would be safe to make the update manually (if needed) and then ignore the next statement from the master.

  3. If you decide that you can skip the next statement from the master, issue the following statements:

     ```
     mysql> SET GLOBAL SQL_SLAVE_SKIP_COUNTER = N;
     mysql> START SLAVE;
     ```

     The value of *`N`* should be 1 if the next statement from the master does not use `AUTO_INCREMENT` or `LAST_INSERT_ID()`. Otherwise, the value should be 2. The reason for using a value of 2 for statements that use `AUTO_INCREMENT` or `LAST_INSERT_ID()` is that they take two events in the binary log of the master.

     See also `SET GLOBAL SQL_SLAVE_SKIP_COUNTER` Syntax.

  4. If you are sure that the slave started out perfectly synchronized with the master, and that no one has updated the tables involved outside of the slave thread, then presumably the discrepancy is the result of a bug. If you are running the most recent version of MySQL, please report the problem. If you are running an older version, try upgrading to the latest production release to determine whether the problem persists.

3.6. How to Report Replication Bugs or Problems

When you have determined that there is no user error involved, and replication still either does not work at all or is unstable, it is time to send us a bug report. We need to obtain as much information as possible from you to be able to track down the bug. Please spend some time and effort in preparing a good bug report.

If you have a repeatable test case that demonstrates the bug, please enter it into our bugs database using the instructions given in How to Report Bugs or Problems. If you have a "phantom" problem (one that you cannot duplicate at will), use the following procedure:

1. Verify that no user error is involved. For example, if you update the slave outside of the slave thread, the data goes out of synchrony, and you can have unique key violations on updates. In this case, the slave thread stops and waits for you to clean up the tables manually to bring them into synchrony. *This is not a replication problem. It is a problem of outside interference causing replication to fail.*

2. Run the slave with the `--log-slave-updates` and `--log-bin` options. These options cause the slave to log the updates that it receives from the master into its own binary logs.

3. Save all evidence before resetting the replication state. If we have no information or only sketchy information, it becomes difficult or impossible for us to track down the problem. The evidence you should collect is:

   - All binary logs from the master

   - All binary logs from the slave

   - The output of `SHOW MASTER STATUS` from the master at the time you discovered the problem

   - The output of `SHOW SLAVE STATUS` from the slave at the time you discovered the problem

   - Error logs from the master and the slave

4. Use `mysqlbinlog` to examine the binary logs. The following should be helpful to find the problem statement. *`log_pos`* and *`log_file`* are the `Master_Log_File` and `Read_Master_Log_Pos` values from `SHOW SLAVE STATUS`.

   ```
   shell> mysqlbinlog --start-position=log_pos log_file | head
   ```

After you have collected the evidence for the problem, try to isolate it as a separate test case first. Then enter the problem with as much information as possible into our bugs database using the instructions at How to Report Bugs or Problems.

Chapter 4. Replication Implementation

The basic mechanics of replication is based on the master server keeping track of all changes to your databases (updates, deletes, and so on) in its binary logs. The binary log serves as a written record of each to the database from the moment the database was started. The binary log contains records of all the statements which edit or modify either the database structure or the data that the structure contains. Typically `SELECT` statements are not recorded, as they do not modify the database data or structure.

Each slave that connects to the master receives a copy of the binary log, and executes the events within the binary log. This has the effect of repeating the original statements and changes just as they were made on the master. Tables are created or their structure modified, and data is inserted, deleted and updated according to the statements that were originally executed on the master.

Because each slave is independent, the replaying of the statements in the masters binary log can occur on each slave that is connected to the master. In addition, because each slave only receives a copy of the binary log by requesting it from the master (it pulls the data from the master, rather than the master pushing the data to the slave), the slave is able to read and update the copy of the database at its own pace and rate and can start and stop the replication process at will without affecting the master or the slaves ability to update to the latest database status.

For more information on the specifics of the replication implementation, see Section 4.1, "Replication Implementation Details".

Slaves and masters report their status in respect of the replication process regularly so that you can monitor the situation. For information on slave states, see Replication Slave I/O Thread States, and Replication Slave SQL Thread States. For master states, see Replication Master Thread States.

