Galera Cluster Documentation

Release

Codership Oy

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CONTENTS

Galera Cluster is a synchronous multi-master database cluster, based on synchronous replication and Oracle's MySQL/InnoDB. When Galera Cluster is in use, you can direct reads and writes to any node, and you can lose any individual node without interruption in operations and without the need to handle complex failover procedures.

At a high level, Galera Cluster consists of a database server—that is, MySQL, MariaDB or Percona XtraDB—that then uses the *Galera Replication Plugin* to manage replication. To be more specific, the MySQL replication plugin API has been extended to provide all the information and hooks required for true multi-master, synchronous replication. This extended API is called the Write-Set Replication API, or wsrep API.

Through the wsrep API, Galera Cluster provides certification-based replication. A transaction for replication, the write-set, not only contains the database rows to replicate, but also includes information on all the locks that were held by the database during the transaction. Each node then certifies the replicated write-set against other write-sets in the applier queue. The write-set is then applied, if there are no conflicting locks. At this point, the transaction is considered committed, after which each node continues to apply it to the tablespace.

This approach is also called virtually synchronous replication, given that while it is logically synchronous, the actual writing and committing to the tablespace happens independently, and thus asynchronously on each node.

Benefits of Galera Cluster

Galera Cluster provides a significant improvement in high-availability for the MySQL ecosystem. The various ways to achieve high-availability have typically provided only some of the features available through Galera Cluster, making the choice of a high-availability solution an exercise in tradeoffs.

The following features are available through Galera Cluster:

- **True Multi-master** Read and write to any node at any time.
- **Synchronous Replication** No slave lag, no data is lost at node crash.
- **Tightly Coupled** All nodes hold the same state. No diverged data between nodes allowed.
- **Multi-threaded Slave** For better performance. For any workload.
- **No Master-Slave Failover Operations or Use of VIP.**
- **Hot Standby** No downtime during failover (since there is no failover).
- **Automatic Node Provisioning** No need to manually back up the database and copy it to the new node.
- **Supports InnoDB.**
- **Transparent to Applications** Required no (or minimal) changes) to the application.
- **No Read and Write Splitting Needed.**

The result is a high-availability solution that is both robust in terms of data integrity and high-performance with instant failovers.

Cloud Implementations with Galera Cluster

An additional benefit of Galera Cluster is good cloud support. Automatic node provisioning makes elastic scale-out and scale-in operations painless. Galera Cluster has been proven to perform extremely well in the cloud, such as when using multiple small node instances, across multiple data centers—AWS zones, for example—or even over Wider Area Networks.

Part I

Getting Started

Galera Cluster for MySQL is a synchronous replication solution that can improve availability and performance of MySQL service. All Galera Cluster nodes are identical and fully representative of the cluster and allow unconstrained transparent `mysql` client access, acting as a single-distributed MySQL server. It provides:

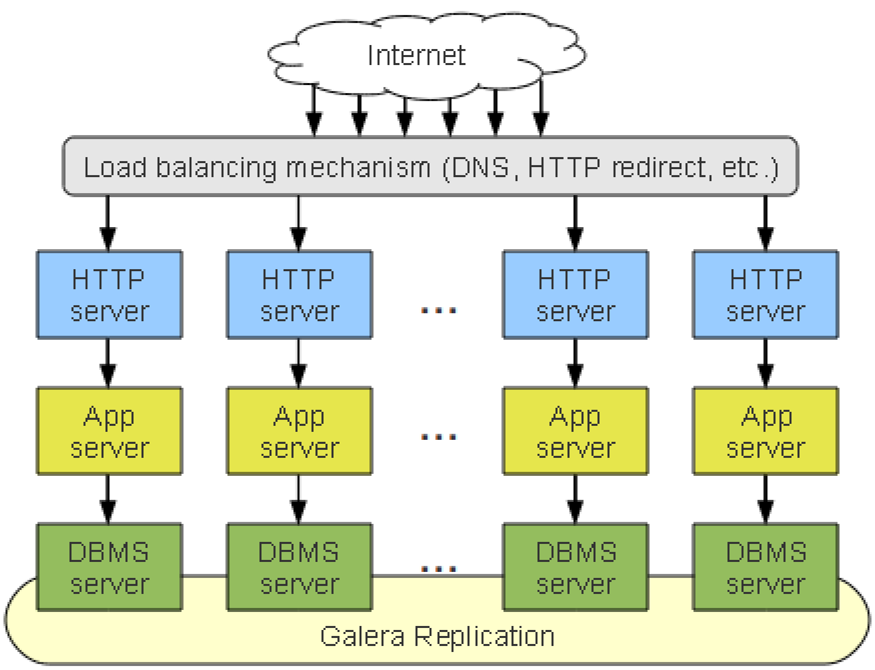
- Transparent client connections, so it's highly compatible with existing applications;
- Synchronous data safety semantics—if a client received confirmation, transactions will be committed on every node; and
- Automatic write conflict detection and resolution, so that nodes are always consistent.

Galera Cluster is well suited for LAN (Local Area Network), WAN (Wide Area Network), and cloud environments. This Getting Started chapter will help you to get started with a basic Galera Cluster. You will need root access to three Linux hosts and their IP Addresses.

How Galera Cluster Works

The primary focus is data consistency. The transactions are either applied on every node or not all. So, the databases stay synchronized, provided that they were properly configured and synchronized at the beginning.

The *Galera Replication Plugin* differs from the standard MySQL Replication by addressing several issues, including multi-master write conflicts, replication lag and slaves being out of sync with the master.



In a typical instance of a Galera Cluster, applications can write to any node in the cluster and transaction commits, (RBR events), are then applied to all the servers, through certification-based replication.

Certification-based replication is an alternative approach to synchronous database replication, using group communication and transaction ordering techniques.

Note: For security and performance reasons, it's recommended that you run Galera Cluster on its own subnet.

CHAPTER ONE

WHAT'S NEW IN GALERA CLUSTER 4.X

With the latest release of Galera Cluster in the 4.x branch, a number of new features are now available to you, including,

- **Non-Blocking Operations** When performing DDL statements that update, analyze or optimize tables, you can now use the Non-Blocking Operation online schema upgrade method. Unlike other methods, this allows you to update the cluster schema without blocking reads on the nodes.

  For more information, see *Non-Blocking Operations* (page 100).

- **Streaming Replication** Under normal operation, the node initiates all replication and certification operations when the transaction commits. In large transactions, this can result in conflicts, as smaller transactions can get in first and cause the large transactions to abort. With Streaming Replication, the node breaks the transaction down into fragments, then certifies and replicates them on all slaves nodes while the transaction is still in progress. Once certified, conflicting transactions can no longer abort the fragment.

  This provides an alternative replication method for handling large or long-running write transactions, or when working with hot records.

  For more information, see *Streaming Replication* (page 69) and *Using Streaming Replication* (page 103).

- **Synchronization Functions** This version introduces a series of SQL functions for use in wsrep synchronization operations. You can use them to obtain the *Global Transaction ID*, based on either the last write or last seen transaction, as well as setting the node to wait for a specific GTID to replicate and apply, before initiating the next transaction.

  For more information, see *Using Synchronization Functions* (page 211) and *MySQL wsrep Functions* (page 241).

CHAPTER

TWO

NODE INITIALIZATION

Galera Cluster for MySQL is not the same as a standard standalone MySQL database server. You will need to install and configure additional software.

This software runs on any unix-like operating system. You can choose to build from source or to install using Debian- or RPM-based binary packages. Once you have the software installed on your individual server, you must also configure the server to function as a node in your cluster.

Installation

Galera Cluster requires server hardware for a minimum of three nodes.

If your cluster runs on a single switch, use three nodes. If your cluster spans switches, use three switches. If your cluster spans networks, use three networks. If your cluster spans data centers, use three data centers. This ensures that the cluster can maintain a Primary Component in the event of network outages.

For server hardware, each node requires at a minimum:

- 1GHz single core CPU
- 512MB RAM
- 100 Mbps network connectivity

Note: **See Also**: Galera Cluster may occasionally crash when run on limited hardware due to insufficient memory. To prevent this, ensure that you have sufficient swap space available. For more information on how to create swap space, see *Configuring Swap Space* (page 29).

For software, each node in the cluster requires:

- Linux or FreeBSD;
- MySQL, MariaDB or Percona XtraDB server with wsrep API patch;
- Galera Replication Plugin.

Note: Binary installation packages for Galera Cluster include the database server with the wsrep API patch. When building from source, you must apply this patch yourself.

Preparing the Server

Before you begin the installation process, there are a few tasks that you need to undertake to prepare the servers for Galera Cluster. You must perform the following steps for each node in your cluster.

Disabling SELinux for mysqld

If you have SELinux enabled, it may block `mysqld` from carrying out required operations. You must either disable SELinux for mysqld or configure it to allow `mysqld` to run external programs and open listen sockets on unprivileged ports—that is, things that an unprivileged user can do.

To disable SELinux for mysql run the following command:

```
# semanage permissive -a mysqld_t
```

This command switches SELinux into permissive mode when it registers activity from the database server. While this is fine during the installation and configuration process, it is not in general a good policy to disable applications that improve security.

In order to use SELinux with Galera Cluster, you need to create an access policy, so that SELinux can understand and allow normal operations from the database server. For information on how to create an access policy, see *SELinux Configuration* (page 177).

Note: See Also: For more information on writing SELinux policies, see SELinux and MySQL.

Firewall Configuration

Next, you need to update the firewall settings on each node so that they can communicate with the cluster. How you do this varies depending upon your distribution and the particular firewall software that you use.

Note: If there is a NAT (Network Address Translation) firewall between the nodes, you must configure it to allow for direct connections between the nodes, such as through port forwarding.

As an example, to open ports between trusted hosts using `iptables` the commands you run on each would look something like this:

```
# iptables --append INPUT --protocol tcp \
      --source 64.57.102.34 --jump ACCEPT
# iptables --apend INPUT --protocol tcp \
      --source 193.166.33.20 --jump ACCEPT
# iptables --append INPUT --protocol tcp \
      --source 193.125.4.10 --jump ACCEPT
```

This causes packet filtering on the kernel to accept TCP (Transmission Control Protocol) connections between the given IP addresses.

Note: Warning: The IP addresses in the example are for demonstration purposes only. Use the real values from your nodes and netmask in the `iptables` configuration for your cluster.

The updated packet filtering rules take effect immediately, but are not persistent. When the server reboots, it reverts to default packet filtering rules, which do not include your updates. To use these rules after rebooting, you need to save them as defaults.

For systems that use `init`, run the following command:

```
# service save iptables
```

For systems that use `systemd`, you need to save the current packet filtering rules to the path that the `iptables` unit reads when it starts. This path can vary by distribution, but you can normally find it in the `/etc` directory.

- `/etc/sysconfig/iptables`
- `/etc/iptables/iptables.rules`

When you find the relevant file, you can save the rules using the `iptables-save` command, then redirecting the output to overwrite this file.

```
# iptables-save > /etc/sysconfig/iptables
```

When `iptables` starts it now reads the new defaults, with your updates to the firewall.

Note: See Also: For more information on setting up the firewall for Galera Cluster and other programs for configuring packet filtering in Linux and FreeBSD, see *Firewall Settings* (page 163).

Disabling AppArmor

By default, some servers—for instance, Ubuntu—include AppArmor, which may prevent `mysqld` from opening additional ports or running scripts. You must disable AppArmor or configure it to allow `mysqld` to run external programs and open listen sockets on unprivileged ports.

To disable AppArmor, run the following commands:

```
$ sudo ln -s /etc/apparmor.d/usr /etc/apparmor.d/disable/.sbin.mysqld
```

You will then need to restart AppArmor. If your system uses init scripts, run the following command:

```
$ sudo service apparmor restart
```

If instead, your system uses `systemd`, run the following command instead:

```
$ sudo systemctl restart apparmor
```

Installing Galera Cluster

There are three versions of Galera Cluster for MySQL: the original Codership reference implementation; Percona XtraDB Cluster; and MariaDB Galera Cluster. For each database server, binary packages are available for Debian- and RPM-based Linux distributions, or you can build them from source.

Galera Cluster for MySQL

Galera Cluster for MySQL - Binary Installation

Galera Cluster for MySQL is the reference implementation from Codership Oy. Binary installation packages are available for Linux distributions using `apt-get`, `yum` and `zypper` package managers through the Codership repository.

Enabling the Codership repository

In order to install Galera Cluster for MySQL through your package manager, you need to first enable the Codership repository on your system. There are different ways to accomplish this, depending on which Linux distribution and package manager you use.

Enabling the `apt` Repository

For Debian and Debian-based Linux distributions, the procedure for adding a repository requires that you first install the Software Properties. The package names vary depending on your distribution. For Debian, in the terminal run the following command:

```
# apt-get install python-software-properties
```

For Ubuntu or a distribution that derives from Ubuntu, instead run this command:

```
$ sudo apt-get install software-properties-common
```

In the event that you use a different Debian-based distribution and neither of these commands work, consult your distribution's package listings for the appropriate package name.

Once you have the Software Properties installed, you can enable the Codership repository for your system.

1. Add the GnuPG key for the Codership repository.

   ```
   # apt-key adv --keyserver keyserver.ubuntu.com \
         --recv BC19DDBA
   ```

2. Add the Codership repository to your sources list. Using your preferred text editor, create a *galera.list* file in the `/etc/apt/sources.list.d/` directory.

   ```
   # Codership Repository (Galera Cluster for MySQL)
   deb http://releases.galeracluster.com/DIST RELEASE main
   ```

   For the repository address, make the following changes:

   - `DIST` Indicates the name of your Linux distribution. For example, `ubuntu`.
   - `RELEASE` Indicates your distribution release. For example, `wheezy`.

     In the event that you do not know which release you have installed on your server, you can find out using the following command:

     ```
     $ lsb_release -a
     ```

3. Update the local cache.

   ```
   # apt-get update
   ```

Packages in the Codership repository are now available for installation through `apt-get`.

Enabling the `yum` Repository

For RPM-based distributions, such as CentOS, Red Hat and Fedora, you can enable the Codership repository by adding a `.repo` file to the `/etc/yum.repos.d/` directory.

Using your preferred text editor, create the `.repo` file.

```
[galera]
name = Galera
baseurl = http://releases.galeracluster.com/DIST/RELEASE/ARCH
gpgkey = http://releases.galeracluster.com/GPG-KEY-galeracluster.com
gpgcheck = 1
```

In the `baseurl` field, make the following changes to web address:

- `DIST` Indicates the distribution name. For example, `centos` or `fedora`.
- `RELEASE` indicates the distribution release number. For example, `6` for CentOS, `20` or `21` for Fedora.
- `ARCH` indicates the architecture of your hardware. For example, `x86_64` for 64-bit systems.

Packages in the Codership repository are now available for installation through `yum`.

Enabling the `zypper` Repository

For distributions that use `zypper` for package management, such as openSUSE and SUSE Linux Enterprise Server, you can enable the Codership repository by importing the GPG key and then creating a `.repo` file in the local directory.

1. Import the GPG key.

   ```
   $ sudo rpm --import "http://releases.galeracluster.com/GPG-KEY-galeracluster.com"
   ```

2. Create a `galera.repo` file in the local directory.

   ```
   [galera]
   name = Galera
   baseurl = http://releases.galeracluster.com/DIST/RELEASE
   ```

   For the `baseurl` repository address, make the following changes:

   - `DIST` indicates the distribution name. For example, `opensuse` or `sles`.
   - `RELEASE` indicates the distribution version number.

3. Add the Codership repository.

   ```
   $ sudo zypper addrepo galera.repo
   ```

4. Refresh `zypper`.

   ```
   $ sudo zypper refresh
   ```

Packages in the Codership repository are now available for installation through `zypper`.

Installing Galera Cluster for MySQL

There are two packages involved in the installation of Galera Cluster for MySQL: the MySQL database server, built to include the *wsrep API*; and the *Galera Replication Plugin*.

Note: For Debian-based distributions, you also need to include a third package, *Galera Arbitrator*. This is only necessary with `apt-get`. The `yum` and `zypper` repositories package Galera Arbitrator with the Galera Replication Plugin.

For Debian-based distributions, run the following command:

```
# apt-get install galera-3 \
            galera-arbitrator-3 \
            mysql-wsrep-5.6
```

For Red Hat, Fedora and CentOS distributions, instead run this command:

```
# yum install galera-3 \
            mysql-wsrep-5.6
```

Note: On CentOS 6 and 7, this command may generate a transaction check error. For more information on this error and how to fix it, see *MySQL Shared Compatibility Libraries* (page 14).

For openSUSE and SUSE Linux Enterprise Server, run this command:

```
# zypper install galera-3 \
            mysql-wsrep-5.6
```

Galera Cluster for MySQL is now installed on your server. You need to repeat this process for each node in your cluster.

Note: **See Also**: In the event that you installed Galera Cluster for MySQL over an existing standalone instance of MySQL, there are some additional steps that you need to take in order to update your system to the new database server. For more information, see *Migrating to Galera Cluster* (page 189).

MySQL Shared Compatibility Libraries

When installing Galera Cluster for MySQL on CentOS, versions 6 and 7, you may encounter a transaction check error that blocks the installation.

```
Transaction Check Error:
file /usr/share/mysql/czech/errmsg.sys from install
mysql-wsrep-server-5.6-5.6.23-25.10.e16.x86_64 conflicts
with file from package mysql-libs-5.1.73-.3.e16_5.x86_64
```

This relates to a dependency issue between the version of the MySQL shared compatibility libraries that CentOS uses and the one that Galera Cluster requires. Upgrades are available through the Codership repository and you can install them with `yum`.

There are two versions available for this package. The version that you need depends on which version of the MySQL wsrep database server that you want to install. Additionally, the package names themselves vary depending on the version of CentOS.

For CentOS 6, run the following command:

```
# yum upgrade -y mysql-wsrep-libs-compat-VERSION
```

Replace `VERSION` with `5.5` or `5.6`, depending upon the version of MySQL you want to use. For CentOS 7, to install MySQL version 5.6, run the following command:

```
# yum upgrade mysql-wsrep-shared-5.6
```

For CentOS 7, to install MySQL version 5.5, you also need to disable the 5.6 upgrade:

```
# yum upgrade -y mysql-wsrep-shared-5.5 \
      -x mysql-wsrep-shared-5.6
```

When `yum` finishes the upgrade, install the MySQL wsrep database server and the Galera Replication Plugin as described above.

Galera Cluster for MySQL - Source Installation

Galera Cluster for MySQL is the reference implementation from Codership Oy. Binary installation packages are available for Debian- and RPM-based distributions of Linux. In the event that your Linux distribution is based upon a different package management system, if your server uses a different unix-like operating system, such as Solaris or FreeBSD, you will need to build Galera Cluster for MySQL from source.

Note: See Also: In the event that you built Galera Cluster for MySQL over an existing standalone instance of MySQL, there are some additional steps that you need to take in order to update your system to the new database server. For more information, see *Migrating to Galera Cluster* (page 189).

Installing Build Dependencies

When building from source code, `make` cannot manage or install dependencies for either Galera Cluster or the build process itself. You need to install these first. For Debian-based systems, run the following command:

```
# apt-get build-dep mysql-server
```

For RPM-based distributions, instead run this command:

```
# yum-builddep MySQL-server
```

In the event that neither command works on your system or that you use a different Linux distribution or FreeBSD, the following packages are required:

- **MySQL Database Server with wsrep API**: Git, CMake, GCC and GCC-C++, Automake, Autoconf, and Bison, as well as development releases of libaio and ncurses.
- **Galera Replication Plugin**: SCons, as well as development releases of Boost, Check and OpenSSL.

Check with the repositories for your distribution or system for the appropriate package names to use during installation. Bear in mind that different systems may use different names and that some may require additional packages to run. For instance, to run CMake on Fedora you need both `cmake` and `cmake-fedora`.

Building Galera Cluster for MySQL

The source code for Galera Cluster for MySQL is available through GitHub. You can download the source code from the website or directly using `git`. In order to build Galera Cluster, you need to download both the database server with the wsrep API patch and the *Galera Replication Plugin*.

To download the database server, complete the following steps:

1. Clone the Galera Cluster for MySQL database server source code.

```
# git clone https://github.com/codership/mysql-wsrep
```

2. Checkout the branch for the version that you want to use.

```
# git checkout 5.6
```

   The main branches available for Galera Cluster for MySQL are:

   - `5.6`
   - `5.5`

You now have the source files for the MySQL database server, including the wsrep API patch needed for it to function as a Galera Cluster node.

In addition to the database server, you need the wsrep Provider, also known as the Galera Replication Plugin. In a separator directory, run the following command:

```
# cd ..
# git clone https://github.com/codership/galera.git
```

Once Git finishes downloading the source files, you can start building the database server and the Galera Replication Plugin. The above procedures created two directories: `mysql-wsrep/` for the database server source and for the Galera source `galera/`

Building the Database Server

The database server for Galera Cluster is the same as that of the standard database servers for standalone instances of MySQL, with the addition of a patch for the wsrep API, which is packaged in the version downloaded from GitHub. You can enable the patch through the wsrep API, requires that you enable it through the `WITH_WSREP` and `WITH_INNODB_DISALLOW_WRITES` CMake configuration options.

To build the database server, `cd` into the `mysql-wsrep/` directory and run the following commands:

```
# cmake -DWITH_WSREP=ON -DWITH_INNODB_DISALLOW_WRITES=ON ./
# make
# make install
```

Building the wsrep Provider

The *Galera Replication Plugin* implements the *wsrep API* and operates as the wsrep Provider for the database server. What it provides is a certification layer to prepare write-sets and perform certification checks, a replication layer and a group communication framework.

To build the Galera Replicator plugin, `cd` into the `galera/` directory and run SCons:

```
# scons
```

This process creates the Galera Replication Plugin, (that is, the `libgalera_smm.so` file). In your `my.cnf` configuration file, you need to define the path to this file for the *wsrep_provider* (page 229) parameter.