The master binary log is written to a local relay log on the slave before it is processed. The slave also records information about the current position with the master's binary log and the local relayed log. See Section 4.2, "Replication Relay and Status Files".

Databases and tables are updated on the slave according to a set of rules that are applied according to the various configuration options and variables that control statement evaluation. For details on how these rules are applied, see Section 4.3, "How Servers Evaluate Replication Rules".

4.1. Replication Implementation Details

MySQL replication capabilities are implemented using three threads (one on the master server and two on the slave):

- **Slave I/O thread.** When a `START SLAVE` statement is issued on a slave server, the slave creates an *I/O thread*, which connects to the master and asks it to send the updates recorded in its binary logs.

  The slave I/O thread reads the updates that the master' `Binlog Dump` thread sends (see next item) and copies them to local files — known as *relay logs* - in the slave's data directory.

  The state of this thread is shown as `Slave_IO_running` in the output of `SHOW SLAVE STATUS` or as `Slave_running` in the output of `SHOW STATUS`.

- **Binlog dump thread.** The master creates a thread to send the binary log contents to the slave. This thread can be identified in the output of `SHOW PROCESSLIST` on the master as the `Binlog Dump` thread.

  The binlog dump thread acquires a lock on the master's binary log for reading each event that is to be sent to the slave. As soon as the event has been read, the lock is released, even before the event is sent to the slave.

- **Slave SQL thread.** The slave creates this thread to read the relay logs that were written by the slave I/O thread. The *slave SQL thread* is also used to execute the updates contained in the relay logs.

> **MySQL Enterprise**
> For constant monitoring of the status of slaves subscribe to the MySQL Enterprise Monitor. For more information, see http://www.mysql.com/products/enterprise/advisors.html.

In the preceding description, there are three threads per master/slave connection. A master that has multiple slaves creates one binlog dump thread for each currently-connected slave, and each slave has its own I/O and SQL threads.

The slave uses two threads so that reading updates from the master and executing them can be separated into two independent tasks. Thus, the task of reading statements is not slowed down if statement execution is slow. For example, if the slave server has not been running for a while, its I/O thread can quickly fetch all the binary log contents from the master when the slave starts, even if the SQL thread lags far behind. If the slave stops before the SQL thread has executed all the fetched statements, the I/O thread has at least fetched everything so that a safe copy of the statements is stored locally in the slave's relay logs, ready for execution the next time that the slave starts. This enables the master server to purge its binary logs sooner because it no longer needs to wait for the slave to fetch their contents.

The `SHOW PROCESSLIST` statement provides information that tells you what is happening on the master and on the slave regarding replication. See Examining Thread Information, for descriptions of all replicated-related states.

The following example illustrates how the three threads show up in the output from `SHOW PROCESSLIST`.

On the master server, the output from `SHOW PROCESSLIST` looks like this:

```
mysql> SHOW PROCESSLIST\G
*************************** 1. row ***************************
     Id: 2
   User: root
   Host: localhost:32931
     db: NULL
Command: Binlog Dump
   Time: 94
  State: Has sent all binlog to slave; waiting for binlog to
         be updated
   Info: NULL
```

Here, thread 2 is a `Binlog Dump` replication thread for a connected slave. The `State` information indicates that all outstanding updates have been sent to the slave and that the master is waiting for more updates to occur. If you see no `Binlog Dump` threads on a master server, this means that replication is not running — that is, that no slaves are currently connected.

On the slave server, the output from `SHOW PROCESSLIST` looks like this:

```
mysql> SHOW PROCESSLIST\G
*************************** 1. row ***************************
     Id: 10
   User: system user
   Host:
     db: NULL
Command: Connect
   Time: 11
  State: Waiting for master to send event
   Info: NULL
*************************** 2. row ***************************
     Id: 11
   User: system user
   Host:
     db: NULL
Command: Connect
   Time: 11
  State: Has read all relay log; waiting for the slave I/O
         thread to update it
   Info: NULL
```

This information indicates that thread 10 is the I/O thread that is communicating with the master server, and thread 11 is the SQL thread that is processing the updates stored in the relay logs. At the time that the `SHOW PROCESSLIST` was run, both threads were idle, waiting for further updates.

The value in the `Time` column can show how late the slave is compared to the master. See Section 3.4, “Replication FAQ”. The amount of time that the slave lags behind the master that is required before the master determines that the slave is no longer connected — as with any other client connection — is dependent on the values of `net_write_timeout` and `net_retry_count`; for more information about these, see Server System Variables.

4.2. Replication Relay and Status Files

During replication the MySQL server creates a number of files that are used to hold the relayed binary log from the master, and record information about the current status and location within the relayed log. There are three file types used in the process:

- The *relay log* consists of the events read from the binary log of the master. Events in this binary log are executed on the slave as part of the replication thread.
- The *master.info* file contains the status and current configuration information for the slave's connectivity to the master. The file holds information on the master host name, login credentials, and the current position within the master's binary log.
- The *relay-log.info* file holds the status information about the execution point within the slave's relay log files.

The relationship between the three files and the replication process is as follows. The `master.info` file retains the point within the master binary log that has been read from the master. These read events are written to the relay log. The `relay-log.info` file records the position within the relay log of the statements that have been executed.

4.2.1. The Slave Relay Log

By default, relay log file names have the form *`host_name`*`-relay-bin.`*`nnnnnn`*, where *`host_name`* is the name of the slave server host and *nnnnnn* is a sequence number. Successive relay log files are created using successive sequence numbers, beginning with 000001. The slave uses an index file to track the relay log files currently in use. The default relay log index file name is *host_name*-relay-bin.index. By default, the slave server creates relay log files in its data directory.

The default file names for relay logs and relay log index files can be overridden with, respectively, the --relay-log and --relay-log-index server options (see Section 1.3, "Replication and Binary Logging Options and Variables"). For this reason, changing a replication slave's host name can cause replication to fail with the errors FAILED TO OPEN THE RELAY LOG and COULD NOT FIND TARGET LOG DURING RELAY LOG INITIALIZATION. This is a known issue which we intend to fix in a future MySQL release (see Bug#2122). If you anticipate that a slave's host name may change in the future (for example, if networking is set up on the slave such that its host name can be modified via DHCP), then you can use these options to prevent this problem from occurring. However, if you encounter this issue, one way to work around it is to stop the slave server, prepend the contents of the old relay log index file to the new one, then restart the slave. On a Unix system, this can be done as shown here, where *new_host_name* is the new host name and *old_host_name* is the old one:

```
shell> cat new_host_name-relay-bin.index >> old_host_name-relay-bin.index
shell> mv old_host_name-relay-bin.index new_host_name-relay-bin.index
```

Relay logs have the same format as binary logs and can be read using mysqlbinlog. The SQL thread automatically deletes each relay log file as soon as it has executed all events in the file and no longer needs it. There is no explicit mechanism for deleting relay logs because the SQL thread takes care of doing so. However, FLUSH LOGS rotates relay logs, which influences when the SQL thread deletes them.

A slave server creates a new relay log file under the following conditions:

- Each time the I/O thread starts.
- When the logs are flushed; for example, with FLUSH LOGS or mysqladmin flush-logs.
- When the size of the current relay log file becomes too large. The meaning of "too large" is determined as follows:
  - If the value of max_relay_log_size is greater than 0, that is the maximum relay log file size.
  - If the value of max_relay_log_size is 0, max_binlog_size determines the maximum relay log file size.

4.2.2. The Slave Status Files

A slave replication server creates two small files in the data directory. These *status files* are named master.info and relay-log.info by default. Their names can be changed by using the --master-info-file and --relay-log-info-file options. See Section 1.3, "Replication and Binary Logging Options and Variables".

The two status files contain information like that shown in the output of the SHOW SLAVE STATUS statement, which is discussed in SQL Statements for Controlling Slave Servers. Because the status files are stored on disk, they survive a slave server's shutdown. The next time the slave starts up, it reads the two files to determine how far it has proceeded in reading binary logs from the master and in processing its own relay logs.

The I/O thread updates the master.info file. The following table shows the correspondence between the lines in the file and the columns displayed by SHOW SLAVE STATUS.