Note: For FreeBSD users, building the Galera Replicator Plugin from source raises certain Linux compatibility issues. You can mitigate these by using the ports build at `/usr/ports/databases/galera`.

Post-installation Configuration

After the build completes, there are some additional steps that you must take in order to finish installing the database server on your system. This is over and beyond the standard configurations listed in *System Configuration* (page 28) and *Replication Configuration* (page 30).

Note: Unless you defined the `CMAKE_INSTALL_PREFIX` configuration variable when you ran `cmake` above, by default the database server installed to the path `/usr/local/mysql/`. If you chose a custom path, adjust the commands below to accommodate the change.

1. Create the user and group for the database server.

   ```
   # groupadd mysql
   # useradd -g mysql mysql
   ```

2. Install the database.

   ```
   # cd /usr/local/mysql
   # ./scripts/mysql_install_db --user=mysql
   ```

   This installs the database in the working directory. That is, at `/usr/local/mysql/data/`. If you would like to install it elsewhere or run it from a different directory, specify the desired path with the `--basedir` and `--datadir` options.

3. Change the user and group for the directory.

   ```
   # chown -R mysql /usr/local/mysql
   # chgrp -R mysql /usr/local/mysql
   ```

4. Create a system unit.

   ```
   # cp /usr/local/mysql/supported-files/mysql.server \
         /etc/init.d/mysql
   # chmod +x /etc/init.d/mysql
   # chkconfig --add mysql
   ```

   This allows you to start Galera Cluster using the `service` command. It also sets the database server to start during boot.

In addition to this procedure, bear in mind that any custom variables you enabled during the build process, such as a nonstandard base or data directory, requires that you add parameters to cover this in the configuration file, (that is, `my.cnf`).

Note: This tutorial omits MySQL authentication options for brevity.

Percona XtraDB Cluster

Percona XtraDB Cluster - Binary Installation

Percona XtraDB Cluster is the Percona implementation of Galera Cluster for MySQL. Binary installation packages are available for Debian- and RPM-based distributions through the Percona repository.

Enabling the Percona Repository

In order to install Percona XtraDB Cluster through your package manager, you need to first enable the Percona repository on your system. There are two different ways to accomplish this, depending upon which Linux distribution you use.

Enabling the `apt` Repository

For Debian and Debian-based Linux distributions, the procedure for adding the Percona repository requires that you first install Software Properties on your system. The package names vary depending upon which distribution you use. For Debian, in the terminal run the following command:

```
# apt-get install python-software-properties
```

For Ubuntu, instead run this command:

```
$ sudo apt-get install software-properties-common
```

In the event that you use a different Debian-based distribution and neither of these commands work, consult your distribution's package listings for the appropriate package name.

Once you have Software Properties installed, you can enable the Percona repository for your system.

1. Add the GnuPG key for the Percona repository:

   ```
   # add-key adv --recv-keys --keyserver \
         keyserver.ubuntu.com 1C4CBDCDCD2EFD2A
   ```

2. Add the Percona repository to your sources list:

   ```
   # add-apt-repository 'deb http://repo.percona.com/apt release main'
   ```

   For the repository address, make the following changes:

   - `release` Indicates the release name for the distribution you are using. For example, `wheezy`.

     In the event that you do not know which release you have installed on your server, you can find out using the following command:

     ```
     $ lsb_release -a
     ```

3. Update the local cache.

```
# apt-get update
```

For more information on the repository, available packages and mirrors, see the Percona apt Repository

Packages in the Percona repository are now available for installation on your server through `apt-get`.

Enabling the `yum` Repository

For RPM-based distributions, you can enable the Percona repository through `yum` using the following command:

```
# yum install http://www.percona.com/downloads/percona-release/redhat/0.1-3/percona-
↪release-0.1-3.noarch.rpm
```

For more information on the repository, package names or available mirrors, see the Percona yum Repository.

Packages in the Percona repository are now available for installation on your server through `yum`.

Installing Percona XtraDB Cluster

There are three packages involved in the installation of Percona XtraDB Cluster: the Percona XtraDB client, a command line tool for accessing the database; the percona XtraDB database server, built to include the *wsrep API* patch and the *Galera Replication Plugin*.

For most Debian-based distributions, you can install all of these through a single package. In the terminal run the following command:

```
# apt-get install percona-xtradb-cluster
```

For Ubuntu and distributions that derive from Ubuntu, however, you will need to specify the meta package. In the terminal, run this command instead:

```
$ sudo apt-get install percona-xtradb-cluster
      percona-xtradb-cluster-galera
```

For RPM-based distributions, instead run this command:

```
# yum install Percona-XtraDB-Cluster
```

Percona XtraDB Cluster is now installed on your server.

Note: **See Also**: In the event that you installed Percona XtraDB Cluster over an existing standalone instance of Percona XtraDB, there are some additional steps that you need to take in order to update your system to the new database server. For more information, see *Migrating to Galera Cluster* (page 189).

Percona XtraDB Cluster - Source Installation

Percona XtraDB Cluster is the Percona implementation of Galera Cluster for MySQL. Binary installation packages are available for Debian- and RPM-based distributions of Linux. In the event that your Linux distribution is based on a different package management system or if it runs on a different unix-like operating system where binary installation packages are unavailable, such as Solaris or FreeBSD, you will need to build Percona XtraDB Cluster from source.

Note: **See Also**: In the event that you built Percona XtraDB Cluster over an existing standalone instance of Percona XtraDB, there are some additional steps that you need to take in order to update your system to the new database server. For more information, see *Migrating to Galera Cluster* (page 189).

Preparing the Server

When building from source code, `make` cannot manage or install dependencies necessary for either Galera Cluster itself or the build process. You need to install these packages first.

- For Debian-based distributions of Linux, if Percona is available in your repositories, you can run the following command:

```
# apt-get build-dep percona-xtradb-cluster
```

- For RPM-based distributions, instead run this command:

```
# yum-builddep percona-xtradb-cluster
```

In the event that neither command works for your system or that you use a different Linux distribution or FreeBSD, the following packages are required:

- **Percona XtraDB Database Server with wsrep API**: Git, CMake, GCC and GCC-C++, Automake, Autoconf, and Bison, as well as development releases of libaio and ncurses.
- **Galera Replication Plugin**: SCons, as well as development releases of Boost, Check and OpenSSL.

Check with the repositories for your distribution or system for the appropriate package names to use during installation. Bear in mind that different systems may use different names and that some may require additional packages to run. For instance, to run CMake on Fedora you need both `cmake` and `cmake-fedora`.

Building Percona XtraDB Cluster

The source code for Percona XtraDB Cluster is available through GitHub. Using Git you can download the source to build both Percona XtraDB Cluster and the Galera Replication Plugin locally on your system.

1. Clone the Percona XtraDB Cluster database server.

```
# git clone https://github.com/percona/percona-xtradb-cluster
```

2. Checkout the branch for the version that you want to use.

```
# git checkout 5.6
```

   The main branches available for Percona XtraDB Cluster are:

   - `5.6`
   - `5.5`

You now have the source files for the Percona XtraDB Cluster database server, set to the branch of development that you want to build.

In addition to the database server, you also need the wsrep Provider, also known as the Galera Replication Plugin. In a separate directory, run the following command:

```
# cd ..
# git clone https://github.com/codership/galera.git
```

Once Git finishes downloading the source file,s you can start building the database server and the Galera Replication Plugin. You now have the source file for the database server in a `percona-xtradb-cluster/` and the Galera source files in `galera/`.

Building the Database Server

The database server for Galera Cluster is the same as that of the standard database servers for standalone instances of Percona XtraDB, with the addition of a patch for the wsrep API, which is packaged in the version downloaded from GitHub. You can enable the patch through the wsrep API, requires that you enable it through the `WITH_WSREP` and `WITH_INNODB_DISALLOW_WRITES` CMake configuration options.

To build the database server, `cd` into the `percona-xtradb-cluster` directory and run the following commands:

```
# cmake -DWITH_WSREP=ON -DWITH_INNDOB_DISALLOW_WRITES=ON ./
# make
# make install
```

Note: In addition to compiling through `cmake` and `make`, there are also a number of build scripts available in the `BUILD/` directory, which you may find more convenient to use. For example:

```
# ./BUILD/compile-pentium64
```

This has the same effect as running the above commands with various build options pre-configured. There are several build scripts available in the `BUILD/` directory. Select the one that best suits your nees.

Building the wsrep Provider

The *Galera Replication Plugin* implements the *wsrep API* and operates as the wsrep Provider for the database server. What it provides is a certification layer to prepare write-sets and perform certification checks, a replication layer and a group communication framework.

To build the Galera Replication Plugin, `cd` into the `galera/` directory and run SCons.

```
# scons
```

This process creates the Galera Replication Plugin, (that is, the `libgalera_smm.so` file). In your `my.cnf` configuration file, you need to define the path to this file for the *wsrep_provider* (page 229) parameter.

Note: For FreeBSD users, building the Galera Replication Plugin from sources raises certain Linux compatibility issues. You can mitigate these by using the ports build available at `/usr/ports/databases/galera` or by install the binary package:

```
# pkg install galera
```

Post-installation Configuration

After the build completes, there are some additional steps that you must take in order to finish installing the database server on your system. This is over and beyond the standard configuration process listed in *System Configuration* (page 28) and *Replication Configuration* (page 30).

Note: Unless you defined the `CMAKE_INSTALL_PREFIX` configuration varaible when you ran `cmake` above, by default the database is installed to the path `/usr/local/mysql/`. If you chose a custom path, adjust the commands below to accommodate this change.

1. Create the user and group for the database server.

```
# groupadd mysql
# useradd -g mysql mysql
```

2. Install the database.

```
# cd /usr/local/mysql
# ./scripts/mysql_install_db --user=mysql
```

This installs the database in the working directory, (that is, at `/usr/local/mysql/data`). If you would like to install it elsewhere or run the script from a different directory, specify the desired paths with the `--basedir` and `--datadir` options.

3. Change the user and group permissions for the base directory.

```
# chown -R mysql /usr/local/mysql
# chgrp -R mysql /usr/local/mysql
```

4. Create a system unit for the database server.

```
# cp /usr/local/mysql/supported-files/mysql.server \
      /etc/init.d/mysql
# chmod +x /etc/init.d/mysql
# chkconfig --add mysql
```

This allows you to start Galera Cluster using the `service` command. It also sets the database server to start during boot.

In addition to this procedure, bear in mind that any further customization variables that you enabled during the build process through `cmake`, (such as nonstandard base or data directories), may require you to define addition parameters in the configuration file, (that is, the `my.cnf`).

Note: This tutorial omits MariaDB authentication options for brevity.

MariaDB Galera Cluster

MariaDB Galera Cluster - Binary Installation

MariaDB Galera Cluster is the MariaDB implementation of Galera Cluster for MySQL. Binary installation packages are available for Debian- and RPM-based distributions of Linux through the MariaDB repository.

Enabling the MariaDB Repository

In order to install MariaDB Galera Cluster through your package manager, you need to first enable the MariaDB repository on your system. There are two different ways to accomplish this, depending on which Linux distribution you use.

Enabling the apt Repository

For Debian and Debian-based Linux distributions, the procedure for adding a repository requires that you first install the Software Properties. The package names vary depending on your distribution. For Debian, in the terminal run the following command:

```
# apt-get install python-software-properties
```

For Ubuntu or a distribution that derives from Ubuntu, instead run this command:

```
$ sudo apt-get install software-properties-common
```

In the event that you use a different Debian-based distribution and neither of these commands work, consult your distribution's package listings for the appropriate package name.

Once you have the Software Properties installed, you can enable the MariaDB repository for your system.

1. Add the GnuPG key for the MariaDB repository.

   ```
   # apt-key adv --recv-keys --keyserver \
         keyserver.ubuntu.com 0xcbcb082a1bb943db
   ```

2. Add the MariaDB repository to your sources list.

   ```
   # add-apt-repository 'deb http://mirror.jmu.edu/pub/mariadb/repo/version/distro␣
   ↪release main'
   ```

   For the repository address, make the following changes:

   - `version` Indicates the version number of MariaDB that you want to use. For example, `5.6`.
   - `distro` Indicates the name of your Linux distribution. For example, `ubuntu`.
   - `release` Indicates your distribution release. For example, `wheezy`.

     In the event that you do not know which release you have installed on your server, you can find out using the following command:

     ```
     $ lsb_release -a
     ```

3. Update the local cache.

   ```
   # apt-get update
   ```

For more information on the repository, package names or available mirrors, see the MariaDB Repository Generator.

Packages in the MariaDB repository are now available for installation through `apt-get`.

Enabling the yum Repository

For RPM-based distributions, such as CentOS, Red Hat and Fedora, you can enable the MariaDB repository by adding a .repo file to the /etc/yum/repos.d/ directory.

Using your preferred text editor, create the .repo file.

```
# vim /etc/yum/repos.d/MariaDB.repo

[mariadb]
name = MariaDB
baseurl = http://yum.mariadb.org/version/package
gpgkey = https://yum.mariadb.org/RPM-GPG-KEY-MariaDB
gpgcheck = 1
```

In the baseurl field, make the following changes to web address:

- version Indicates the version of MariaDB you want to use. For example, 5.6.
- package indicates the package name for your distribution, release and architecture. For example, rhel6-amd64 would reference packages for a Red Hat Enterprise Linux 6 server running on 64-bit hardware.

For more information on the repository, package names or available mirrors, see the MariaDB Repository Generator.

Installing MariaDB Galera Cluster

There are three packages involved in the installation of MariaDB Galera Cluster: the MariaDB database client, a command line tool for accessing the database; the MariaDB database server, built to include the *wsrep API* patch; and the *Galera Replication Plugin*.

For Debian-based distributions, in the terminal run the following command:

```
# apt-get install mariadb-client \
      mariadb-galera-server \
      galera
```

For RPM-based distributions, instead run this command:

```
# yum install MariaDB-client \
      MariaDB-Galera-server \
      galera
```

MariaDB Galera Cluster is now installed on your server. You will need to repeat this process for each node in your cluster.

Note: See Also: In the event that you installed MariaDB Galera Cluster over an existing standalone instance of MariaDB, there are some additional steps that you need to take in order to update your system to the new database server. For more information, see *Migrating to Galera Cluster* (page 189).

MariaDB Galera Cluster- Source Installation

MariaDB Galera Cluster is the MariaDB implementation of Galera Cluster for MySQL. Binary installation packages are available for Debian- and RPM-based distributions of Linux. In the event that your Linux distribution is based on a different package management system, or if it runs on a different unix-like operating system where binary installation packages are not available, such as Solaris or FreeBSD, you will need to build MariaDB Galera Cluster from source.

Note: **See Also**: In the event that you built MariaDB Galera Cluster over an existing standalone instance of MariaDB, there are some additional steps that you need to take in order to update your system to the new database server. For more information, see *Migrating to Galera Cluster* (page 189).

Preparing the Server

When building from source code, `make` cannot manage or install dependencies for either Galera Cluster or the build process itself. You need to install these packages first.

- For Debian-based distributions of Linux, if MariaDB is available in your repositories, you can run the following command:

```
# apt-get build-dep mariadb-server
```

- For RPM-based distributions, instead run this command:

```
# yum-builddep MariaDB-server
```

In the event that neither command works for your system or that you use a different Linux distribution or FreeBSD, the following packages are required:

- **MariaDB Database Server with wsrep API**: Git, CMake, GCC and GCC-C++, Automake, Autoconf, and Bison, as well as development releases of libaio and ncurses.
- **Galera Replication Plugin**: SCons, as well as development releases of Boost, Check and OpenSSL.

Check with the repositories for your distribution or system for the appropriate package names to use during installation. Bear in mind that different systems may use different names and that some may require additional packages to run. For instance, to run CMake on Fedora you need both `cmake` and `cmake-fedora`.

Building MariaDB Galera Cluster

The source code for MariaDB Galera Cluster is available through GitHub. Using Git you can download the source code to build MariaDB and the Galera Replicator Plugin locally on your system.

1. Clone the MariaDB database server repository.

```
# git clone https://github.com/mariadb/server
```

2. Checkout the branch for the version that you want to use.

```
# git checkout 10.0-galera
```

   The main branches available for MariaDB Galera Cluster are:

   - `10.1`
   - `10.0-galera`
   - `5.5-galera`

Starting with version 10.1, MariaDB includes the wsrep API for Galera Cluster by default.

Note: **Warning**: MariaDB version 10.1 is still in beta.

You now have the source files for the MariaDB database server with the wsrep API needed to function as a Galera Cluster node.

In addition to the database server, you also need the wsrep Provider, also known as the Galera Replicator Plugin. In a separate directory run the following command:

```
# cd ..
# git clone https://github.com/codership/galera.git
```

Once Git finishes downloading the source files, you can start building the database server and the Galera Replicator Plugin. You now have the source files for the database server in a `server/` directory and the Galera source files in `galera/`.

Building the Database Server

The database server for Galera Cluster is the same as that of the standard database servers for standalone instances of MariaDB, with the addition of a patch for the wsrep API, which is packaged in the version downloaded from GitHub. You can enable the patch through the `WITH_WSREP` and `WITH_INNODB_DISALLOW_WRITES` CMake configuration options.

To build the database server, `cd` into the `server/` directory and run the following commands:

```
# cmake -DWITH_WSREP=ON -DWITH_INNODB_DISALLOW_WRITES=ON ./
# make
# make install
```

Note: In addition to compiling through `cmake` and `make`, there are also a number of build scripts in the `BUILD/` directory, which you may find more convenient to use. For example,

```
# ./BUILD/compile-pentium64-wsrep
```

This has the same effect as running the above commands with various build options pre-configured. There are several build scripts available in the directory, select the one that best suits your needs.

Building the wsrep Provider

The *Galera Replication Plugin* implements the *wsrep API* and operates as the wsrep Provider for the database server. What it provides is a certification layer to prepare write-sets and perform certification checks, a replication layer and a group communication framework.

To build the Galera Replication Plugin, `cd` into the `galera/` directory and run SCons.

```
# scons
```

This process creates the Galera Replication Pluigin, (that is, the `libgalera_smm.so` file). In your `my.cnf` configuration file, you need to define the path to this file for the *wsrep_provider* (page 229) parameter.

Note: For FreeBSD users, building the Galera Replication Plugin from source raises certain issues due to Linux dependencies. You can mitgate these by using the ports build available at `/usr/ports/databases/galera` or by installing the binary package:

```
# pkg install galera
```

Post-installation Configuration

After the build completes, there are some additional steps that you must take in order to finish installing the database server on your system. This is over and beyond the standard configuration process listed in *System Configuration* (page 28) and *Replication Configuration* (page 30).

Note: Unless you defined the `CMAKE_INSTALL_PREFIX` configuration variable when you ran `cmake` above, by default the database is installed to the path `/usr/local/mysql/`. If you chose a custom path, adjust the commands below to accommodate the change.

1. Create the user and group for the database server.

```
# groupadd mysql
# useradd -g mysql mysql
```

2. Install the database.

```
# cd /usr/local/mysql
# ./scripts/mysql_install_db --user=mysql
```

   This installs the database in the working directory, (that is, at `/usr/local/mysql/data`). If you would like to install it elsewhere or run the script from a different directory, specify the desired paths with the `--basedir` and `--datadir` options.

3. Change the user and group permissions for the base directory.

```
# chown -R mysql /usr/local/mysql
# chgrp -R mysql /usr/local/mysql
```

4. Create a system unit for the database server.

```
# cp /usr/local/mysql/supported-files/mysql.server \
      /etc/init.d/mysql
# chmod +x /etc/init.d/mysql
# chkconfig --add mysql
```

   This allows you to start Galera Cluster using the `service` command. It also sets the database server to start during boot.

In addition to this procedure, bear in mind that any further customization variables you enabled during the build process, such as a nonstandard base or data directory, may require you to define additional parameters in the configuration file, (that is, `my.cnf`).

Note: This tutorial omits MariaDB authentication options for brevity.

Note: See Also: In the event that you build or install Galera Cluster over an existing standalone instance of MySQL, MariaDB or Percona XtraDB there are some additional steps that you need to take in order to update your system to the new database server. For more information, see *Migrating to Galera Cluster* (page 189).

System Configuration

When you have finished installing Galera Cluster on your server hardware, you are ready to configure the database itself to serve as a node in your cluster. To do this, you will need to edit the MySQL configuration file.

Using your preferred text editor, edit the `/etc/my.cnf` file.

```
[mysqld]
datadir=/var/lib/mysql
socket=/var/lib/mysql/mysql.sock
user=mysql
binlog_format=ROW
bind-address=0.0.0.0
default_storage_engine=innodb
innodb_autoinc_lock_mode=2
innodb_flush_log_at_trx_commit=0
innodb_buffer_pool_size=122M
wsrep_provider=/usr/lib/libgalera_smm.so
wsrep_provider_options="gcache.size=300M; gcache.page_size=300M"
wsrep_cluster_name="example_cluster"
wsrep_cluster_address="gcomm://IP.node1,IP.node2,IP.node3"
wsrep_sst_method=rsync

[mysql_safe]
log-error=/var/log/mysqld.log
pid-file=/var/run/mysqld/mysqld.pid
```

Configuring Database Server

There are certain basic configurations that you will need to set up in the `/etc/my.cnf` file. Before starting the database server, edit the configuration file for the following:

- Ensure that `mysqld` is not bound to 127.0.0.1. This is IP address for localhost. If the configuration variable appears in the file, comment it out:

  ```
  # bind-address = 127.0.0.1
  ```

- Ensure that the configuration file includes the `conf.d/`.

  ```
  !includedir /etc/mysql/conf.d/
  ```

- Ensure that the binary log format is set to use row-level replication, as opposed to statement-level replication.

  ```
  binlog_format=ROW
  ```

  Do not change this value, as it affects performance and consistency. The binary log can only use row-level replication.

- Ensure that the default storage engine is InnoDB

```
default_storage_engine=InnoDB
```

Galera Cluster will not work with MyISAM or similar nontransactional storage engines.

- Ensure that the InnoDB locking mode for generating auto-increment values is set to interleaved lock mode, which is designated by a `2` value.

```
innodb_autoinc_lock_mode=2
```

Do not change this value. Other modes may cause `INSERT` statements on tables with `AUTO_INCREMENT` columns to fail.

Note: **Warning**: When innodb_autoinc_lock_mode is set to traditional lock mode, indicated by `0`, or to consecutive lock mode, indicated by `1`, in Galera Cluster it can cause unresolved deadlocks and make the system unresponsive.

- Ensure that the InnoDB log buffer is written to file once per second, rather than on each commit, to improve performance.

```
innodb_flush_log_at_trx_commit=0
```

Note: **Warning**: While setting innodb_flush_log_at_trx_commit to a value of `0` or `2` improves performance, it also introduces certain dangers. Operating system crashes or power outages can erase the last second of transaction. Although normally you can recover this data from another node, it can still be lost entirely in the event that the cluster goes down at the same time, (for instance, in the event of a data center power outage).

After you save the configuration file, you are ready to configure the database privileges.

Configuring the InnoDB Buffer Pool

The InnoDB storage engine uses a memory buffer to cache data and indexes of its tables, which you can configure through the innodb_buffer_pool_size parameter. The default value is 128MB. To compensate for the increased memory usage of Galera Cluster over the standalone MySQL database server, you should scale your usual value back by 5%.

```
innodb_buffer_pool_size=122M
```

Configuring Swap Space

Memory requirements for Galera Cluster are difficult to predict with any precision. The particular amount of memory it uses can vary significantly, depending upon the load the given node receives. In the event that Galera Cluster attempts to use more memory than the node has available, the `mysqld` instance crashes.

The way to protect your node from such crashing is to ensure that you have sufficient swap space available on the server, either in the form of a swap partition or swap files. To check the available swap space, run the following command:

```
$ swapon --summary
Filename        Type        Size      Used     Priority
/dev/sda2       partition   3369980   0        -1
```

```
/swap/swap1      file         524284    0        -2
/swap/swap2      file         524284    0        -3
```

If your system does not have swap space available or if the allotted space is insufficient for your needs, you can fix this by creating swap files.

1. Create an empty file on your disk, set the file size to whatever size you require.

   ```
   # fallocate -l 512M /swapfile
   ```

   Alternatively, you can manage the same using `dd`.

   ```
   # dd if=/dev/zero of=/swapfile bs=1M count=512
   ```

2. Secure the swap file.

   ```
   # chmod 600 /swapfile
   ```

   This sets the file permissions so that only the root user can read and write to the file. No other user or group member can access it. You can view the results with `ls`:

   ```
   $ ls -a / | grep swapfile
   -rw------- 1 root root 536870912 Feb 12 23:55 swapfile
   ```

3. Format the swap file.

   ```
   # mkswap /swapfile
   ```

4. Activate the swap file.

   ```
   # swapon /swapfile
   ```

5. Using your preferred text editor, update the `/etc/fstab` file to include the swap file by adding the following line to the bottom:

   ```
   /swapfile none swap defaults 0 0
   ```

After you save the `/etc/fstab` file, you can see the results with `swapon`.

```
$ swapon --summary
Filename         Type         Size      Used     Priority
/swapfile        file         524284    0        -1
```

Replication Configuration

In addition to the configuration for the database server, there are some specific options that you need to set to enable write-set replication. You must apply these changes to the configuration file, that is `my.cnf`, for each node in your cluster.

- *wsrep_cluster_name* (page 218) Use this parameter to set the logical name for your cluster. You must use the same name for every node in your cluster. The connection fails on nodes that have different values for this parameter.
- *wsrep_cluster_address* (page 217) Use this parameter to define the IP addresses for the cluster in a comma separated list.

Note: See Also: There are additional schemas and options available through this parameter. For more information on the syntax, see *Understanding Cluster Addresses* (page 31) below.

- *wsrep_node_name* (page 226) Use this parameter to define the logical name for the individual node—for convenience.
- *wsrep_node_address* (page 225) Use this parameter to explicitly set the IP address for the individual node. It gets used in the event that the auto-guessing does not produce desirable results.

```
[mysql]
wsrep_cluster_name=MyCluster
wsrep_cluster_address="gcomm://192.168.0.1,192.168.0.2,192.168.0.3"
wsrep_node_name=MyNode1
wsrep_node_address="192.168.0.1"
```

Understanding Cluster Addresses

For each node in the cluster, you must provide IP addresses for all other nodes in the cluster, using the *wsrep_cluster_address* (page 217) parameter. Cluster addresses are listed using a particular syntax:

```
<backend schema>://<cluster address>[?<option1>=<value1>[&<option2>=<value2>]]
```

Backend Schema

There are two backend schemas available for Galera Cluster.

- `dummy` Which provides a pass-through back-end for testing and profiling purposes. It does not connect to any other nodes. It ignores any values given to it.
- `gcomm` Which provides the group communications back-end for use in production. It takes an address and has several settings that you can enable through the option list, or by using the *wsrep_provider_options* (page 230) parameter.

Cluster Addresses

For this section, provide a comma separate list of IP addresses for nodes in the cluster. The values here can indicate,

- The IP addresses of any current members, in the event that you want to connect to an existing cluster; or,
- The IP addresses of any possible cluster members, assuming that the list members can belong to no more than one Primary Component;

If you start the node without an IP address for this parameter, the node assumes that it is the first node of a new cluster. It initializes a cluster as though you launched `mysqld` with the `--wsrep-new-cluster` option.

Options

You can also use the options list to set backend parameters, such as the listen address and timeout values.

Note: **See Also**: The *wsrep_cluster_address* (page 217) options list is not durable. The node must resubmit the options on every connection to the cluster. To make these options durable, set them in the configuration file using the *wsrep_provider_options* (page 230) parameter.

The options list set in the URL take precedent over parameters set elsewhere. Parameters that you can set through the options list are prefixed by `evs`, `pc` and `gmcast`.

Note: **See Also**: For more information on the available parameters, see *Galera Parameters* (page 243).

You can set the options with a list of `key=value` pairs according to the URL standard. For example,

```
wsrep_cluster_address="gcomm://192.168.0.1, 192.168.0.2, 192.168.0.3 ? gmcast.
↪segment=0 & evs.max_install_timeouts=1"
```

Note: If the listen address and port are not set in the parameter list, `gcomm` will listen on all interfaces. The listen port will be taken from the cluster address. If it is not specified in the cluster address, the default port is `4567`.

CHAPTER

THREE

CLUSTER INITIALIZATION

Once you have Galera Cluster installed and configured on your servers, you are ready to initialize the cluster for operation. You do this by starting the cluster on the first node, then adding the remaining nodes to it.

Starting the Cluster

When you finish installing and configuring Galera Cluster you have the databases ready for use, but they are not yet connected to each other to form a cluster. To do this, you will need to start `mysqld` on one node, using the `--wsrep-new-cluster` option. This initializes the new *Primary Component* for the cluster. Each node you start after this will connect to the component and begin replication.

Before you attempt to initialize the cluster, check that you have the following ready:

- Database hosts with Galera Cluster installed, you will need a minimum of three hosts;
- No firewalls between the hosts;
- SELinux and AppArmor set to permit access to `mysqld`; and,
- Correct path to `libgalera_smm.so` given to the *wsrep_provider* (page 229) option. For example,

```
wsrep_provider=/usr/lib64/libgalera_smm.so
```

With the hosts prepared, you are ready to initialize the cluster.

Note: **See Also**: When migrating from an existing, standalone instance of MySQL, MariaDB or Percona XtraDB to Galera Cluster, there are some additional steps that you must take. For more information on what you need to do, see *Migrating to Galera Cluster* (page 189).

Starting the First Cluster Node

By default, nodes do not start as part of the *Primary Component*. Instead, they assume that the Primary Component exists already somewhere in the cluster.

When nodes start, they attempt to establish network connectivity with the other nodes in the cluster. For each node they find, they check whether or not it is a part of the Primary Component. When they find the Primary Component, they request a state transfer to bring the local database into sync with the cluster. If they cannot find the Primary Component, they remain in a nonoperational state.

There is no Primary Component when the cluster starts. In order to initialize it, you need to explicitly tell one node to do so with the `--wsrep-new-cluster` argument. By convention, the node you use to initialize the Primary Component is called the first node, given that it is the first that becomes operational.

Note: **See Also**: When you start a new cluster, any node can serve as the first node, since all the databases are empty. When you migrate from MySQL to Galera Cluster, use the original master node as the first node. When restarting the cluster, use the most advanced node. For more information, see *Migrating to Galera Cluster* (page 189) and *Resetting the Quorum* (page 87).

Bear in mind, the first node is only "first" in that it initializes the Primary Component. This node can fall behind and leave the cluster without necessarily affecting the Primary Component.

To start the first node, launch the database server on your first node. For systems that use `init`, run the following command:

```
# service mysql start --wsrep-new-cluster
```

For systems that use `systemd`, instead use this command:

```
# systemctl start mysql --wsrep-new-cluster
```

This starts `mysqld` on the node.

Note: **Warning**: Only use the `--wsrep-new-cluster` argument when initializing the Primary Component. Do not use it when you want the node to connect to an existing cluster.

Once the node starts the database server, check that startup was successful by checking *wsrep_cluster_size* (page 268). In the database client, run the following query:

```
SHOW STATUS LIKE 'wsrep_cluster_size';

+--------------------+-------+
| Variable_name      | Value |
+--------------------+-------+
| wsrep_cluster_size | 1     |
+--------------------+-------+
```

This status variable tells you the number of nodes that are connected to the cluster. Since you have just started your first node, the value is `1`.

Note: Do not restart `mysqld` at this point.

Adding Additional Nodes to the Cluster

When you start the first node you initialize a new cluster. Once this is done, the procedure for adding all the other nodes is the same.

To add a node to an existing cluster, launch `mysqld` as you would normally. If your system uses `init`, run the following command:

```
# service mysql start
```

For systems that use `systemd`, instead run this command:

```
# systemctl start mysql
```

When the database server initializes as a new node, it connects to the cluster members as defined by the *wsrep_cluster_address* (page 217) parameter. Using this parameter, it automatically retrieves the cluster map and connects to all other available nodes.

You can test that the node connection was successful using the *wsrep_cluster_size* (page 268) status variable. In the database client, run the following query:

```
SHOW STATUS LIKE 'wsrep_cluster_size';

+--------------------+-------+
| Variable_name      | Value |
+--------------------+-------+
| wsrep_cluster_size | 2     |
+--------------------+-------+
```

This indicates that the second node is now connected to the cluster. Repeat this procedure to add the remaining nodes to your cluster.

When all nodes in the cluster agree on the membership state, they initiate state exchange. In state exchange, the new node checks the cluster state. If the node state differs from the cluster state, (which is normally the case), the new node requests a state snapshot transfer from the cluster and it installs it on the local database. After this is done, the new node is ready for use.

Testing the Cluster

When you have your cluster up and running, you may want to test certain features to ensure that they are working properly or to prepare yourself for actual problems that may arise.

Replication Testing

To test that Galera Cluster is working as expected, complete the following steps:

1. On the database client, verify that all nodes have connected to each other:

```
SHOW STATUS LIKE 'wsrep_%';

 +---------------------------+------------+
 | Variable_name             | Value      |
 +---------------------------+------------+
 ...
 | wsrep_local_state_comment | Synced (6) |
 | wsrep_cluster_size        | 3          |
 | wsrep_ready               | ON         |
 +---------------------------+------------+
```

- *wsrep_local_state_comment* (page 278): The value `Synced` indicates that the node is connected to the cluster and operational.
- *wsrep_cluster_size* (page 268): The value indicates the nodes in the cluster.
- *wsrep_ready* (page 280): The value `ON` indicates that this node is connected to the cluster and able to handle transactions.

2. On the database client of `node1`, create a table and insert data:

```
CREATE DATABASE galeratest;
USE galeratest;
CREATE TABLE test_table (
        id INT PRIMARY KEY AUTO_INCREMENT,
        msg TEXT ) ENGINE=InnoDB;
INSERT INTO test_table (msg)
        VALUES ("Hello my dear cluster.");
INSERT INTO test_table (msg)
        VALUES ("Hello, again, cluster dear.");
```

3. On the database client of `node2`, check that the data was replicated correctly:

```
USE galeratest;
SELECT * FROM test_table;

 +----+-----------------------------+
 | id | msg                         |
 +----+-----------------------------+
 |  1 | Hello my dear cluster.      |
 |  2 | Hello, again, cluster dear. |
 +----+-----------------------------+
```

The results given in the `SELECT` query indicates that data you entered in node1 has replicated into node2.

Split-brain Testing

To test Galera Cluster for split-brain situations on a two node cluster, complete the following steps:

1. Disconnect the network connection between the two cluster nodes.

   The quorum is lost and the nodes do not serve requests.

2. Reconnect the network connection.

   The quorum remains lost, and the nodes do not serve requests.

3. On one of the database clients, reset the quorum:

```
SET GLOBAL wsrep_provider_options='pc.bootstrap=1';
```

The quorum is reset and the cluster recovered.

Failure Simulation

You can also test Galera Cluster by simulating various failure situations on three nodes as follows:

- To simulate a crash of a single `mysqld` process, run the command below on one of the nodes:

  ```
  $ killall -9 mysqld
  ```

- To simulate a network disconnection, use `iptables` or `netem` to block all TCP/IP traffic to a node.
- To simulate an entire server crash, run each `mysqld` in a virtualized guest, and abrubtly terminate the entire virtual instance.

If you have three or more Galera Cluster nodes, the cluster should be able to survive the simulations.

Restarting the Cluster

Occasionally, you may have to restart the entire Galera Cluster. This may happen, for example, in the case of a power failure where every node is shut down and you have no `mysqld` process at all.

To restart an entire Galera Cluster, complete the following steps:

1. Identify the node with the most advanced node state ID.
2. Start the most advanced node as the first node of the cluster.
3. Start the rest of the node as usual.

Identifying the Most Advanced Node

Identifying the most advanced node state ID is managed by comparing the *Global Transaction ID* values on different nodes in your cluster. You can find this in the `grastate.dat` file, located in the datadir for your database.

If the `grastate.dat` file looks like the example below, you have found the most advanced node state ID:

```
# GALERA saved state
version: 2.1
uuid:    5ee99582-bb8d-11e2-b8e3-23de375c1d30
seqno:   8204503945773
cert_index:
```

To find the sequence number of the last committed transaction, run `mysqld` with the `--wsrep-recover` option. This recovers the InnoDB table space to a consistent state, prints the corresponding Global Transaction ID value into the error log, and then exits. For example:

```
130514 18:39:13 [Note] WSREP: Recovered position: 5ee99582-bb8d-11e2-b8e3-
23de375c1d30:8204503945771
```

This value is the node state ID. You can use it to manually update the `grastate.dat` file, by entering it for the `seqno` field, or let `mysqld_safe` recover automatically and pass the value to your database server the next time you start it.

Identifying Crashed Nodes

If the `grastate.dat` file looks like the example below, the node has either crashed during execution of a non-transactional operation, (such as `ALTER TABLE`), or aborted due to a database inconsistency:

```
# GALERA saved state
version: 2.1
uuid:    5ee99582-bb8d-11e2-b8e3-23de375c1d30
seqno:   -1
cert_index:
```

It is possible for you to recover the *Global Transaction ID* of the last committed transaction from InnoDB, as described above, but the recovery is rather meaningless. After the crash, the node state is probably corrupted and may not even prove functional.

In the event that there are no other nodes in the cluster with a well-defined state, then there is no need to preserve the node state ID. You must perform a thorough database recovery procedure, similar to that used on standalone database servers. Once you recover one node, use it as the first node in a new cluster.

Part II

Technical Description

CHAPTER

FOUR

DATABASE REPLICATION

Database replication refers to the frequent copying of data from one node—a database on a server—into another. Think of a database replication system as a distributed database, where all nodes share the same level of information. This system is also known as a *database cluster*.

The database clients, such as web browsers or computer applications, do not see the database replication system, but they benefit from close to native DBMS (Database Management System) behavior.

Masters and Slaves

Many DATABASE MANAGEMENT SYSTEMS (DBMS) replicate the database.

The most common replication setup uses a master/slave relationship between the original data set and the copies.

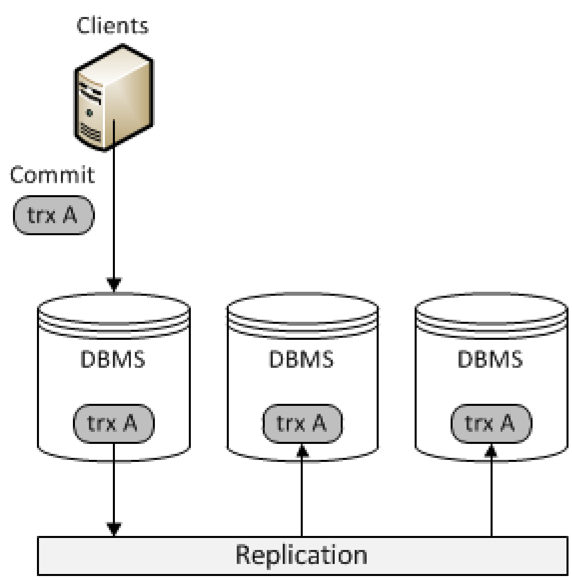


Fig. 4.1: *Master/Slave Replication*

In this system, the master database server logs the updates to the data and propagates those logs through the network to the slaves. The slave database servers receive a stream of updates from the master and apply those changes.

Another common replication setup uses mult-master replication, where all nodes function as masters.

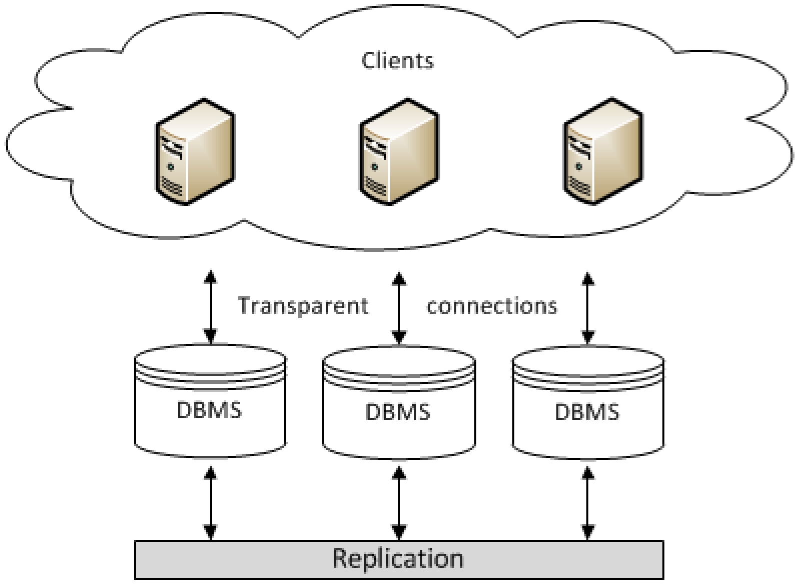


Fig. 4.2: *Multi-master Replication*

In a multi-master replication system, you can submit updates to any database node. These updates then propagate through the network to other database nodes. All database nodes function as masters. There are no logs available and the system provides no indicators sent to tell you if the updates were successful.

Asynchronous and Synchronous Replication

In addition to the setup of how different nodes relate to one another, there is also the protocol for how they propagate database transactions through the cluster.

- **Synchronous Replication** Uses the approach of eager replication. Nodes keep all replicas synchronized by updating all replicas in a single transaction. In other words, when a transaction commits, all nodes have the same value.
- **Asynchronous Replication** Uses the approach of lazy replication. The master database asynchronously propagates replica updates to other nodes. After the master node propagates the replica, the transaction commits. In other words, when a transaction commits, for at least a short time, some nodes hold different values.

Advantages of Synchronous Replication

In theory, there are several advantages that synchronous replication has over asynchronous replication. For instance:

- **High Availability** Synchronous replication provides highly available clusters and guarantees 24/7 service availability, given that:
  - No data loss when nodes crash.
  - Data replicas remain consistent.
  - No complex, time-consuming failovers.
- **Improved Performance** Synchronous replications allows you to execute transactions on all nodes in the cluster in parallel to each other, increasing performance.

- **Causality across the Cluster** Synchronous replication guarantees causality across the whole cluster. For example, a `SELECT` query issued after a transaction always sees the effects of the transaction, even if it were executed on another node.

Disadvantages of Synchronous Replication

Traditionally, eager replication protocols coordinate nodes one operation at a time. They use a two phase commit, or distributed locking. A system with n number of nodes due to process o operations with a throughput of t transactions per second gives you m messages per second with:

$$m = n \times o \times t$$

What this means that any increase in the number of nodes leads to an exponential growth in the transaction response times and in the probability of conflicts and deadlock rates.

For this reason, asynchronous replication remains the dominant replication protocol for database performance, scalability and availability. Widely adopted open source databases, such as MySQL and PostgreSQL only provide asynchronous replication solutions.

Solving the Issues in Synchronous Replication

There are several issues with the traditional approach to synchronous replication systems. Over the past few years, researchers from around the world have begun to suggest alternative approaches to synchronous database replication.

In addition to theory, several prototype implementations have shown much promise. These are some of the most important improvements that these studies have brought about:

- **Group Communication** This is a high-level abstraction that defines patterns for the communication of database nodes. The implementation guarantees the consistency of replication data.
- **Write-sets** This bundles database writes in a single write-set message. The implementation avoids the coordination of nodes one operation at a time.
- **Database State Machine** This processes read-only transactions locally on a database site. The implementation updates transactions are first executed locally on a database site, on shallow copies, and then broadcast as a read-set to the other database sites for certification and possibly commits.
- **Transaction Reordering** This reorders transactions before the database site commits and broadcasts them to the other database sites. The implementation increases the number of transactions that successfully pass the certification test.