Line	Status Column	Description
1		Number of lines in the file
2	Master_Log_File	The name of the master binary log currently being read from the master.
3	Read_Master_Log_Pos	The current position within the master binary log that have been read from the master.
4	Master_Host	The host name of the master.
5	Master_User	The user name used to connect to the master.
6	Password (not shown by SHOW SLAVE STATUS)	The password used to connect to the master.
7	Master_Port	The network port used to connect to the master.
8	Connect_Retry	The period (in seconds) that the slave will wait before trying to reconnect to the master.
9	Master_SSL_Allowed	Indicates whether the server supports SSL connections.
10	Master_SSL_CA_File	The file used for the Certificate Authority (CA) certificate.
11	Master_SSL_CA_Path	The path to the Certificate Authority (CA) certificates.

12	`Master_SSL_Cert`	The name of the SSL certificate file.
13	`Master_SSL_Cipher`	The name of the cipher in use for the SSL connection.
14	`Master_SSL_Key`	The name of the SSL key file.
15	`Master_SSL_Verify_Server_Cert`	Whether to verify the server certificate.
17	`Replicate_Ignore_Server_Ids`	The number of server IDs to be ignored, followed by the actual server IDs. Added in MySQL 6.0.10.

The SQL thread updates the `relay-log.info` file. The following table shows the correspondence between the lines in the file and the columns displayed by `SHOW SLAVE STATUS`.

Line	**Status Column**	**Description**
1	`Relay_Log_File`	The name of the current relay log file.
2	`Relay_Log_Pos`	The current position within the relay log file. Events up to this position have been executed on the slave database.
3	`Relay_Master_Log_File`	The name of the master binary log file from which the events in the relay log file were read.
4	`Exec_Master_Log_Pos`	The equivalent position within the master's binary log file of events that have already been executed.

The contents of the `relay-log.info` file and the states shown by the `SHOW SLAVE STATES` command may not match if the `relay-log.info` file has not been flushed to disk. Ideally, you should only view `relay-log.info` on a slave that is offline (i.e. `mysqld` is not running). For a running system, `SHOW SLAVE STATUS` should be used.

4.3. How Servers Evaluate Replication Rules

If a master server does not write a statement to its binary log, the statement is not replicated. If the server does log the statement, the statement is sent to all slaves and each slave determines whether to execute it or ignore it.

On the master you can control which databases write events to the binary log using the `--binlog-do-db` and `--binlog-ignore-db` options to control binary logging. For a description of the rules that servers use in evaluating these options, see The Binary Log. You should not use these options to control the databases and tables that are replicated, instead, use filtering on the slave to control the events that are executed on the slave.

On the slave side, decisions about whether to execute or ignore statements received from the master are made according to the `--replicate-*` options that the slave was started with. (See Section 1.3, “Replication and Binary Logging Options and Variables”.) The slave evaluates these options using the following procedure, which first checks the database-level options and then the table-level options.

In the simplest case, when there are no `--replicate-*` options, the procedure yields the result that the slave executes all statements that it receives from the master. Otherwise, the result depends on the particular options given. In general, to make it easier to determine what effect an option set will have, it is recommended that you avoid mixing “do” and “ignore” options, or wildcard and non-wildcard options.

Stage 1. Check the database options.

At this stage, the slave checks whether there are any `--replicate-do-db` or `--replicate-ignore-db` options that specify database-specific conditions:

- *No*: Permit the statement and proceed to the table-checking stage.
- *Yes*: Test the options using the same rules as for the `--binlog-do-db` and `--binlog-ignore-db` options to determine whether to permit or ignore the statement. What is the result of the test?
  - *Permit*: Do not execute the statement immediately. Defer the decision and proceed to the table-checking stage.
  - *Ignore*: Ignore the statement and exit.

This stage can permit a statement for further option-checking, or cause it to be ignored. However, statements that are permitted at this stage are not actually executed yet. Instead, they pass to the following stage that checks the table options.

Stage 2. Check the table options.

First, as a preliminary condition, the slave checks whether statement-based replication is enabled. If so and the statement occurs within a stored function, execute the statement and exit. (If row-based replication is enabled, the slave does not know whether a statement occurred within a stored function on the master, so this condition does not apply.)