The certification-based replication system that Galera Cluster uses is built on these approaches.

CHAPTER FIVE

CERTIFICATION-BASED REPLICATION

Certification-based replication uses group communication and transaction ordering techniques to achieve synchronous replication.

Transactions execute optimistically in a single node, or replica, and then at commit time, they run a coordinated certification process to enforce global consistency. It achieves global coordination with the help of a broadcast service that establishes a global total order among concurrent transactions.

What Certification-based Replication Requires

It is not possible to implement certification-based replication for all database systems. It requires certain features of the database in order to work.

- **Transactional Database** It requires that the database is transactional. Specifically, that the database can rollback uncommitted changes.
- **Atomic Changes** It requires that replication events change the database atomically. Specifically, that the series of database operations must either all occur, else nothing occurs.
- **Global Ordering** It requires that replication events are ordered globally. Specifically, that they are applied on all instances in the same order.

How Certification-based Replication Works

The main idea in certification-based replication is that a transaction executes conventionally until it reaches the commit point, assuming there is no conflict. This is called optimistic execution.

When the client issues a `COMMIT` command, but before the actual commit occurs, all changes made to the database by the transaction and primary keys of the changed rows are collected into a write-set. The database then sends this write-set to all the other nodes.

The write-set then undergoes a deterministic certification test, using the primary keys. This is done on each node in the cluster, including the node that originates the write-set. It determines whether or not the node can apply the write-set.

If the certification test fails, the node drops the write-set and the cluster rolls back the original transaction. If the test succeeds, the transaction commits and the write-set is applied to the rest of the cluster.

Certification-based Replication in Galera Cluster

The implementation of certification-based replication in Galera Cluster depends on the global ordering of transactions.

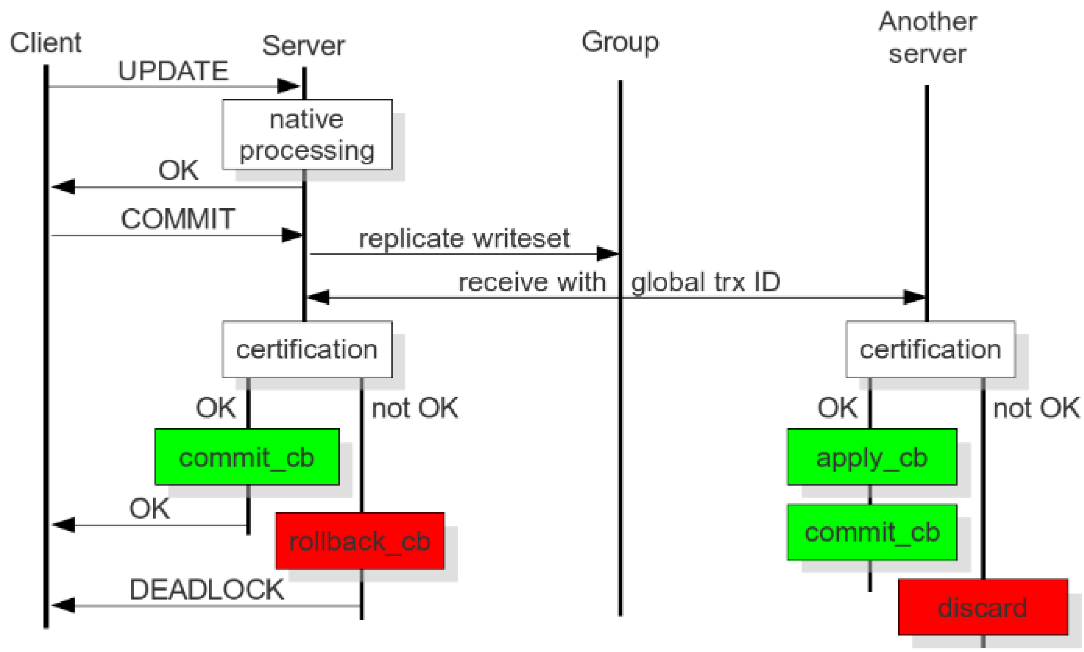


Fig. 5.1: *Certification Based Replication*

Galera Cluster assigns each transaction a global ordinal sequence number, or seqno, during replication. When a transaction reaches the commit point, the node checks the sequence number against that of the last successful transaction. The interval between the two is the area of concern, given that transactions that occur within this interval have not seen the effects of each other. All transactions in this interval are checked for primary key conflicts with the transaction in question. The certification test fails if it detects a conflict.

The procedure is deterministic and all replica receive transactions in the same order. Thus, all nodes reach the same decision about the outcome of the transaction. The node that started the transaction can then notify the client application whether or not it has committed the transaction.

CHAPTER

SIX

REPLICATION API

Synchronous replication systems use eager replication. Nodes in the cluster synchronize with all other nodes by updating the replicas through a single transaction. Meaning that, when a transaction commits, all nodes have the same value. This process takes place using write-set replication through group communication.

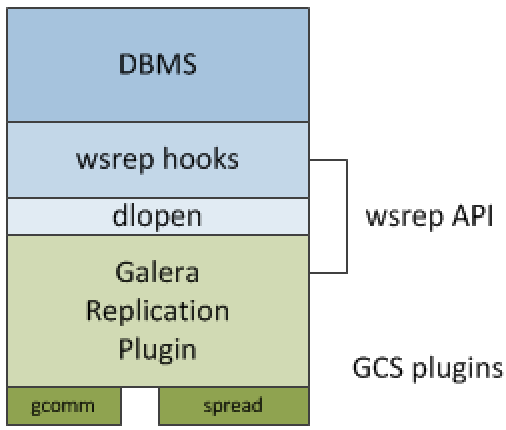


Fig. 6.1: *Replication API*

The internal architecture of Galera Cluster revolves around four components:

- **Database Management System (DBMS)** The database server that runs on the individual node. Galera Cluster can use MySQL, MariaDB or Percona XtraDB.
- **wsrep API** The interface and the responsibilities for the database server and replication provider. It consists of:
- *wsrep hooks* The integration with the database server engine for write-set replication.
- *dlopen()* The function that makes the wsrep provider available to the wsrep hooks.
- **Galera Replication Plugin** The plugin that enables write-set replication service functionality.
- **Group Communication plugins** The various group communication systems available to Galera Cluster. For instance, *gcomm* and Spread.

wsrep API

The *wsrep API* is a generic replication plugin interface for databases. It defines a set of application callbacks and replication plugin calls.

The wsrep API uses a replication model that considers the database server to have a state. The state refers to the contents of the database. When a database is in use, clients modify the database content, thus changing its state. The wsrep API represents the changes in the database state as a series of atomic changes, or transactions.

In a database cluster, all nodes always have the same state. They synchronize with each other by replicating and applying state changes in the same serial order.

From a more technical perspective, Galera Cluster handles state changes in the following process:

1. On one node in the cluster, a state change occurs on the database.
2. In the database, the wsrep hooks translate the changes to the write-set.
3. `dlopen()` makes the wsrep provider functions available to the wsrep hooks.
4. The Galera Replication plugin handles write-set certification and replication to the cluster.

For each node in the cluster, the application process occurs by high-priority transaction(s).

Global Transaction ID

In order to keep the state identical across the cluster, the wsrep API uses a *Global Transaction ID*, or GTID. This allows it to identify state changes and to identify the current state in relation to the last state change.

```
45eec521-2f34-11e0-0800-2a36050b826b:94530586304
```

The Global Transaction ID consists of the following components:

- **State UUID** A unique identifier for the state and the sequence of changes it undergoes.
- **Ordinal Sequence Number** The seqno, a 64-bit signed integer used to denote the position of the change in the sequence.

The Global Transaction ID allows you to compare the application state and establish the order of state changes. You can use it to determine whether or not a change was applied and whether the change is applicable at all to a given state.

Galera Replication Plugin

The *Galera Replication Plugin* implements the *wsrep API*. It operates as the wsrep Provider.

From a more technical perspective, the Galera Replication Plugin consists of the following components:

- **Certification Layer** This layer prepares the write-sets and performs the certification checks on them, ensuring that they can be applied.
- **Replication Layer** This layer manages the replication protocol and provides the total ordering capability.
- **Group Communication Framework** This layer provides a plugin architecture for the various group communication systems that connect to Galera Cluster.

Group Communication Plugins

The Group Communication Framework provides a plugin architecture for the various gcomm systems.

Galera Cluster is built on top of a proprietary group communication system layer, which implements a virtual synchrony QoS (Quality of Service). Virtual synchrony unifies the data delivery and cluster membership services, providing clear formalism for message delivery semantics.

While virtual synchrony guarantees consistency, it does not guarantee temporal synchrony, which is necessary for smooth multi-master operations. To get around this, Galera Cluster implements its own runtime-configurable temporal flow control. Flow control keeps nodes synchronized to the faction of a second.

In addition to this, the Group Communication Framework also provides a total ordering of messages from multiple sources. It uses this to generate *Global Transaction ID*'s in a multi-master cluster.

At the transport level, Galera Cluster is a symmetric undirected graph. All database nodes connect to each other over a TCP connection. By default TCP is used for both message replication and the cluster membership services, but you can also use UDP (User Datagram Protocol) multicast for replication in a LAN.

CHAPTER

SEVEN

ISOLATION LEVELS

In a database system, concurrent transactions are processed in "isolation" from each other. The level of isolation determines how transactions can affect each other.

Intra-Node vs. Inter-Node Isolation in Galera Cluster

Before going into details about possible isolation levels which can be set for a client session in Galera Cluster it is important to make a distinction between single node and global cluster transaction isolation. Individual cluster nodes can provide any isolation level *to the extent* it is supported by MySQL/InnoDB. However isolation level *between* the nodes in the cluster is affected by replication protocol, so transactions issued on different nodes may not be isolated *identically* to transactions issued on the same node.

Overall isolation levels that are supported cluster-wide are

- *READ-UNCOMMITTED* (page 52)
- *READ-COMMITTED* (page 52)
- *REPEATABLE-READ* (page 52)

For transactions issued on different nodes, isolation is also strengthened by the "first committer wins" rule, which eliminates the "lost update anomaly" inherent to these levels, whereas for transactions issued on the same node this rule does not hold (as per original MySQL/InnoDB behavior). This makes for different outcomes depending on transaction origin (transaction issued on the same node may succeed, whereas the same transaction issued on another node would fail), but in either case it is no weaker than that isolation level on a standalone MySQL/InnoDB.

SERIALIZABLE (page 52) isolation level is honored only between transactions issued on the same node and thus should be avoided.

Data consistency between the nodes is always guaranteed regardless of the isolation level chosen by the client. However the client logic may break if it relies on an isolation level which is not not supported in the given configuration.

Understanding Isolation Levels

Note: **Warning**: When using Galera Cluster in master-slave mode, all four levels are available to you, to the extend that MySQL supports it. In multi-master mode, however, you can only use the `REPEATABLE-READ` level.

READ-UNCOMMITTED

Here transactions can see changes to data made by other transactions that are not yet committed.

In other words, transactions can read data that eventually may not exist, given that other transactions can always rollback the changes without commit. This is known as a dirty read. Effectively, `READ-UNCOMMITTED` has no real isolation at all.

READ-COMMITTED

Here dirty reads are not possible. Uncommitted changes remain invisible to other transactions until the transaction commits.

However, at this isolation level `SELECT` queries use their own snapshots of committed data, that is data committed before the `SELECT` query executed. As a result, `SELECT` queries, when run multiple times within the same transaction, can return different result sets. This is called a non-repeatable read.

REPEATABLE-READ

Here non-repeatable reads are not possible. Snapshots taken for the `SELECT` query are taken the first time the `SELECT` query runs during the transaction.

The snapshot remains in use throughout the entire transaction for the `SELECT` query. It always returns the same result set. This level does not take into account changes to data made by other transactions, regardless of whether or not they have been committed. IN this way, reads remain repeatable.

SERIALIZABLE

Here all records accessed within a transaction are locked. The resource locks in a way that also prevents you from appending records to the table the transaction operates upon.

`SERIALIZABLE` prevents a phenomenon known as a phantom read. Phantom reads occur when, within a transaction, two identical queries execute, and the rows the second query returns differ from the first.

CHAPTER

EIGHT

STATE TRANSFERS

The process of replicating data from the cluster to the individual node, bringing the node into sync with the cluster, is known as provisioning. There are two methods available in Galera Cluster to provision nodes:

- *State Snapshot Transfers (SST)* (page 53) Where a snapshot of the entire node state transfers.
- *Incremental State Transfers (IST)* (page 54) Where only the missing transactions transfer.

State Snapshot Transfer (SST)

In a *State Snapshot Transfer* (SST), the cluster provisions nodes by transferring a full data copy from one node to another. When a new node joins the cluster, the new node initiates a State Snapshot Transfer to synchronize its data with a node that is already part of the cluster.

You can choose from two conceptually different approaches in Galera Cluster to transfer a state from one database to another:

- **Logical** This method uses `mysqldump`. It requires that you fully initialize the receiving server and ready it to accept connections *before* the transfer.

  This is a blocking method. The donor node becomes `READ-ONLY` for the duration of the transfer. The State Snapshot Transfer applies the `FLUSH TABLES WITH READ LOCK` command on the donor node.

  `mysqldump` is the slowest method for State Snapshot Transfers. This can be an issue in a loaded cluster.

- **Physical** This method uses `rsync`, `rsync_wan`, `xtrabackup` and other methods and copies the data files directly from server to server. It requires that you initialize the receiving server *after* the transfer.

  This method is faster than `mysqldump`, but they have certain limitations. You can only use them on server startup. The receiving server requires very similar configurations to the donor, (for example, both servers must use the same innodb_file_per_table value).

  Some of these methods, such as `xtrabackup` can be made non-blocking on the donor. They are supported through a scriptable SST interface.

Note: See Also: For more information on the particular methods available for State Snapshot Transfers, see the *State Snapshot Transfers* (page 77).

You can set which State Snapshot Transfer method a node uses from the confirmation file. For example:

```
wsrep_sst_method=rsync_wan
```

Incremental State Transfer (IST)

In an *Incremental State Transfer* (IST), the cluster provisions a node by identifying the missing transactions on the joiner and sends them only, instead of the entire state.

This provisioning method is only available under certain conditions:

- Where the joiner node *state UUID* is the same as that of the group.
- Where all missing write-sets are available in the donor's write-set cache.

When these conditions are met, the donor node transfers the missing transactions alone, replaying them in order until the joiner catches up with the cluster.

For example, say that you have a node in your cluster that falls behind the cluster. This node carries a node state that reads:

```
5a76ef62-30ec-11e1-0800-dba504cf2aab:197222
```

Meanwhile, the current node state on the cluster reads:

```
5a76ef62-30ec-11e1-0800-dba504cf2aab:201913
```

The donor node on the cluster receives the state transfer request from the joiner node. It checks its write-set cache for the *sequence number* `197223`. If that seqno is not available in the *write-set cache*, a State Snapshot Transfer initiates. If that seqno is available in the write-set cache, the donor node sends the commits from `197223` through to `201913` to the joiner, instead of the full state.

The advantage of Incremental State Transfers is that they can dramatically speed up the reemerging of a node to the cluster. Additionally, the process is non-blocking on the donor.

Note: The most important parameter for Incremental State Transfers is `gcache.size` on the donor node. This controls how much space you allocate in system memory for caching write-sets. The more space available the more write-sets you can store. The more write-sets you can store the wider the seqno gaps you can close through Incremental State Transfers.

On the other hand, if the write-set cache is much larger than the size of your database state, Incremental State Transfers begun less efficient than sending a state snapshot.

Write-set Cache (GCache)

Galera Cluster stores write-sets in a special cache called the *Write-set Cache*, or GCache. GCache cache is a memory allocator for write-sets. Its primary purpose is to minimize the *write-set* footprint on the RAM (Random Access Memory). Galera Cluster improves upon this through the offload write-set storage to disk.

GCache employs three types of storage:

- **Permanent In-Memory Store** Here write-sets allocate using the default memory allocator for the operating system. This is useful in systems that have spare RAM. The store has a hard size limit.

  By default it is disabled.

- **Permanent Ring-Buffer File** Here write-sets pre-allocate to disk during cache initialization. This is intended as the main write-set store.

  By default, its size is 128Mb.

- **On-Demand Page Store** Here write-sets allocate to memory-mapped page files during runtime as necessary.

  By default, its size is 128Mb, but can be larger if it needs to store a larger write-set. The size of the page store is limited by the free disk space. By default, Galera Cluster deletes page files when not in use, but you can set a limit on the total size of the page files to keep.

  When all other stores are disabled, at least one page file remains present on disk.

Note: **See Also**: For more information on parameters that control write-set caching, see the `gcache.*` parameters on *Galera Parameters* (page 243).

Galera Cluster uses an allocation algorithm that attempts to store write-sets in the above order. That is, first it attempts to use permanent in-memory store. If there is not enough space for the write-set, it attempts to store to the permanent ring-buffer file. The page store always succeeds, unless the write-set is larger than the available disk space.

By default, the write-set cache allocates files in the working directory of the process. You can specify a dedicated location for write-set caching, using the *gcache.dir* (page 252) parameter.

Note: Given that all cache files are memory-mapped, the write-set caching process may appear to use more memory than it actually does.

CHAPTER

NINE

FLOW CONTROL

Galera Cluster manages the replication process using a feedback mechanism, called Flow Control. Flow Control allows a node to pause and resume replication according to its needs. This prevents any node from lagging too far behind the others in applying transactions.

How Flow Control Works

Galera Cluster achieves synchronous replication by ensuring that transactions copy to all nodes an execute according to a cluster-wide ordering. That said, the transaction applies and commits occur asynchronously as they replicate through the cluster.

Nodes receive write-sets and organize them into the global ordering. Transactions that the node receives from the cluster but which it has not applied and committed, are kept in the received queue.

When the received queue reaches a certain size the node triggers Flow Control. The node pauses replication, then works through the received queue. When it reduces the received queue to a more manageable size, the node resumes replication.

Understanding Node States

Galera Cluster implements several forms of Flow Control, depending on the node state. This ensures temporal synchrony and consistency—as opposed to logical, which virtual synchrony provides.

There are four primary kinds of Flow Control:

- *No Flow Control* (page 57)
- *Write-set Caching* (page 58)
- *Catching Up* (page 58)
- *Cluster Sync* (page 58)

No Flow Control

This Flow Control takes effect when nodes are in the `OPEN` or `PRIMARY` states.

When nodes hold these states, they are not considered part of the cluster. These nodes are not allowed to replicate, apply or cache any write-sets.

Write-set Caching

This Flow Control takes effect when nodes are in the `JOINER` and `DONOR` states.

Nodes cannot apply any write-sets while in this state and must cache them for later. There is no reasonable way to keep the node synchronized with the cluster, except for stopping all replication.

It is possible to limit the replication rate, ensuring that the write-set cache does not exceed the configured size. You can control the write-set cache with the following parameters:

- *gcs.recv_q_hard_limit* (page 255) Maximum write-set cache size (in bytes).
- *gcs.max_throttle* (page 255) Smallest fraction to the normal replication rate the node can tolerate in the cluster.
- *gcs.recv_q_soft_limit* (page 255) Estimate of the average replication rate for the node.

Catching Up

This Flow Control takes effect when nodes are in the `JOINED` state.

Nodes in this state can apply write-sets. Flow Control here ensures that the node can eventually catch up with the cluster. It specifically ensures that its write-set cache never grows. Because of this, the cluster wide replication rate remains limited by the rate at which a node in this state can apply write-sets. Since applying write-sets is usually several times faster than processing a transaction, nodes in this state hardly ever effect cluster performance.

The one occasion when nodes in the `JOINED` state do effect cluster performance is at the very beginning, when the buffer pool on the node in question is empty.

Note: You can significantly speed this up with parallel applying.

Cluster Sync

This Flow Control takes effect when nodes are in the `SYNCED` state.

When nodes enter this state Flow Control attempts to keep the slave queue to a minimum. You can configure how the node handles this using the following parameters:

- *gcs.fc_limit* (page 254) Used to determine the point where Flow Control engages.
- *gcs.fc_factor* (page 254) Used to determine the point where Flow Control disengages.

Changes in the Node State

The node state machine handles different state changes on different layers of Galera Cluster. These are the node state changes that occur at the top most layer:

1. The node starts and establishes a connection to the *Primary Component*.
2. When the node succeeds with a state transfer request, it begins to cache write-sets.
3. The node receives a *State Snapshot Transfer*. It now has all cluster data and begins to apply the cached write-sets.

   Here the node enables Flow Control to ensure an eventual decrease in the slave queue.

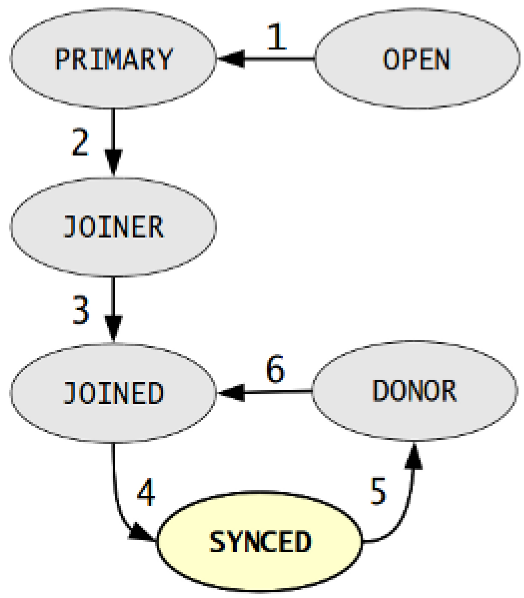


Fig. 9.1: *Galera Cluster Node State Changes*

4. The node finishes catching up with the cluster. Its slave queue is now empty and it enables Flow Control to keep it empty.

   The node sets the MySQL status variable *wsrep_ready* (page 280) to the value `1`. The node is now allowed to process transactions.