Next, the slave checks for table options and evaluates them. If the server reaches this point, it executes all statements if there are no table options. If there are "do" table options, the statement must match one of them if it is to be executed; otherwise, it is ignored. If there are any "ignore" options, all statements are executed except those that match any "ignore" option. The following steps describe how this evaluation occurs in more detail.

1. Are there any `--replicate-*-table` options?
   - *No*: There are no table restrictions, so all statements match. Execute the statement and exit.
   - *Yes*: There are table restrictions. Evaluate the tables to be updated against them. There might be multiple tables to update, so loop through the following steps for each table looking for a matching option. In this case, the behavior depends on whether statement-based replication or row-based replication is enabled:
     - *Statement-based replication*: Proceed to the next step and begin evaluating the table options in the order shown (first the non-wild options, and then the wild options). Only tables that are to be updated are compared to the options. For example, if the statement is `INSERT INTO sales SELECT * FROM prices`, only `sales` is compared to the options). If several tables are to be updated (multiple-table statement), the first table that matches "do" or "ignore" wins. That is, the server checks the first table against the options. If no decision could be made, it checks the second table against the options, and so on.
     - *Row-based replication*: All table row changes are filtered individually. For multiple-table updates, each table is filtered separately according to the options. Some updates may be executed and some not, depending on the options and the changes to be made. Row-based replication correctly handles cases that would not replicate correctly with statement-based replication, as in this example which assumes that tables in the `foo` database should be replicated:

       ```
       mysql> USE bar;
       mysql> INSERT INTO foo.sometable VALUES (1);
       ```

2. Are there any `--replicate-do-table` options?
   - *No*: Proceed to the next step.
   - *Yes*: Does the table match any of them?
     - *No*: Proceed to the next step.
     - *Yes*: Execute the statement and exit.
3. Are there any `--replicate-ignore-table` options?
   - *No*: Proceed to the next step.
   - *Yes*: Does the table match any of them?
     - *No*: Proceed to the next step.
     - *Yes*: Ignore the statement and exit.
4. Are there any `--replicate-wild-do-table` options?
   - *No*: Proceed to the next step.
   - *Yes*: Does the table match any of them?
     - *No*: Proceed to the next step.
     - *Yes*: Execute the statement and exit.
5. Are there any `--replicate-wild-ignore-table` options?
   - *No*: Proceed to the next step.
   - *Yes*: Does the table match any of them?
     - *No*: Proceed to the next step.

    - *Yes*: Ignore the statement and exit.

6. No `--replicate-*-table` option was matched. Is there another table to test against these options?

   - *No*: We have now tested all tables to be updated and could not match any option. Are there `--replicate-do-table` or `--replicate-wild-do-table` options?

     - *No*: There were no “do” table options, so no explicit “do” match is required. Execute the statement and exit.

     - *Yes*: There were “do” table options, so the statement is executed only with an explicit match to one of them. Ignore the statement and exit.

   - *Yes*: Loop.

Examples:

- No `--replicate-*` options at all

  The slave executes all statements that it receives from the master.

- `--replicate-*-db` options, but no table options

  The slave permits or ignores statements using the database options. Then it executes all statements permitted by those options because there are no table restrictions.

- `--replicate-*-table` options, but no database options

  All statements are permitted at the database-checking stage because there are no database conditions. The slave executes or ignores statements based on the table options.

- A mix of database and table options

  The slave permits or ignores statements using the database options. Then it evaluates all statements permitted by those options according to the table options. In some cases, this process can yield what might seem a counterintuitive result. Consider the following set of options:

  ```
  [mysqld]
  replicate-do-db    = db1
  replicate-do-table = db2.mytbl2
  ```

  Suppose that `db1` is the default database and the slave receives this statement:

  ```
  INSERT INTO mytbl1 VALUES(1,2,3);
  ```

  The database is `db1`, which matches the `--replicate-do-db` option at the database-checking stage. The algorithm then proceeds to the table-checking stage. If there were no table options, the statement would be executed. However, because the options include a “do” table option, the statement must match if it is to be executed. The statement does not match, so it is ignored. (The same would happen for any table in `db1`.)