5. The node receives a state transfer request. Flow Control relaxes to `DONOR`. The node caches all write-sets it cannot apply.

6. The node completes the state transfer to joiner node.

For the sake of legibility, certain transitions were omitted from the above description. Bear in mind the following points:

- **Connectivity** Cluster configuration change events can send a node in any state to `PRIMARY` or `OPEN`. For instance, a node that is `SYNCED` reverts to `OPEN` when it loses its connection to the Primary Component due to network partition.
- **Missing Transitions** In the event that the joining node does not require a state transfer, the node state changes from the `PRIMARY` state directly to the `JOINED` state.

Note: See Also: For more information on Flow Control see Galera Flow Control in Percona XtraDB Cluster.

CHAPTER

TEN

NODE FAILURE AND RECOVERY

Individual nodes fail to operate when they loose touch with the cluster. This can occur due to various reasons. For instance, in the event of hardware failure or software crash, the loss of network connectivity or the failure of a state transfer. Anything that prevents the node from communicating with the cluster is generalized behind the concept of node failure. Understanding how nodes fail will help in planning for their recovery.

Detecting Single Node Failures

When a node fails the only sign is the loss of connection to the node processes as seen by other nodes. Thus nodes are considered failed when they lose membership with the cluster's *Primary Component*. That is, from the perspective of the cluster when the nodes that form the Primary Component can no longer see the node, that node is failed. From the perspective of the failed node itself, assuming that it has not crashed, it has lost its connection with the Primary Component.

Although there are third-party tools for monitoring nodes—such as ping, Heartbeat, and Pacemaker—they can be grossly off in their estimates on node failures. These utilities do not participate in the Galera Cluster group communications and remain unaware of the Primary Component.

If you want to monitor the Galera Cluster node status poll the *wsrep_local_state* (page 278) status variable or through the *Notification Command* (page 157).

Note: See Also: For more information on monitoring the state of cluster nodes, see the chapter on *Monitoring the Cluster* (page 149).

The cluster determines node connectivity from the last time it received a network packet from the node. You can configure how often the cluster checks this using the *evs.inactive_check_period* (page 248) parameter. During the check, if the cluster finds that the time since the last time it received a network packet from the node is greater than the value of the *evs.keepalive_period* (page 250) parameter, it begins to emit heartbeat beacons. If the cluster continues to receive no network packets from the node for the period of the *evs.suspect_timeout* (page 251) parameter, the node is declared suspect. Once all members of the Primary Component see the node as suspect, it is declared inactive—that is, failed.

If no messages were received from the node for a period greater than the *evs.inactive_timeout* (page 249) period, the node is declared failed regardless of the consensus. The failed node remains non-operational until all members agree on its membership. If the members cannot reach consensus on the liveness of a node, the network is too unstable for cluster operations.

The relationship between these option values is:

evs.keepalive_period (page 250)	<=	*evs.inactive_check_period* (page 248)
evs.inactive_check_period (page 248)	<=	*evs.suspect_timeout* (page 251)
evs.suspect_timeout (page 251)	<=	*evs.inactive_timeout* (page 249)
evs.inactive_timeout (page 249)	<=	*evs.consensus_timeout* (page 247)

Note: Unresponsive nodes that fail to send messages or heartbeat beacons on time—for instance, in the event of heavy swapping—may also be pronounced failed. This prevents them from locking up the operations of the rest of the cluster. If you find this behavior undesirable, increase the timeout parameters.

Cluster Availability vs. Partition Tolerance

Within the CAP theorem, Galera Cluster emphasizes data safety and consistency. This leads to a trade-off between cluster availability and partition tolerance. That is, when using unstable networks, such as WAN, low *evs.suspect_timeout* (page 251) and *evs.inactive_timeout* (page 249) values may result in false node failure detections, while higher values on these parameters may result in longer availability outages in the event of actual node failures.

Essentially what this means is that the *evs.suspect_timeout* (page 251) parameter defines the minimum time needed to detect a failed node. During this period, the cluster is unavailable due to the consistency constraint.

Recovering from Single Node Failures

If one node in the cluster fails, the other nodes continue to operate as usual. When the failed node comes back online, it automatically synchronizes with the other nodes before it is allowed back into the cluster.

No data is lost in single node failures.

Note: **See Also**: For more information on manually recovering nodes, see *Node Provisioning and Recovery* (page 75).

State Transfer Failure

Single node failures can also occur when a *state snapshot transfer* fails. This failure renders the receiving node unusable, as the receiving node aborts when it detects a state transfer failure.

When the node fails while using `mysqldump`, restarting may require you to manually restore the administrative tables. For the `rsync` method in state transfers this is not an issue, given that it does not require the database server to be in an operational state to work.

CHAPTER

ELEVEN

WEIGHTED QUORUM

In addition to single node failures, the cluster may split into several components due to network failure. A component is a set of nodes that are connected to each other, but not to the nodes that form other components. In these situations, only one component can continue to modify the database state to avoid history divergence. This component is called the *Primary Component*.

Under normal operations, your Primary Component is the cluster. When cluster partitioning occurs, Galera Cluster invokes a special quorum algorithm to select one component as the Primary Component. This guarantees that there is never more than one Primary Component in the cluster.

Note: See Also: In addition to the individual node, quorum calculations also take into account a separate process called `garbd`. For more information on its configuration and use, see *Galera Arbitrator* (page 115).

Weighted Quorum

The current number of nodes in the cluster defines the current cluster size. There is no configuration setting that allows you to define the list of all possible cluster nodes. Every time a node joins the cluster, the total cluster size increases. When a node leaves the cluster, gracefully, the cluster size decreases. Cluster size determines the number of votes required to achieve quorum.

Galera Cluster takes a quorum vote whenever a node does not respond and is suspected of no longer being a part of the cluster. You can fine tune this no response timeout using the *evs.suspect_timeout* (page 251) parameter. The default setting is 5 seconds.

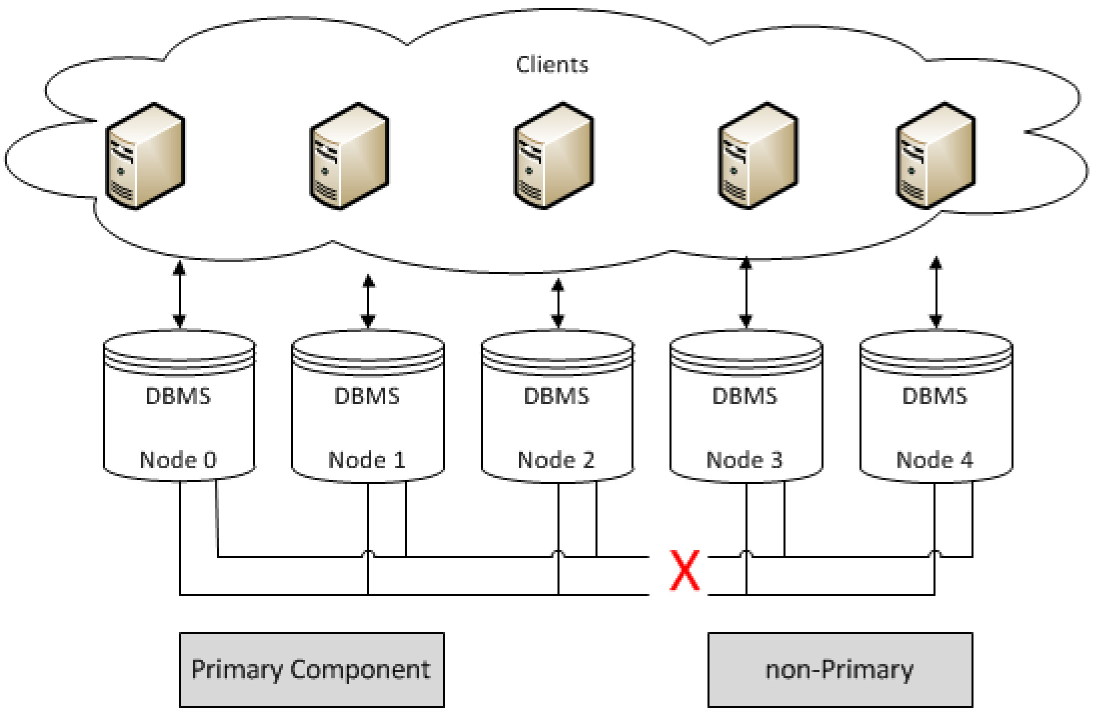
When the cluster takes a quorum vote, if the majority of the total nodes connected from before the disconnect remain, that partition stays up. When network partitions occur, there are nodes active on both sides of the disconnect. The component that has quorum alone continues to operate as the *Primary Component*, while those without quorum enter the non-primary state and begin attempt to connect with the Primary Component.

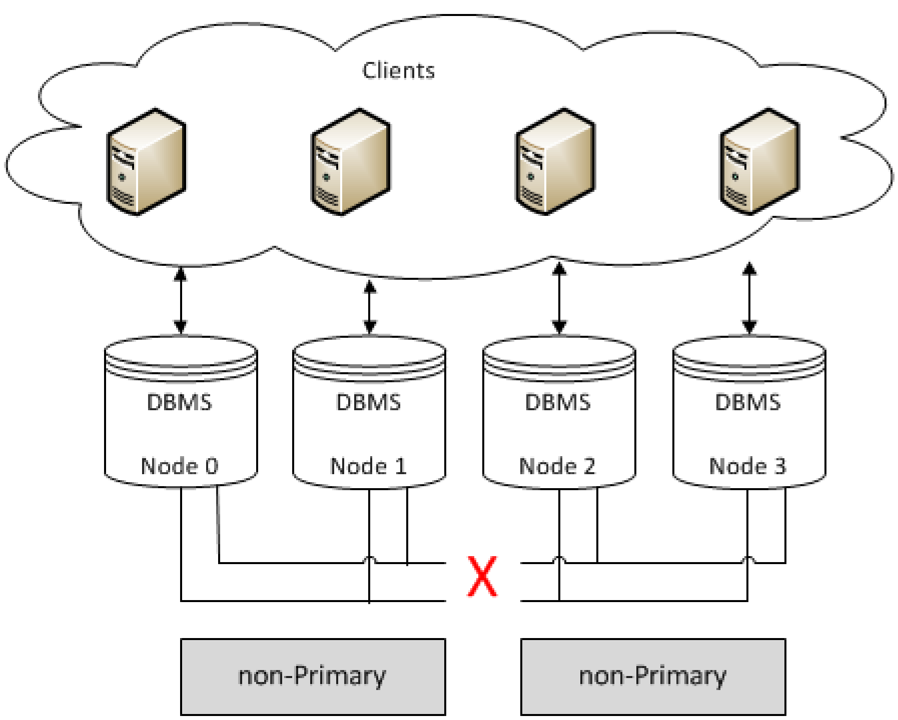
Quorum requires a majority, meaning that you cannot have automatic failover in a two node cluster. This is because the failure of one causes the remaining node automatically go into a non-primary state.

Clusters that have an even number of nodes risk split-brain conditions. If should you lose network connectivity somewhere between the partitions in a way that causes the number of nodes to split exactly in half, neither partition can retain quorum and both enter a non-primary state.

In order to enable automatic failovers, you need to use at least three nodes. Bear in mind that this scales out to other levels of infrastructure, for the same reasons.

- Single switch clusters should use a minimum of 3 nodes.
- Clusters spanning switches should use a minimum of 3 switches.


Clients
DBMS
Node 0
DBMS
Node 1
DBMS
Node 2
DBMS
Node 3
DBMS
Node 4
X
Primary Component
non-Primary


Clients
DBMS
Node 0
DBMS
Node 1
DBMS
Node 2
DBMS
Node 3
X
non-Primary
non-Primary

- Clusters spanning networks should use a minimum of 3 networks.
- Clusters spanning data centers should use a minimum of 3 data centers.

Split-brain Condition

Cluster failures that result in database nodes operating autonomous of each other are called split-brain conditions. When this occurs, data can become irreparably corrupted, such as would occur when two database nodes independently update the same row on the same table. As is the case with any quorum-based system, Galera Cluster is subject to split-brain conditions when the quorum algorithm fails to select a *Primary Component*.

For example, this can occur if you have a cluster without a backup switch in the event that the main switch fails. Or, when a single node fails in a two node cluster.

By design, Galera Cluster avoids split-brain condition. In the event that a failure results in splitting the cluster into two partitions of equal size, (unless you explicitly configure it otherwise), neither partition becomes a Primary Component.

To minimize the risk of this happening in clusters that do have an even number of nodes, partition the cluster in a way that one component always forms the Primary cluster section.

```
4 node cluster -> 3 (Primary) + 1 (Non-primary)
6 node cluster -> 4 (Primary) + 2 (Non-primary)
6 node cluster -> 5 (Primary) + 1 (Non-primary)
```

In these partitioning examples, it is very difficult for any outage or failure to cause the nodes to split exactly in half.

Note: See Also: For more information on configuring and managing the quorum, see *Resetting the Quorum* (page 87).

Quorum Calculation

Galera Cluster supports a weighted quorum, where each node can be assigned a weight in the 0 to 255 range, with which it will participate in quorum calculations.

The quorum calculation formula is

$$\frac{\sum_{p_i \times w_i} - \sum_{l_i \times w_i}}{2} < \sum_{m_i \times w_i}$$

Where:

- p_i Members of the last seen primary component;
- l_i Members that are known to have left gracefully;
- m_i Current component members; and,
- w_i Member weights.

What this means is that the quorum is preserved if (and only if) the sum weight of the nodes in a new component strictly exceeds half that of the preceding *Primary Component*, minus the nodes which left gracefully.

You can customize node weight using the *pc.weight* (page 260) parameter. By default, node weight is `1`, which translates to the traditional node count behavior.

Note: You can change node weight in runtime by setting the *pc.weight* (page 260) parameter.

```
SET GLOBAL wsrep_provider_options="pc.weight=3";
```

Galera Cluster applies the new weight on the delivery of a message that carries a weight. At the moment, there is no mechanism to notify the application of a new weight, but will eventually happen when the message is delivered.

Note: Warning: If a group partitions at the moment when the weight change message is delivered, all partitioned components that deliver weight change messages in the transitional view will become non-primary components. Partitions that deliver messages in the regular view will go through quorum computation with the applied weight when the following transitional view is delivered.

In other words, there is a corner case where the entire cluster can become non-primary component, if the weight changing message is sent at the moment when partitioning takes place. Recovering from such a situation should be done either by waiting for a re-merge or by inspecting which partition is most advanced and by bootstrapping it as a new Primary Component.

Weighted Quorum Examples

Now that you understand how quorum weights work, here are some examples of deployment patterns and how to use them.

Weighted Quorum for Three Nodes

When configuring quorum weights for three nodes, use the following pattern:

```
node1: pc.weight = 2
node2: pc.weight = 1
node3: pc.weight = 0
```

Under this pattern, killing `node2` and `node3` simultaneously preserves the *Primary Component* on `node1`. Killing `node1` causes `node2` and `node3` to become non-primary components.

Weighted Quorum for a Simple Master-Slave Scenario

When configuring quorum weights for a simple master-slave scenario, use the following pattern:

```
node1: pc.weight = 1
node2: pc.weight = 0
```

Under this pattern, if the master `node` dies, `node2` becomes a non-primary component. However, in the event that `node2` dies, `node1` continues as the *Primary Component*. If the network connection between the nodes fails, `node1` continues as the Primary Component while `node2` becomes a non-primary component.

Weighted Quorum for a Master and Multiple Slaves Scenario

When configuring quorum weights for a master-slave scenario that features multiple slave nodes, use the following pattern:

```
node1: pc.weight = 1
node2: pc.weight = 0
node3: pc.weight = 0
...
noden: pc.weight = 0
```

Under this pattern, if `node1` dies, all remaining nodes end up as non-primary components. If any other node dies, the *Primary Component* is preserved. In the case of network partitioning, `node1` always remains as the Primary Component.

Weighted Quorum for a Primary and Secondary Site Scenario

When configuring quorum weights for primary and secondary sites, use the following pattern:

```
Primary Site:
  node1: pc.weight = 2
  node2: pc.weight = 2

Secondary Site:
  node3: pc.weight = 1
  node4: pc.weight = 1
```

Under this pattern, some nodes are located at the primary site while others are at the secondary site. In the event that the secondary site goes down or if network connectivity is lost between the sites, the nodes at the primary site remain the *Primary Component*. Additionally, either `node1` or `node2` can crash without the rest of the nodes becoming non-primary components.

CHAPTER

TWELVE

STREAMING REPLICATION

Under normal operation, the node performs all replication and certification events when the transaction commits. When working with small transactions this is fine, but it poses an issue with long-running writes and changes to large data-sets.

In *Streaming Replication*, the node breaks the transaction down into fragments, then certifies and replicates them on the slaves while the transaction is still in progress. Once certified, the fragment can no longer be aborted by conflicting transactions.

Additionally, Streaming Replication allows the node to process transaction write-sets greater than 2Gb.

Note: Streaming Replication is a new feature introduced in version 4.0 of Galera Cluster. Older versions do not support these operations.

When to Use Streaming Replication

In most cases, the normal method Galera Cluster uses in replication is sufficient in transferring data from the node to the cluster. *Streaming Replication* provides you with an alternative for situations where this is not the case. Bear in mind that there are some limitations to its use. It is recommended that you only enable it at a session-level, and then only on specific transactions that require the feature.

Note: For more information on the limitations to Streaming Replication, see *Limitations* (page 70).

Long-running Write Transactions

When using normal replication, you may occasionally encounter issues with long-running write transactions.

The longer it takes for the node to commit the transaction, the greater the likelihood that the cluster will apply a smaller, conflicting transaction before the longer one can replicate to the cluster. When this happens, the cluster aborts the long-running transaction.

Using *Streaming Replication* on long-running transactions mitigates this situation. Once the node replicates and certifies a fragment, it is no longer possible for other transactions to abort it.

Large Data Write Transactions

When using normal replication, the node processes the transaction locally and doesn't replicate the data until you commit. This can create problems when updating a large volume of data, especially on nodes with slower network connections.

Additionally, while slave nodes apply a large transaction, they cannot commit other transactions that they receive, which may result in Flow Control throttling of the entire cluster.

With *Streaming Replication*, the node begins to replicate the data with each transaction fragment, rather than waiting for the commit. This allows you to spread the replication out over the lifetime of the transaction.

In the case of the slave nodes, after the slave applies a fragment, it is free to apply and commit other, concurrent transactions without blocking. This allows the slave node to incrementally process the entire large transaction with a minimal impact on the cluster.

Hot Records

In cases where an application frequently updates one and the same records from the same table, (such as when implementing a locking scheme, a counter, or a job queue), you can use *Streaming Replication* to force critical updates to replicate to the entire cluster.

Running the transaction in this way effectively locks the hot record on all nodes, preventing other transactions from modifying the row. It also increases the chances that the transaction will commit successfully and that the client in turn will receive the desired outcome.

Note: For more information and an example of how to implement Streaming Replication in situations such as this, see *Using Streaming Replication with Hot Records* (page 104).

Limitations

In deciding whether you want to use *Streaming Replication* with your application, consider the following limitations.

Replication Fragment Size

While a transaction is in progress, Streaming Replication fragments are temporarily stored as blobs in a dedicated InnoDB table. In MySQL 5.6, InnoDB limits the maximum blob size to 10% of the total redo log size. If the redo log size is insufficient to store a particular fragment, an error will be returned to the client:

```
ERROR 1534 (HY000): Writing one row to the row-based binary log failed
```

and an error will be reported in the error log:

```
2016-06-23 10:41:36 49989 [ERROR] InnoDB: The total blob data length (10485855) is␣
↪greater than 10% of the total redo log size (10485760). Please increase total redo␣
↪log size.
2016-06-23 10:41:36 49989 [ERROR] WSREP: Error writing into wsrep_schema.SR: 139
2016-06-23 10:41:36 49989 [ERROR] WSREP: Failed to write to frag table: 1
2016-06-23 10:41:36 49989 [ERROR] WSREP: Failed to append frag to persistent storage
```

To accomodate larger fragments, increase the InnoDB redo log size using the `innodb_log_file_size` variable.

Performance during the Transaction

When you enable *Streaming Replication*, each node in the cluster begins recording their write-sets to the `SR` table in the `wsrep_schema` database. The nodes do this to ensure the persistence of Streaming Replication updates in the event that they crash. However, this operation increases the load on the node, which may adversely affect its performance.

As such, it is recommend that you only enable Streaming Replication at a session-level and then only for transactions that would not run correctly without it.

Performance during Rollbacks

Occasionally, you may encounter situations where the cluster needs to roll back a transaction while *Streaming Replication* is in use. In these cases, the rollback operation consumes system resources on all nodes.

When long-running write transactions frequently need to be rolled back, this can become a performance issue. Therefore, it is a good application design policy to use shorter transactions wherever possible. In the event that your application performs batch processing or scheduled housekeeping tasks, consider splitting these into smaller transactions in addition to using Streaming Replication.

Interaction with LOAD DATA Splitting

The *wsrep_load_data_splitting* (page 223) variable, which controls the `LOAD DATA` splitting functionality, has no effect for statements where *Streaming Replication* is in effect.

Part III

Administration

CHAPTER

THIRTEEN

NODE PROVISIONING

When the state of a new or failed node differs from that of the cluster's *Primary Component*, the new or failed node must be synchronized with the cluster. Because of this, the provisioning of new nodes and the recover of failed nodes are essentially the same process as that of joining a node to the cluster Primary Component.

Galera reads the initial node state ID from the **grastate.txt** file, found in the directory assigned by the `wsrep_data_dir` parameter. Each time the node gracefully shuts down, Galera saves to this file.

In the event that the node crashes while in *Total Order Isolation* mode, its database state is unknown and its initial node state remains undefined:

```
00000000-0000-0000-0000-000000000000:-1
```

Note: In normal transaction processing, only the seqno part of the GTID remains undefined, (that is, with a value of `-1`. The UUID, (that is, the remainder of the node state), remains valid. In such cases, you can recover the node through an *Incremental State Transfer*.

How Nodes Join the Cluster

When a node joins the cluster, it compares its own *state UUID* to that of the *Primary Component*. If the state UUID does not match, the joining node requests a state transfer from the cluster.

There are two options available to determining the state transfer donor:

- **Automatic** When the node attempts to join the cluster, the group communication layer determines the state donor it should use from those members available in the Primary Component.
- **Manual** When the node attempts to join the cluster, it uses the *wsrep_sst_donor* (page 234) parameter to determine which state donor it should use. If it finds that the state donor it is looking for is not part of the Primary Component, the state transfer fails and the joining node aborts. For *wsrep_sst_donor* (page 234), use the same name as you use on the donor node for the *wsrep_node_name* (page 226) parameter.

Note: A state transfer is a heavy operation. This is true not only for the joining node, but also for the donor. In fact, a state donor may not be able to serve client requests.

Thus, whenever possible: manually select the state donor, based on network proximity and configure the load balancer to transfer client connections to other nodes in the cluster for the duration of the state transfer.

When a state transfer is in process, the joining node caches write-sets that it receives from other nodes in a slave queue. Once the state transfer is complete, it applies the write-sets from the slave queue to catch up with the current Primary

Component state. Since the state snapshot carries a state UUID, it is easy to determine which write-sets the snapshot contains and which it should discard.

During the catch-up phase, flow control ensures that the slave queue shortens, (that is, it limits the cluster replication rates to the write-set application rate on the node that is catching up).

While there is no guarantee on how soon a node will catch up, when it does the node status updates to `SYNCED` and it begins to accept client connections.

State Transfers

There are two types of state transfers available to bring the node up to date with the cluster:

- *State Snapshot Transfer* (SST) Where donor transfers to the joining node a snapshot of the entire node state as it stands.
- *Incremental State Transfer* (IST) Where the donor only transfers the results of transactions missing from the joining node.

When using automatic donor selection, starting in Galera Cluster version 3.6, the cluster decides which state transfer method to use based on availability.

- If there are no nodes available that can safely perform an incremental state transfer, the cluster defaults to a state snapshot transfer.
- If there are nodes available that can safely perform an incremental state transfer, the cluster prefers a local node over remote nodes to serve as the donor.
- If there are no local nodes available that can safely perform an incremental state transfer, the cluster chooses a remote node to serve as the donor.
- Where there are several local or remote nodes available that can safely perform an incremental state transfer, the cluster chooses the node with the highest seqno to serve as the donor.

CHAPTER FOURTEEN

STATE SNAPSHOT TRANSFERS

When a node requires a state transfer from the cluster, by default it attempts the *Incremental State Transfer* (IST) method. In the event that there are no nodes available for this or if it finds a manual donor defined through the *wsrep_sst_donor* (page 234) parameter, uses a *State Snapshot Transfer* (SST) method.

Galera Cluster supports several back-end methods for use in state snapshot transfers. There are two types of methods available: Logical State Snapshots, which interface through the database server and client; and Physical State Snapshots, which copy the data files directly from node to node.

Method	Speed	Blocks Donor	Available on Live Node	Type	DB Root Access
mysqldump (page 78)	Slow	Blocks	Available	*Logical* (page 77)	Donor and Joiner
rsync (page 80)	Fastest	Blocks	Unavailable	*Physical* (page 79)	None
xtrabackup (page 80)	Fast	Briefly	Unavailable	*Physical* (page 79)	Donor only

To set the State Snapshot Transfer method, use the *wsrep_sst_method* (page 235) parameter. For example:

```
wsrep_sst_method = rsync
```

There is no single best method for State Snapshot Transfers. You must decide which best suits your particular needs and cluster deployment. Fortunately, you need only set the method on the receiving node. So long as the donor has support, it servers the transfer in whatever method the joiner requests.

Logical State Snapshot

There is one back-end method available for a Logical State Snapshots: `mysqldump`.

The *Logical State Transfer Method* has the following advantages:

- These transfers are available on live servers. In fact, only a fully initialized server can receive a Logical State Snapshot.
- These transfers do not require the receptor node to have the same configuration as the donor node. This allows you to upgrade storage engine options.

  For example, when using this transfer method you can migrate from the Antelope to the Barracuda file format, use compression resize, or move iblog* files from one partition into another.

The Logical State Transfer Method has the following disadvantages:

- These transfers are as slow as `mysqldump`.

- These transfers require that you configure the receiving database server to accept root connections from potential donor nodes.
- The receiving server must have a non-corrupted database.

mysqldump

The main advantage of `mysqldump` is that you can transfer a state snapshot to a working server. That is, you start the server standalone and then instruct it to join a cluster from within the database client command line. You can also use it to migrate from an older database format to a newer one.

`mysqldump` requires that the receiving node have a fully functional database, which can be empty. It also requires the same root credentials as the donor and root access from the other nodes.

This transfer method is several times slower than the others on sizable databases, but it may prove faster in cases of very small databases. For instance, on a database that is smaller than the log files.

Note: **Warning**: This transfer method is sensitive to the version of `mysqldump` each node uses. It is not uncommon for a given cluster to have installed several versions. A State Snapshot Transfer can fail if the version one node uses is older and incompatible with the newer server.

On occasion, `mysqldump` is the only option available. For instance, if you upgrade from a cluster using MySQL 5.1 with the built-in InnoDB support to MySQL 5.5, which uses the InnoDB plugin.

The `mysqldump` script only runs on the sending node. The output from the script gets piped to the MySQL client that connects to the joiner node.

Because `mysqldump` interfaces through the database client, configuring it requires several steps beyond setting the *wsrep_sst_method* (page 235) parameter. For more information on its configuration, see:

Enabling mysqldump

The *Logical State Transfer Method* `mysqldump` works by interfacing through the database server rather than the physical data. As such, they require some additional configurations beyond setting the *wsrep_sst_method* (page 235) parameter.

Configuring SST Privileges

In order for `mysqldump` to interface with the database server, it requires root connections for both the donor and joiner nodes. You can enable this through the *wsrep_sst_auth* (page 234) parameter.

Using your preferred text editor, open `wsrep.cnf` file. You can find it in `/etc/mysql/conf.d/`), and enter the relevant authentication information.

```
# wsrep SST Authentication
wsrep_sst_auth = wsrep_sst_username:password
```

This provides authentication information that the node requires to establish connections. Use the same values for every node in your cluster.

Note: **Warning**: Use your own authentication parameters in place of `wsrep_sst_user` and `password`.

Granting SST Privileges

When the database server start, it reads from the above file the authentication information it needs to access another database server. In order for the node to accept connections from the cluster, you must also create and configure the State Snapshot Transfer user through the database client.

In order to do this, you need to start the database server. If you have not used this node on the cluster before, start it with replication disabled. For servers that use `init`, run the following command:

```
# service mysql start --wsrep-on=off
```

For servers that use `systemd`, instead run this command:

```
# systemctl start mysql --wsrep-on=OFF
```

When the database server is running, log into the database client and run the `GRANT ALL` command for the IP address of each node in your cluster.

```
GRANT ALL ON *.* TO 'wsrep_sst_user'@'node1_IP_address'
     IDENTIFIED BY 'password';
GRANT ALL ON *.* TO 'wsrep_sst_user'@'node2_IP_address'
     IDENTIFIED BY 'password';
GRANT ALL ON *.* TO 'wsrep_sst_user'@'node3_IP_address'
     IDENTIFIED BY 'password';
```

These commands grant each node in your cluster access to the database server on this node. You need to run these commands on every other cluster node to allow `mysqldump` in state transfers between them.

In the event that you have not yet created your cluster, you can stop the database server while you configure the other nodes. For servers that use `init`, run the following command:

```
# service mysql stop
```

For servers that use `systemd`, instead run this command:

```
# systemctl stop mysql
```

Note: See Also: For more information on `mysqldump`, see mysqldump Documentation.

Physical State Snapshot

There are two back-end methods available for Physical State Snapshots: `rsync` and `xtrabackup`.

The *Physical State Transfer Method* has the following advantages:

- These transfers physically copy the data from one node to the disk of the other, and as such do not need to interact with the database server at either end.
- These transfers do not require the database to be in working condition, as the donor node overwrites what was previously on the joining node disk.
- These transfers are faster.

The Physical State Transfer Method has the following disadvantages:

- These transfers require the joining node to have the same data directory layout and the same storage engine configuration as the donor node. For example, you must use the same file-per-table, compression, log file size and similar settings for InnoDB.
- These transfers are not accepted by servers with initialized storage engines.

  What this means is that when your node requires a state snapshot transfer, the database server must restart to apply the changes. The database server remains inaccessible to the client until the state snapshot transfer is complete, since it cannot perform authentication without the storage engines.

`rsync`

The fastest back-end method for State Snapshot Transfers is `rsync`. It carries all the advantages and disadvantages of of the Physical Snapshot Transfer. While it does block the donor node during transfer, `rsync` does not require database configuration or root access, which makes it easier to configure.

When using terabyte-scale databases, `rsync` is considerably faster, (1.5 to 2 times faster), than `xtrabackup`. This translates to a reduction in transfer times by several hours.

`rsync` also features the rsync-wan modification, which engages the `rsync` delta transfer algorithm. However, given that this makes it more I/O intensive, you should only use it when the network throughput is the bottleneck, which is usually the case in WAN deployments.

Note: The most common issue encountered with this method is due to incompatibilities between the various versions of `rsync` on the donor and joining nodes.

The `rsync` script runs on both donor and joining nodes. On the joiner, it starts `rsync` in server-mode and waits for a connection from the donor. On the donor, it starts `rsync` in client-mode and sends the contents of the data directory to the joining node.

```
wsrep_sst_method = rsync
```

For more information about `rsync`, see the rsync Documentation.

`xtrabackup`

The most popular back-end method for State Snapshot Transfers is `xtrabackup`. It carries all the advantages and disadvantages of a Physical State Snapshot, but is virtually non-blocking on the donor node.

`xtrabackup` only blocks the donor for the short period of time it takes to copy the MyISAM tables, (for instance, the system tables). If these tables are small, the blocking time remains very short. However, this comes at the cost of speed: a state snapshot transfer that uses `xtrabackup` can be considerably slower than one that uses `rsync`.

Given that `xtrabackup` copies a large amount of data in the shortest possible time, it may also noticeably degrade donor performance.

Note: The most common issue encountered with this method is due to its configuration. `xtrabackup` requires that you set certain options in the configuration file, which means having local root access to the donor server.

```
[mysqld]
wsrep_sst_auth = <wsrep_sst_user>:<password>
wsrep_sst_method = xtrabackup
datadir = /path/to/datadir
```

```
[client]
socket = /path/to/socket
```

For more information on `xtrabackup`, see the Percona XtraBackup User Manual and XtraBackup SST Configuration.

CHAPTER FIFTEEN

RECOVERING THE PRIMARY COMPONENT

Cluster nodes can store the *Primary Component* state to disk. The node records the state of the Primary Component and the UUID's of the nodes connected to it. In the event of an outage, once all nodes that were part of the last saved state achieve connectivity, the cluster recovers the Primary Component.

In the event that the write-set position differs between the nodes, the recovery process also requires a full state snapshot transfer.

Note: See Also: For more information on this feature, see the *pc.recovery* (page 258) parameter. By default, it is enabled starting in version 3.6.

Understanding the Primary Component State

When a node stores the *Primary Component* state to disk, it saves it as the `gvwstate.dat` file. The node creates and updates this file when the cluster forms or changes the Primary Component. This ensures that the node retains the latest Primary Component state that it was in. If the node loses connectivity, it has the file to reference. If the node shuts down gracefully, it deletes the file.

```
my_uuid: d3124bc8-1605-11e4-aa3d-ab44303c044a
#vwbeg
view_id: 3 0dae1307-1606-11e4-aa94-5255b1455aa0 12
bootstrap: 0
member: 0dae1307-1606-11e4-aa94-5255b1455aa0 1
member: 47bbe2e2-1606-11e4-8593-2a6d8335bc79 1
member: d3124bc8-1605-11e4-aa3d-ab44303c044a 1
#vwend
```

The `gvwstate.dat` file breaks into two parts:

- **Node Information** Provides the node's UUID, in the `my_uuid` field.
- **View Information** Provides information on the node's view of the Primary Component, contained between the `#vwbeg` and `#vwend` tags.
  - `view_id` Forms an identifier for the view from three parts:
    - *view_type* Always gives a value of `3` to indicate the primary view.
    - *view_uuid* and *view_seq* together form a unique value for the identifier.
  - `bootstrap` Displays whether or not the node is bootstrapped, but does not effect the Primary Component recovery process.
  - `member` Displays the UUID's of nodes in this primary component.

Modifying the Saved Primary Component State

In the event that you find yourself in the unusual situation where you need to force certain nodes to join each other specifically, you can do so by manually changing the saved *Primary Component* state.

Note: Warning: Under normal circumstances, for safety reasons, you should entirely avoid editing or otherwise modifying the `gvwstate.dat` file. Doing so may lead to unexpected results.

When a node starts for the first time or after a graceful shutdown, it randomly generates and assigns to itself a UUID, which serves as its identifier to the rest of the cluster. If the node finds a `gvwstate.dat` file in the data directory, it reads the `my_uuid` field to find the value it should use.

By manually assigning arbitrary UUID values to the respective fields on each node, you force them to join each other, forming a new Primary Component, as they start.

For example, assume that you have three nodes that you would like to start together to form a new Primary Component for the cluster. You will need to generate three UUID values, one for each node.

```
SELECT UUID();

+--------------------------------------+
| UUID()                               |
+--------------------------------------+
| 47bbe2e2-1606-11e4-8593-2a6d8335bc79 |
+--------------------------------------+
```

You would then take these values and use them to modify the `gwstate.dat` file on `node1`:

```
my_uuid: d3124bc8-1605-11e4-aa3d-ab44303c044a
#vwbeg
view_id: 3 0dae1307-1606-11e4-aa94-5255b1455aa0 12
bootstrap: 0
member: 0dae1307-1606-11e4-aa94-5255b1455aa0 1
member: 47bbe2e2-1606-11e4-8593-2a6d8335bc79 1
member: d3124bc8-1605-11e4-aa3d-ab44303c044a 1
#vwend
```

Then repeat the process for `node2`:

```
my_uuid: 47bbe2e2-1606-11e4-8593-2a6d8335bc79
#vwbeg
view_id: 3 0dae1307-1606-11e4-aa94-5255b1455aa0 12
bootstrap: 0
member: 0dae1307-1606-11e4-aa94-5255b1455aa0 1
member: 47bbe2e2-1606-11e4-8593-2a6d8335bc79 1
member: d3124bc8-1605-11e4-aa3d-ab44303c044a 1
#vwend
```

And, the same again for `node3`:

```
my_uuid: d3124bc8-1605-11e4-aa3d-ab44303c044a
#vwbeg
view_id: 3 0dae1307-1606-11e4-aa94-5255b1455aa0 12
bootstrap: 0
member: 0dae1307-1606-11e4-aa94-5255b1455aa0 1
member: 47bbe2e2-1606-11e4-8593-2a6d8335bc79 1
```

```
member: d3124bc8-1605-11e4-aa3d-ab44303c044a 1
#vwend
```

Then start all three nodes without the bootstrap flag. When they start, Galera Cluster reads the `gvwstate.dat` file for each. It pulls its UUID from the file and uses those of the `member` field to determine which nodes it should join in order to form a new Primary Component.

CHAPTER

SIXTEEN

RESETTING THE QUORUM

Occasionally, you may find your nodes no longer consider themselves part of the *Primary Component*. For instance, in the event of a network failure, the failure of more than half of the cluster, or a split-brain situation. In these cases, the node come to suspect that there is another Primary Component, to which they are no longer connected.

When this occurs, all nodes return an `Unknown command` error to all queries. You can check if this is happening using the *wsrep_cluster_status* (page 269) status variable. Run the following query on each node:

```
SHOW GLOBAL STATUS LIKE 'wsrep_cluster_status';

+----------------------+---------+
| Variable_name        | Value   |
+----------------------+---------+
| wsrep_cluster_status | Primary |
+----------------------+---------+
```

The return value `Primary` indicates that it the node is part of the Primary Component. When the query returns any other value it indicates that the node is part of a nonoperational component. If none of the nodes return the value `Primary`, it means that you need to reset the quorum.

Note: Bear in mind that situations where none of the nodes show as part of the Primary Component are very rare. In the event that you do find one or more nodes that return the value `Primary`, this indicates an issue with network connectivity rather than a need to reset the quorum. Troubleshoot the connection issue. Once the nodes regain network connectivity they automatically resynchronize with the Primary Component.

Finding the Most Advanced Node

Before you can reset the quorum, you need to identify the most advanced node in the cluster. That is, you must find the node whose local database committed the last transaction. Regardless of the method you use in resetting the quorum, this node serves as the starting point for the new *Primary Component*.

Identifying the most advanced node in the cluster requires that you find the node with the most advanced sequence number, or seqno. You can determine this using the *wsrep_last_committed* (page 274) status variable.

From the database client on each node, run the following query:

```
SHOW STATUS LIKE 'wsrep_last_committed';

+----------------------+--------+
| Variable_name        | Value  |
+----------------------+--------+
```

```
| wsrep_last_committed | 409745 |
+----------------------+--------+
```

The return value is the seqno for the last transaction the node committed. The node that provides the highest seqno is the most advanced node in your cluster. Use it as the starting point in the next section when bootstrapping the new Primary Component.

Resetting the Quorum

When you reset the quorum what you are doing is bootstrapping the *Primary Component* on the most advanced node you have available. This node then functions as the new Primary Component, bringing the rest of the cluster into line with its state.

There are two methods available to you in this process: automatic and manual.

Note: The preferred method for a quorum reset is the automatic method. Unlike the manual method, automatic bootstraps preserve the write-set cache, or GCache, on each node. What this means is that when the new Primary Component starts, some or all of the joining nodes can provision themselves using the *Incremental State Transfer* (IST) method, rather than the much slower *State Snapshot Transfer* (SST) method.

Automatic Bootstrap

Resetting the quorum bootstraps the *Primary Component* onto the most advanced node. In the automatic method this is done by enabling *pc.bootstrap* (page 258) under *wsrep_provider_options* (page 230) dynamically through the database client. This makes the node a new Primary Component.

To perform an automatic bootstrap, on the database client of the most advanced node, run the following command:

```
SET GLOBAL wsrep_provider_options='pc.bootstrap=YES';
```

The node now operates as the starting node in a new Primary Component. Nodes in nonoperational components that have network connectivity attempt to initiate incremental state transfers if possible, state snapshot transfers if not, with this node, bringing their own databases up-to-date.

Manual Bootstrap

Resetting the quorum bootstraps the *Primary Component* onto the most advanced node. In the manual method this is done by shutting down the cluster, then starting it up again beginning with the most advanced node.

To manually bootstrap your cluster, complete the following steps:

1. Shut down all cluster nodes. For servers that use `init`, run the following command from the console:

   ```
   # service mysql stop
   ```

   For servers that use `systemd`, instead run this command:

   ```
   # systemctl stop mysql
   ```

2. Start the most advanced node with the `--wsrep-new-cluster` option. For servers that use `init`, run the following command:

```
# service mysql start --wsrep-new-cluster
```

For servers that use `systemd`, instead run this command:

```
# systemctl start mysql --wsrep-new-cluster
```

3. Start every other node in the cluster. For servers that use `init`, run the following command:

```
# service mysql start
```

For servers that use `systemd`, instead run this command:

```
# systemctl start mysql
```

When the first node starts with the `--wsrep-new-cluster` option, it initializes a new cluster using the data from the most advanced state available from the previous cluster. As the other nodes start they connect to this node and request state snapshot transfers, to bring their own databases up-to-date.

CHAPTER

SEVENTEEN

MANAGING FLOW CONTROL

The cluster replicates changes synchronously through global ordering, but applies these changes asynchronously from the originating node out. To prevent any one node from falling too far behind the cluster, Galera Cluster implements a feedback mechanism called Flow Control.

Nodes queue the write-sets they receive in the global order and begin to apply and commit them on the database. In the event that the received queue grows too large, the node initiates Flow Control. The node pauses replication while it works the received queue. Once it reduces the received queue to a more manageable size, the node resumes replication.

Monitoring Flow Control

Galera Cluster provides global status variables for use in monitoring Flow Control. These break down into those status variables that count Flow Control pause events and those that measure the effects of pauses.

```
SHOW STATUS LIKE 'wsrep_flow_control_%';
```

Running these status variables returns only the node's present condition. You are likely to find the information more useful by graphing the results, so that you can better see the points where Flow Control engages.

For instance, using myq_gadgets:

```
$ mysql -u monitor -p -e 'FLUSH TABLES WITH READ LOCK;' \
   example_database
$ myq_status wsrep

Wsrep    Cluster         Node           Queue  Ops      Bytes    Flow          Conflct
time     name      P cnf  # name   cmt  sta  Up  Dn   Up  Dn    Up    Dn pau snt dst lcf␣
↪bfa
09:22:17 cluster1 P   3  3 node3 Sync T/T   0   0    0   9     0   13K 0.0   0 101   0  ␣
↪0
09:22:18 cluster1 P   3  3 node3 Sync T/T   0   0    0  18     0   28K 0.0   0 108   0  ␣
↪0
09:22:19 cluster1 P   3  3 node3 Sync T/T   0   4    0   3     0 4.3K 0.0   0 109   0  ␣
↪0
09:22:20 cluster1 P   3  3 node3 Sync T/T   0  18    0   0     0    0 0.0   0 109   0  ␣
↪0
09:22:21 cluster1 P   3  3 node3 Sync T/T   0  27    0   0     0    0 0.0   0 109   0  ␣
↪0
09:22:22 cluster1 P   3  3 node3 Sync T/T   0  29    0   0     0    0 0.9   1 109   0  ␣
↪0
09:22:23 cluster1 P   3  3 node3 Sync T/T   0  29    0   0     0    0 1.0   0 109   0  ␣
↪0
```

You can find the slave queue under the `Queue Dn` column and `FC pau` refers to Flow Control pauses. When the slave queue rises to a certain point, Flow Control changes the pause value to `1.0`. The node will hold to this value until the slave queue is worked down to a more manageable size.

Note: **See Also**: For more information on status variables that relate to flow control, see *Galera Status Variables* (page 265).

Monitoring for Flow Control Pauses

When Flow Control engages, it notifies the cluster that it is pausing replication using an `FC_Pause` event. Galera Cluster provides two status variables that monitor for these events.

- *wsrep_flow_control_sent* (page 273) This status variable shows the number of Flow Control pause events sent by the local node since the last status query.
- *wsrep_flow_control_recv* (page 272) This status variable shows the number of Flow Control pause events on the cluster, both those from other nodes and those sent by the local node, since the last status query.

Measuring the Flow Control Pauses

In addition to tracking Flow Control pauses, Galera Cluster also allows you to track the amount of time since the last `SHOW STATUS` query during which replication was paused due to Flow Control.

You can find this using one of two status variables:

- *wsrep_flow_control_paused* (page 272) Provides the amount of time replication was paused as a fraction. Effectively, how much the slave lag is slowing the cluster. The value `1.0` indicates replication is paused now.
- *wsrep_flow_control_paused_ns* (page 272) Provides the amount of time replication was paused in nanoseconds.

Configuring Flow Control

Galera Cluster provides two sets of parameters that allow you to manage how nodes handle the replication rate and Flow Control. The first set controls the write-set cache, the second relates to the points at which the node engages and disengages Flow Control.

Managing the Replication Rate

These three parameters control how nodes respond to changes in the replication rate. They allow you to manage the write-set cache on an individual node.

- *gcs.recv_q_hard_limit* (page 255) This sets the maximum write-set cache size (in bytes). The parameter value depends on the amount of RAM, swap size and performance considerations.

  The default value is `SSIZE_MAX` minus 2 gigabytes on 32-bit systems. There is no practical limit on 64-bit systems.

  In the event that a node exceeds this limit and *gcs.max_throttle* (page 255) is not set at `0.0`, the node aborts with an out-of-memory error. If *gcs.max_throttle* (page 255) is set at `0.0.`, replication in the cluster stops.

- *gcs.max_throttle* (page 255) This sets the smallest fraction to the normal replication rate the node can tolerate in the cluster. If you set the parameter to `1.0` the node does not throttle the replication rate. If you set the parameter for `0.0`, a complete replication stop is possible.

  The default value is `0.25`.

- *gcs.recv_q_soft_limit* (page 255) This serves to estimate the average replication rate for the node. It is a fraction of the *gcs.recv_q_hard_limit* (page 255). When the replication rate exceeds the soft limit, the node calculates the average replication rate (in bytes) during this period. After that, the node decreases the replication rate linearly with the cache size so that at the *gcs.recv_q_hard_limit* (page 255) it reaches the value of the *gcs.max_throttle* (page 255) times the average replication rate.

  The default value is `0.25`.

  Note: When the node estimates the average replication rate, it can reach a value that is way off from the sustained replication rate.

The write-set cache grows semi-logarithmically with time after the *gcs.recv_q_soft_limit* (page 255) and the time needed for a state transfer to complete.

Managing Flow Control

These parameters control the point at which the node triggers Flow Control and the factor used in determining when it should disengage Flow Control and resume replication.

- *gcs.fc_limit* (page 254) This parameter determines the point at which Flow Control engages. When the slave queue exceeds this limit, the node pauses replication.

  It is essential for multi-master configurations that you keep this limit low. The certification conflict rate is proportional to the slave queue length. In master-save setups, you can use a considerably higher value to reduce Flow Control intervention.

  The default value is `16`.

- *gcs.fc_factor* (page 254) This parameter is used in determining when the node can disengage Flow Control. When the slave queue on the node drops below the value of *gcs.fc_limit* (page 254) times that of *gcs.fc_factor* (page 254) replication resumes.

  The default value is `0.5`.

Bear in mind that, while it is critical for multi-master operations that you use as small a slave queue as possible, the slave queue length is not so critical in master-slave setups. Depending on your application and hardware, the node can apply even 1K of write-sets in a fraction of a second. The slave queue length has no effect on master-slave failover.

Note: **Warning**: Cluster nodes process transactions asynchronously with regards to each other. Nodes cannot anticipate in any way the amount of replication data. Because of this, Flow Control is always reactive. That is, it only comes into affect after the node exceeds certain limits. It cannot prevent exceeding these limits or, when they are exceeded, it cannot make any guarantee as to the degree they are exceeded.

Meaning, if you were to configure a node with:

```
gcs.recv_q_hard_limit=100Mb
```

That node can still exceed that limit from a 1Gb write-set.

CHAPTER

EIGHTEEN

AUTO EVICTION

When Galera Cluster notices erratic behavior in a node, such as unusually delayed response times, it can initiate a process to remove the node permanently from the cluster. This process is called Auto Eviction.

Configuring Auto Eviction

Each node in your cluster monitors the group communication response times from all other nodes in the cluster. When the cluster registers delayed responses from a node, it adds an entry for the node to the delayed list.

If the delayed node becomes responsive again for a fixed period, entries for that node are removed from the delayed list. If the node receives enough delayed entries and it is found on the delayed list for the majority of the cluster, the delayed node is evicted permanently from the cluster.

Evicted nodes cannot rejoin the cluster until restarted.

You can configure Auto Eviction by setting options through the *wsrep_provider_options* (page 230) parameter.

- *evs.delayed_margin* (page 248) This sets the time period that a node can delay its response from expectations until the cluster adds it to the delayed list. You must set this parameter to a value higher than the round-trip delay time (RTT) between the nodes.

  The default value is `PT1S`.

- *evs.delayed_keep_period* (page 247) This sets the time period you require a node to remain responsive until one entry is removed from the delayed list.

  The default value is `PT30S`.

- *evs.evict* (page 248) This sets the point where the cluster triggers manual eviction to a certain node value. Setting this parameter as an empty string causes it to clear the evict list on the node where it is set.

- *evs.auto_evict* (page 246) This sets the number of entries allowed for a delayed node before Auto Eviction takes place. Setting this to `0` disables the Auto Eviction protocol on the node, though the node will continue to monitor node response times.

  The default value is `0`.

- *evs.version* (page 252) This sets which version of the EVS Protocol the node uses. Galera Cluster enables Auto Eviction starting with EVS Protocol version 1.

  The default value is version `0`, for backwards compatibility.

Checking Eviction Status

In the event that you suspect the node or a node in your cluster is entering a delayed, you can check its eviction status through Galera status variables.

- *wsrep_evs_state* (page 271) This status variable gives the internal state of the EVS Protocol.
- *wsrep_evs_delayed* (page 270) This status variable gives a comma separated list of nodes on the delayed list.

  The node listing format is `uuid:address:count`. The `count` referrs to the number of entries for the given delayed node.
- *wsrep_evs_evict_list* (page 271) This status variable lists the UUID's of evicted nodes.

You can check these status variables using the `SHOW STATUS` query from the database client. For example,

```
SHOW STATUS LIKE 'wsrep_evs_delayed';
```

Upgrading from Previous Versions

Releases of Galera Cluster prior to version 3.8 use EVS Protocol version 0, which is not directly compatible with version 1. As such, when you upgrade Galera Cluster for your node, the node continues to use EVS Protocol version 0.

To update the EVS Protocol version, you must first update the Galera Cluster software on each node:

1. Choose a node to start the upgrade and stop `mysqld`. For systems that use `init`, run the following command:

   ```
   # service mysql stop
   ```

   For systems that run `systemd`, instead use this command:

   ```
   # systemctl stop mysql
   ```

2. Once you stop `mysqld`, update the Galera Cluster software for the node. This can vary depending upon how you installed Galera Cluster and which distribution and database server you use.

3. Using a text editor, edit your configuration file, `/etc/my.cnf`, setting the EVS Protocol version to `0`.

   ```
   wsrep_provider_options="evs.version=0"
   ```

4. Restart the node. For systems that use `init`, run the following command:

   ```
   # service mysql start
   ```

   For systems that run `systemd`, instead use this command:

   ```
   # systemctl start mysql
   ```

5. Using the database client, check the node state.

   ```
   SHOW STATUS LIKE 'wsrep_local_state_comment';

   +----------------------------+--------+
   | Variable_name              | Value  |
   +----------------------------+--------+
   | wsrep_local_state_comment  | Joined |
   +----------------------------+--------+
   ```

```
```

When the node state reads as Synced, the node is back in sync with the cluster.

Repeat the above procedure to update the remaining nodes in the cluster. Once this process is complete, your cluster will have the latest version of Galera Cluster. You can then begin updating the EVS Protocol version for each node.

1. Choose a node to start on, then using a text editor, update the EVS Protocol version in the configuration file, /etc/my.cnf.

```
wsrep_provider_options="evs.version=1"
```

2. Restart mysqld. If your system uses init, run the following command:

```
# service mysql restart
```

For system that run systemd, instead use this command:

```
# systemctl restart mysql
```

3. Using the database clinet, check that the EVS Protocol is using version 1 by running the new *wsrep_evs_state* (page 271) status variable.

```
SHOW STATUS LIKE 'wsrep_evs_state';
```

If the STATUS query returns an empty set, something went wrong and your database server is still on EVS Protocol version 0. If it returns a set, the EVS Protocol is on the right version and you can proceed.

4. Check the node state.

```
SHOW STATUS LIKE 'wsrep_local_state_comment';

+----------------------------+--------+
| Variable_name              | Value  |
+----------------------------+--------+
| wsrep_local_state_comment  | Joined |
+----------------------------+--------+
```

When the node state reads as Synced, the node is back in sync with the cluster.

This updates the EVS Protocol version for one node in your cluster. Repeat the process on the remaining nodes, so that they all use EVS Protocol version 1.

Note: See Also: For more information on upgrading in general, see *Upgrading Galera Cluster* (page 107).

CHAPTER

NINETEEN

SCHEMA UPGRADES

Any DDL (Data Definition Language) statement that runs for the database, such as `CREATE TABLE` or `GRANT`, upgrades the schema. These DDL statements change the database itself and are non-transactional.

Galera Cluster processes schema upgrades in two different methods:

- *Total Order Isolation* (page 99) (TOI) Where the schema upgrades run on all cluster nodes in the same total order sequence, preventing other transations from committing for the duration of the operation.
- *Rolling Schema Upgrade* (page 100) (RSU) Where the schema upgrades run locally, affecting only the node on which they are run. The changes do *not* replicate to the rest of the cluster.
- *Non-Blocking Operation* (page 100) (NBO)

You can set the method for online schema upgrades by using the `wsrep_OSU_method` parameter in the configuration file, (**my.ini** or **my.cnf**, depending on your build) or through the MySQL client. Galera Cluster defaults to the Total Order Isolation method.

Note: See Also: If you are using Galera Cluster for Percona XtraDB Cluster, see the the pt-online-schema-change in the Percona Toolkit.

Total Order Isolation

When you want your online schema upgrades to replicate through the cluster and don't mind that other transactions will be blocked while the cluster processes the DDL statements, use the *Total Order Isolation* method.

```
SET GLOBAL wsrep_OSU_method='TOI';
```

In Total Order Isolation, queries that update the schema replicate as statements to all nodes in the cluster. The nodes wait for all preceding transactions to commit then, simultaneously, they execute the schema upgrade in isolation. For the duration of the DDL processing, no other transactions can commit.

The main advantage of Total Order Isolation is its simplicity and predictability, which guarantees data consistency.

In addition, when using Total Order Isolation, you should take the following particularities into consideration:

- From the perspective of certification, schema upgrades in Total Order Isolation never conflict with preceding transactions, given that they only execute after the cluster commits all preceding transactions. What this means is that the certification interval for schema upgrades using this method has a zero length. Therefore, schema upgrades will never fail certification and their execution is guaranteed.
- Transactions that were in progress while the DDL was running and that involved the same database resource will get a deadlock error at commit time and will be rolled back.

- The cluster replicates the schema upgrade query as a statement before its execution. There is no way to know whether or not individual nodes succeed in processing the query. This prevents error checking on schema upgrades in Total Order Isolation.

Rolling Schema Upgrade

When you want to maintain high-availability during schema upgrades and can avoid conflicts between new and old schema definitions, use the *Rolling Schema Upgrade* method.

```
SET GLOBAL wsrep_OSU_method='RSU';
```

In Rolling Schema Upgrade, queries that update the schema are only processed on the local node. While the node processes the schema upgrade, it desynchronizes with the cluster. When it finishes processing the schema upgrade it applies delayed replication events and synchronizes itself with the cluster.

To upgrade the schema cluster-wide, you must manually execute the query on each node in turn. Bear in mind that during a rolling schema upgrade the cluster continues to operate, with some nodes using the old schema structure while others use the new schema structure.

The main advantage of the Rolling Schema Upgrade is that it only blocks one node at a time.

The main disadvantage of the Rolling Schema Upgrade is that it is potentially unsafe, and may fail if the new and old schema definitions are incompatible at the replication event level.

Note: **Warning**: To avoid conflicts between new and old schema definitions, execute operations such as `CREATE TABLE` and `DROP TABLE` using the *Total Order Isolation* (page 99) method.

Non-Blocking Operation

When you want to maintain high-availability while altering, analyzing or optimizing tables and don't mind the particular limitations, use the *Non-Blocking Operation* method.

Under the *Total Order Isolation* method, when DDL statements replicate, the nodes block almost all updates and with some statements this can go on for a particularly long time. In the Non-Blocking Operation method, the node applies special table locks called metadata locks on all nodes, in order to ensure consistency. The nodes all execute the DDL statements, using a separate applier thread. Then, once the statement is applied, all nodes simultaneously release the locks.

```
SET SESSION wsrep_OSU_method='NBO';
```

Given its *limitations* (page 101), the recommended method in updating the schema with a Non-Blocking Operation is to enable it at a session level, run the command, and then reset the Online Schema Upgrade method back to `TOI` or `RSU`.

DDL statements that support Non-Blocking Operation:

- `ALTER TABLE table_name LOCK = {SHARED|EXCLUSIVE}, alter_specification`
- `ALTER TABLE table_name LOCK = {SHARED|EXCLUSIVE} PARTITION`
- `CREATE INDEX ... LOCK = {SHARED|EXCLUSIVE}`
- `DROP INDEX`
- `ANALYZE TABLE`

- OPTIMIZE TABLE

Note: For partition-management operations, no comma is used after LOCK = {SHARED|EXCLUSIVE}.

DDL statements that do not support Non-Blocking Operation:

- ALTER TABLE LOCK = {DEFAULT|NONE}, including ALTER statements without the LOCK clause, as such statements default to the DEFAULT lock.
- CREATE TABLE, RENAME, DROP, and REPAIR.

Issuing unsupported operations while using the Non-Blocking Operation method results in an error code. For example,

```
SET SESSION wsrep_OSU_method='NBO';
CREATE TABLE table_name (
     id INT,
     title VARCHAR(255)) ENGINE=InnoDB;

Error 42000: wsrep_OSU_method NBO not supported for query
```

Limitations

In addition to unsupported DDL statements, there are a number of limitations in using the *Non-Blocking Operation* method to consider:

- Given that DDL statements such as CREATE or using ALTER without the LOCK clause results in an error under the Non-Blocking Operation method, it is not recommended that you set *wsrep_OSU_method* (page 228) to NBO server-wide.

  Instead, only use the Non-Blocking Operation method for specific sessions that run supported DDL statements.
- While the node processes a DDL statement under the Non-Blocking Operation method, it is not possible to write to the table being altered. The node blocks write attempts until it finishes applying the ALTER.

  When you set the lock to EXCLUSIVE, the node also blocks reads to the table. When you set the lock to SHARED, the node allows read operations on the table.
- The acquisition of the table metadata lock at the beginning of the operation remains a blocking operation. Long transactions already running against the table may lead the cluster to block while the lock is granted. To avoid this, ensure that no clients have open transactions that include the table prior to running the ALTER statement.
- During NBO DDL operations, nodes cannot serve as donors for a *State Snapshot Transfer*.

  What this means is that nodes are unable to join the cluster while DDL statements are in progress under this method. Nodes that attempt to rejoin the cluster, must have sufficient data in their write-set caches to perform a *Incremental State Transfer*. Those that do not are unable to rejoin.

  Note: If you expect a DDL statement to take an hour to run, adjust the *gcache.size* (page 253) wsrep option accordingly so that the nodes cache enough data to perform incremental state transfers, in the event that they need to during the process.

- Under this method, nodes that leave the cluster during DDL operations will have an inconsistent snapshot of the data, meaning that they can only rejoin the cluster through a State Snapshot Transfer, rather than the much faster Incremental State Transfer.
- Do not use DDL statements with this method that operate on more than one table at a time.

- Do not execute other DDL statements, such as ones using the *Rolling Schema Upgrade* method while upgrades using the Non-Blocking Operation method are in progress.

CHAPTER

TWENTY

USING STREAMING REPLICATION

When a node replicates a transaction under *Streaming Replication*, it breaks the transaction down into fragments, then certifies and applies the fragments to slave nodes while the transaction is still in progress.

This allows you to work with larger data-sets, manage hot records, and help avoid conflicts and hangs in the case of long-running transactions.

Note: Streaming Replication is a new feature introduced in version 4.0 of Galera Cluster. Older versions do not support these operations.

Enabling Streaming Replication

The best practice when working with *Streaming Replication* is to enable it at a session-level for specific transactions or parts thereof. The reason is that Streaming Replication increases the load on all nodes when applying and rolling back transactions. Meaning, you'll get better performance if you only enable Streaming Replication on those transactions that won't run correctly without it.

Note: For more information, see *When to Use Streaming Replication* (page 69).

Enabling Streaming Replication requires that you define the replication unit and number of units to use in forming the transaction fragments. Two parameters control these variables: *wsrep_trx_fragment_unit* (page 239) and *wsrep_trx_fragment_size* (page 239).

```
SET SESSION wsrep_trx_fragment_unit='statement';
SET SESSION wsrep_trx_fragment_size=3;
```

In the example, the fragment is set to three statements. For every three statements from the transaction, the node will generate, replicate and certify a fragment.

You can choose between several replication units when forming fragments:

- **bytes** Defines the fragment size in bytes.
- **events** Defines the fragment size as the number of binary log events generated.
- **rows** Defines the fragment size as the number of rows the fragment updates.
- **statements** Defines the fragment size as the number of statements in a fragment.

Choose the replication unit and fragment size that best suits the specific operation you want to run.

Streaming Replication with Hot Records

When your application needs to frequently update the same records from the same table, (such as when implementing a locking scheme, a counter, or a job queue), Streaming Replication allows you to force critical changes to replicate to the entire cluster.

For instance, consider the use case of a web application that creates work orders for a company. When the transaction starts it updates the table `work_orders` setting the queue position for the order. Under normal replication, two transactions can come into conflict if they attempt to update the queue position at the same time.

You can avoid this with Streaming Replication:

1. Begin the transaction:

   ```
   START TRANSACTION;
   ```

2. After reading the data that you need for the application, enable Streaming Replication:

   ```
   SET SESSION wsrep_trx_fragment_unit='statement';
   SET SESSION wsrep_trx_fragment_size=1;
   ```

3. Set the user's position in the queue:

   ```
   UPDATE work_orders SET queue_position = queue_position + 1;
   ```

4. Disable Streaming Replication:

   ```
   SET SESSION wsrep_trx_fragment_size=0;
   ```

5. Perform whatever additional tasks you need to ready the work order, then commit the transaction:

   ```
   COMMIT;
   ```

During the work order transaction, the client initiates Streaming Replication for a single statement, which it uses to set the queue position. The queue position update then replicates throughout the cluster, which prevents other nodes from coming into conflict with the new work order.

CHAPTER

TWENTYONE

SYSTEM DATABASES

When you install Galera Cluster, it creates a set of system databases that it uses to store configuration information. For instance, the underlying database server uses the `mysql` database for system tables, which record such things as user names, passwords and what databases and tables those users can access.

Note: Nodes begin using the `wsrep_schema` database in version 4.0 of Galera Cluster. This feature does not exist in older versions of Galera Cluster.

wsrep Schema Database

Similar to the `performance_schema` and `information_schema` databases, the node uses `wsrep_schema` to store information about the state of the cluster, including the nodes that current part of the *Primary Component* as well as a history of nodes that were previously in the cluster.

You may find this information useful in diagnosing issues or in checking the state of the cluster through a monitoring solution.

Note: For more information on monitoring, see *Monitor* (page 147).

The database contains the following tables:

- `cluster` Table contains the current state of the cluster. It contains a single row:

Column	Description
`cluster_uuid`	Provides the current UUID of the cluster.
`view_id`	Provides a sequential ID that indicates the current topology of the cluster. This value increments with changes in cluster membership.

- `members` Table contains the current cluster membership.

Column	Description
`node_uuid`	Provides the node UUID.
`cluster_uuid`	Provides the cluster UUID.
`node_name`	Provides the logical name of the node.
`node_incoming_address`	Provides the node IP address and port on which the node listens for incoming SQL client connections.

- `member_history` Table contains the complete cluster membership, including a row for every node in the current cluster as well as nodes that currently are not members.

Column	Description
node_uuid	Provides the node UUID.
cluster_uuid	Provides the cluster UUID.
last_view_id	Provides the view ID that was in use the last time the node was in the cluster.
node_name	Provides the logical name of the node.
node_incoming_address	Provides the node IP address and port on which the node listens for incoming SQL client connections.

If the value of the last_view_id column is less than the view_id on the wsrep_schema.cluster table, the node is currently not a part of the cluster.

You can query these tables the same as any other. For instance,

```
SELECT node_name, node_incoming_address
FROM wsrep_schema.members;

+-----------------------+-----------------------+
| node_name             | node_incoming_address |
+-----------------------+-----------------------+
| localhost.localdomain | 127.0.0.1:13000       |
+-----------------------+-----------------------+
| localhost.localdomain | 127.0.0.1.13004       |
+-----------------------+-----------------------+
```

Would indicate that the cluster current has two nodes, both of which are running on localhost. Alternatively, you might query members_history for a more complete membership list:

```
SELECT node_name, node_incoming_address, last_view_id
FROM wsrep_schema.members_history;

+-----------------------+-----------------------+--------------+
| node_name             | node_incoming_address | last_view_id |
+-----------------------+-----------------------+--------------+
| localhost.localdomain | 127.0.0.1:13000       |            4 |
+-----------------------+-----------------------+--------------+
| localhost.localdomain | 127.0.0.1:13004       |            4 |
+-----------------------+-----------------------+--------------+
| localhost.localdomain | 127.0.0.1:13008       |            3 |
+-----------------------+-----------------------+--------------+
```

Indicates that, previously, there was a third node running on localhost that is not present in the current cluster topology. This is indicated by the last_view_id on one node being less than the others.

CHAPTER

TWENTYTWO

UPGRADING GALERA CLUSTER

You have three methods available in upgrading Galera Cluster:

- *Rolling Upgrade* (page 107) Where you upgrade each node one at a time.
- *Bulk Upgrade* (page 108) Where you upgrade all nodes together.
- *Provider Upgrade* (page 109) Where you only upgrade the Galera Replication Plugin.

There are advantages and disadvantages to each method. For instance, while a rolling upgrade may prove time consuming, the cluster remains up. Similarly, while a bulk upgrade is faster, problems can result in longer outages. You must choose the best method to implement in upgrading your cluster.

Rolling Upgrade

When you need the cluster to remain live and do not mind the time it takes to upgrade each node, use rolling upgrades.

In rolling upgrades, you take each node down individually, upgrade its software and then restart the node. When the node reconnects, it brings itself back into sync with the cluster, as it would in the event of any other outage. Once the individual finishes syncing with the cluster, you can move to the next in the cluster.

The main advantage of a rolling upgrade is that in the even that something goes wrong with the upgrade, the other nodes remain operational, giving you time to troubleshoot the problem.

Some of the disadvantages to consider in rolling upgrades are:

- **Time Consumption** Performing a rolling upgrade can take some time, longer depending on the size of the databases and the number of nodes in the cluster, during which the cluster operates at a diminished capacity.

  Unless you use *Incremental State Transfer*, as you bring each node back online after an upgrade, it initiates a full *State Snapshot Transfer*, which can take a long time to process on larger databases and slower state transfer methods.

  During the State Snapshot Transfer, the node continues to accumulate catch-up in the replication event queue, which it will then have to replay to synchronize with the cluster. At the same time, the cluster is operational and continues to add further replication events to the queue.

- **Blocking Nodes** When the node comes back online, if you use **mysqldump** for State Snapshot Transfers, the donor node remains blocked for the duration of the transfer. In practice, this means that the cluster is short two nodes for the duration of the state transfer, one for the donor node and one for the node in catch-up.

  Using **xtrabackup** or **rsync** with the LVM state transfer methods, you can avoid blocking the donor, but doing so may slow the donor node down.

Note: Depending on the load balancing mechanism, you may have to configure the load balancer not to direct requests at joining and donating nodes.

- **Cluster Availability** Taking down nodes for a rolling upgrade can greatly diminish cluster performance or availability, such as if there are too few nodes in the cluster to begin with or where the cluster is operating at its maximum capacity.

  In such cases, losing access to two nodes during a rolling upgrade can create situations where the cluster can no longer serve all requests made of it or where the execution times of each request increase to the point where services become less available.

- **Cluster Performance** Each node you bring up after an upgrade, diminishes cluster performance until the node buffer pool warms back up. Parallel applying can help with this.

To perform a rolling upgrade on Galera Cluster, complete the following steps for each node:

Note: Transfer all client connections from the node you are upgrading to the other nodes for the duration of this procedure.

1. Shut down the node.
2. Upgrade the software.
3. Restart the node.

Once the node finishes synchronizing with the cluster and completes its catch-up, move on tot he next node in the cluster. Repeat the procedure until you have upgraded all nodes in the cluster.

Tip: If you are upgraded a node that is or will be part of a weighted quorum, set the initial node weight to zero. This guarantees that if the joining node should fail before it finishes synchronizing, it will not affect any quorum computations that follow.

Bulk Upgrade

When you want to avoid time-consuming state transfers and the slow process of upgrading each node, one at a time, use a bulk upgrade.

In bulk upgrades, you take all of the nodes down in an idle cluster, perform the upgrades, then bring the cluster back online. This allows you to upgrade your cluster quickly, but does mean a complete service outage for your cluster.

Note: **Warning**: Always use bulk upgrades when using a two-node cluster, as the rolling upgrade would result in a much longer service outage.

The main advantage of bulk upgrade is that when you are working with huge databases, it is much faster and results in better availability than rolling upgrades.

The main disadvantage is that it relies on the upgrade and restart being quick. Shutting down InnoDB may take a few minutes as it flushes dirty pages. If something goes wrong during the upgrade, there is little time to troubleshoot and fix the problem.

Note: To minimize any issues that might arise from an upgrade, do not upgrade all of the nodes at once. Rather, run the upgrade on a single node first. If it runs without issue, upgrade the rest of the cluster.

To perform a bulk upgrade on Galera Cluster, complete the following steps:

1. Stop all load on the cluster
2. Shut down all the nodes
3. Upgrade software
4. Restart the nodes. The nodes will merge to the cluster without state transfers, in a matter of seconds.
5. Resume the load on the cluster

Note: You can carry out steps 2-3-4 on all nodes in parallel, therefore reducing the service outage time to virtually the time needed for a single server restart.

Provider-only Upgrade

When you only need to upgrade the Galera provider, you can further optimize the bulk upgrade to only take a few seconds.

Important: In provider-only upgrade, the warmed up InnoDB buffer pool is fully preserved and the cluster continues to operate at full speed as soon as you resume the load.

Upgrading Galera Replication Plugin

If you installed Galera Cluster for MySQL using the binary package from the Codership repository, you can upgrade the Galera Replication Plugin through your package manager..

To upgrade the Galera Replicator Plugin on an RPM-based Linux distribution, run the following command for each node in the cluster:

```
$ yum update galera
```

To upgrade the Galera Replicator Plugin on a Debian-based Linux distribution, run the following commands for each node in the cluster:

```
$ apt-get update
$ apt-get upgrade galera
```

When `apt-get` or `yum` finish, you will have the latest version of the Galera Replicator Plugin available on the node. Once this process is complete, you can move on to updating the cluster to use the newer version of the plugin.

Updating Galera Cluster

After you upgrade the Galera Replicator Plugin package on each node in the cluster, you need to run a bulk upgrade to switch the cluster over to the newer version of the plugin.

1. Stop all load on the cluster.
2. For each node in the cluster, issue the following queries:

```
SET GLOBAL wsrep_provider='none';
SET GLOBAL wsrep_provider='/usr/lib64/galera/libgalera_smm.so';
```

3. One any one node in the cluster, issue the following query:

```
SET GLOBAL wsrep_cluster_address='gcomm://';
```

4. For every other node in the cluster, issue the following query:

```
SET GLOBAL wsrep_cluster_address='gcomm://node1addr';
```

   For `node1addr`, use the address of the node in step 3.

5. Resume the load on the cluster.

Reloading the provider and connecting it to the cluster typically takes less than ten seconds, so there is virtually no service outage.

CHAPTER

TWENTYTHREE

SCRIPTABLE STATE SNAPSHOT TRANSFERS

When a node sends and receives a *State Snapshot Transfer*, it manage it through processes that run external to the database server. In the event that you need more from these processes that the default behavior provides, Galera Cluster provides an interface for custom shell scripts to manage state snapshot transfers on the node.

Using the Common SST Script

Galera Cluster includes a common script for managing a *State Snapshot Transfer*, which you can use as a starting point in building your own custom script. The filename is `wsrep_sst_common.sh`. For Linux users, the package manager typically installs it for you in `/usr/bin`.

The common SST script provides ready functions for parsing argument lists, logging errors, and so on. There are no constraints on the order or number of parameters it takes. You can add to it new parameters and ignore any of the existing as suits your needs.

It assumes that the storage engine initialization on the receiving node takes place only after the state transfer is complete. Meaning that it copies the contents of the source data directory to the destination data directory (with possible variations).

State Transfer Script Parameters

When Galera Cluster starts an external process for state snapshot transfers, it passes a number of parameters to the script, which you can use in configuring your own state transfer script.

General Parameters

These parameters are passed to all state transfer scripts, regardless of method or whether the node is sending or receiving:

- `--role` The script is given a string, either `donor` or `joiner`, to indicate whether the node is using it to send or receive a state snapshot transfer.
- `--address` The script is given the IP address of the joiner node.

  When the script is run by the joiner, the node uses the value of either the *wsrep_sst_receive_address* (page 237) parameter or a sensible default formatted as `<ip_address>:<port>`. When the script is run by the donor, the node uses the value from the state transfer request.
- `--auth` The script is given the node authentication information.

When the script is run by the joiner, the node uses the value given to the *wsrep_sst_auth* (page 234) parameter. When the script is run by the donor, it uses the value given by the state transfer request.

- `--datadir` The script is given the path to the data directory. The value is drawn from the `mysql_real_data_home` parameter.
- `--defaults-file` The script is given the path to the `my.cnf` configuration file.

The values the node passes to these parameters varies depending on whether the node calls the script to send or receive a state snapshot transfer. For more information, see *Calling Conventions* (page 112) below.

Donor-specific Parameters

These parameters are passed only to state transfer scripts initiated by a node serving as the donor node, regardless of the method being used:

- `--gtid` The node gives the *Global Transaction ID*, which it forms from the state UUID and the sequence number, or seqno, of the last committed transaction.
- `--socket` The node gives the local server socket for communications, if required.
- `--bypass` The node specifies whether the script should skip the actual data transfer and only pass the Global Transaction ID to the receiving node. That is, whether the node should initiate an *Incremental State Transfer*.

Logical State Transfer-specific Parameters

These parameters are passed only to the `wsrep_sst_mysqldump.sh` state transfer script by both the sending and receiving nodes:

- `--user` The node gives to the script the database user, which the script then uses to connect to both donor and joiner database servers. Meaning, this user must be the same on both servers, as defined by the *wsrep_sst_auth* (page 234) parameter.
- `--password` The node gives to the script the password for the database user, as configured by the *wsrep_sst_auth* (page 234) paraemter.
- `--host` The node gives to the script the IP address of the joiner node.
- `--port` The node gives to the script the port number to use with the joiner node.
- `--local-port` The node gives to the script the port number to use in sending the state transfer.

Calling Conventions

In writing your own custom script for state snapshot transfers, there are certain conventions that you need to follow in order to accommodate how Galera Cluster calls the script.

Receiver

When the node calls for a state snapshot transfer as a joiner, it begins by passing a number of arguments to the state transfer script, as defined in *General Parameters* (page 111) above. For your own script you can choose to use or ignore these arguments as suits your needs.

After the script receives these arguments, prepare the node to accept a state snapshot transfer. For example, in the case of `wsrep_sst_rsync.sh`, the script starts `rsync` in server mode.

To signal that the node is ready to receive the state transfer, print the following string to standard output: `ready <address>:port\n`. Use the IP address and port at which the node is waiting for the state snapshot. For example:

```
ready 192.168.1.1:4444
```

The node responds by sending a state transfer request to the donor node. The node forms the request with the address and port number of the joiner node, the values given to *wsrep_sst_auth* (page 234), and the name of your script. The donor receives the request and uses these values as input parameters in running your script on that node to send back the state transfer.

When the joiner node receives the state transfer and finishes applying it, print to standard output the *Global Transaction ID* of the received state. For example:

```
e2c9a15e-5485-11e0-0800-6bbb637e7211:8823450456
```

Then exit the script with a `0` status, to indicate that the state transfer was successful.

Sender

When the node calls for a state snapshot transfer as a donor, it begins by passing a number of arguments to the state transfer script, as defined in *General Parameters* (page 111) above. For your own script, you can choose to use or ignore these arguments as suits your needs.

While your script runs, Galera Cluster accepts the following signals. You can trigger them by printing to standard output:

- `flush tables\n` Optional signal that asks the database server to run `FLUSH TABLES`. When complete, the database server creates a `tables_flushed` file in the data directory.
- `continue\n` Optional signal that tells the database server that it can continue to commit transactions.
- `done\n` Mandatory signal that tells the database server that the state transfer is complete and successful.

After your script sends the `done\n` signal, exit with a `0` return code.

In the event of failure, Galera Cluster expects your script to return a code that corresponds to the error it encountered. The donor node returns this code to the joiner through group communication. Given that its data directory now holds an inconsistent state, the joiner node then leaves the cluster and aborts the state transfer.

Note: Without the `continue\n` signal, your script runs in Total Order Isolation, which guarantees that no further commits occur until the script exits.

Enabling Scriptable SST's

Whether you use `wsrep_sst_common.sh` directly or decide to write a script of your own from scratch, the process for enabling it remains the same. The filename must follow the convention of `wsrep_sst_<name>.sh`, with `<name>` being the value that you give for the *wsrep_sst_method* (page 235) parameter in the configuration file.

For example, if you write a script with the filename `wsrep_sst_galera-sst.sh`, you would add the following line to your `my.cnf`:

```
wsrep_sst_method = galera-sst
```

When the node starts, it uses your custom script for state snapshot transfers.

CHAPTER

TWENTYFOUR

GALERA ARBITRATOR

The recommended deployment of Galera Cluster is that you use a minimum of three instances. Three nodes, three datacenters and so on.

In the event that the expense of adding resources, such as a third datacenter, is too costly, you can use *Galera Arbitrator*. Galera Arbitrator is a member of the cluster that participates in voting, but not in the actual replication.

Note: **Warning** While Galera Arbitrator does not participate in replication, it does receive the same data as all other nodes. You must secure its network connection.

Galera Arbitrator serves two purposes:

- When you have an even number of nodes, it functions as an odd node, to avoid split-brain situations.
- It can request a consistent application state snapshot, for use in making backups.

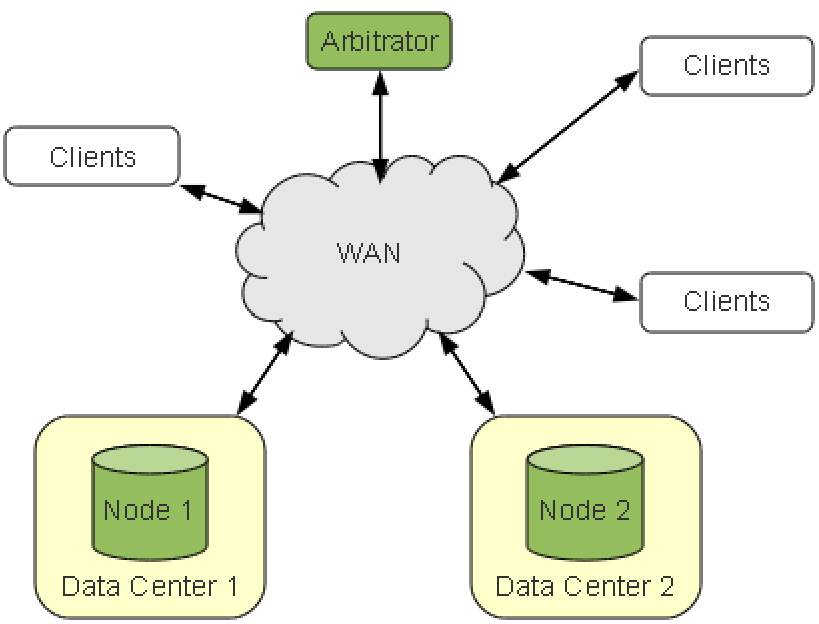


Fig. 24.1: *Galera Arbitrator*

If one datacenter fails or loses WAN connection, the node that sees the arbitrator, and by extension sees clients, continues operation.

Note: Even though Galera Arbitrator does not store data, it must see all replication traffic. Placing Galera Arbitrator in a location with poor network connectivity to the rest of the cluster may lead to poor cluster performance.

In the event that Galera Arbitrator fails, it does not affect cluster operation. You can attach a new instance to the cluster at any time and there can be several instances running in the cluster.

Note: **See Also**: For more information on using Galera Arbitrator in making backups, see *Backing Up Cluster Data* (page 119).

Starting Galera Arbitrator

Galera Arbitrator is a separate daemon from Galera Cluster, called `garbd`. This means that you must start it separate from the cluster. It also means that you cannot configure Galera Arbitrator through the `my.cnf` configuration file.

How you configure Galera Arbitrator depends on how you start it. That is, whether it runs from the shell or as a service.

Note: When Galera Arbitrator starts, the script executes a `sudo` statement as the user `nobody` during its process. There is a particular issue in Fedora and some other distributions of Linux, where the default `sudo` configuration blocks users that operate without `tty` access. To correct this, using your preferred text editor, edit the `/etc/sudoers` file and comment out the line

```
Defaults requiretty
```

This prevents the operating system from blocking Galera Arbitrator.

Starting Galera Arbitrator from the Shell

When starting Galera Arbitrator from the shell, you have two options in how you configure it. Firstly, you can set the parameters through the command line arguments. For example,

```
$ garbd --group=example_cluster \
     --address="gcomm://192.168.1.1,192.168.1.2,192.168.1.3" \
     --option="socket.ssl_key=/etc/ssl/galera/server-key.pem;socket.ssl_cert=/etc/ssl/
↪galera/server-cert.pem;socket.ssl_ca=/etc/ssl/galera/ca-cert.pem;socket.ssl_
↪cipher=AES128-SHA""
```

If you use SSL it is necessary to also specify the cipher, otherwise there will be "terminate called after throwing an instance of 'gu::NotSet'" after initializing the ssl context.

If you do not want to type out the options every time you start Galera Arbitrator from the shell, you can set the options you want to use in a configuration file:

```
# arbtirator.config
group = example_cluster
address = gcomm://192.168.1.1,192.168.1.2,192.168.1.3
```

Then, when you start Galera Arbitrator, use the `--cfg` option.

```
$ garbd --cfg /path/to/arbitrator.config
```

For more information on the options available to Galera Arbitrator through the shell, run it with the `--help` argument.

```
$ garbd --help

Usage: garbd [options] [group address]

Configuration:
  -d [ --daemon ]        Become daemon
  -n [ --name ] arg      Node name
  -a [ --address ] arg   Group address
  -g [ --group ] arg     Group name
  --sst arg              SST request string
  --donor arg            SST donor name
  -o [ --options ] arg   GCS/GCOMM option list
  -l [ --log ] arg       Log file
  -c [ --cfg ] arg       Configuration file

Other options:
  -v [ --version ]       Print version
  -h [ --help ]          Show help message
```

In addition to the standard configurations, any parameter available to Galera Cluster also works with Galera Arbitrator, excepting those prefixed by `repl`. When you start it from the shell, you can set these using the `--option` argument.

Note: **See Also**: For more information on the options available to Galera Arbitrator, see *Galera Parameters* (page 243).

Starting Galera Arbitrator as a Service

When starting Galera Aribtrator as a service, whether using `init` or `systemd`, you use a different format for the configuration file than you would use when starting it from the shell.

```
# Copyright (C) 2013-2015 Codership Oy
# This config file is to be sourced by garbd service script.

# A space-separated list of node addresses (address[:port]) in the cluster:
GALERA_NODES="192.168.1.1:4567 192.168.1.2:4567"

# Galera cluster name, should be the same as on the rest of the node.
GALERA_GROUP="example_wsrep_cluster"

# Optional Galera internal options string (e.g. SSL settings)
# see http://galeracluster.com/documentation-webpages/galeraparameters.html
GALERA_OPTIONS="socket.ssl_cert=/etc/galera/cert/cert.pem;socket.ssl_key=/$"

# Log file for garbd. Optional, by default logs to syslog
LOG_FILE="/var/log/garbd.log"
```

In order for Galera Arbitrator to use the configuration file, you must place it in a directory that your system looks to for service configurations. There is no standard location for this directory, it varies from distribution to distribution, though it usually somewhere in `/etc`.

Common locations include:

- `/etc/defaults/`
- `/etc/init.d/`
- `/etc/systemd/`
- `/etc/sysconfig/`

Check the documentation for your distribution to determine where to place service configuration files.

Once you have the service configuration file in the right location, you can start the `garb` service. For systems that use `init`, run the following command:

```
# service garb start
```

For systems that run `systemd`, instead use this command:

```
# systemctl start garb
```

This starts Galera Arbitrator as a service. It uses the parameters set in the configuration file.

In addition to the standard configurations, any parameter available to Galera Cluster also works with Galera Arbitrator, excepting those prefixed by `repl`. When you start it as a service, you can set these using the `GALERA_OPTIONS` parameter.

Note: **See Also**: For more information on the options available to Galera Arbitrator, see *Galera Parameters* (page 243).

CHAPTER

TWENTYFIVE

BACKING UP CLUSTER DATA

You can perform backups with Galera Cluster at the same regularity as with the standard database server, using a backup script. Given that replication ensures that all nodes carry the same data, running the script on one node backs up the data on all nodes in the cluster.

The problem with such backups is that they lack a *Global Transaction ID*. You can use backups of this kind to recover data, but they are insufficient for use in recovering nodes to a well-defined state. Furthermore, some backup procedures can block cluster operations for the duration of the backup.

Getting backups with the associated Global Transaction ID requires a different approach.

State Snapshot Transfer as Backup

Taking a full data backup is very similar to node provisioning through a *State Snapshot Transfer*. In both cases, the node creates a full copy of the database contents, using the same mechanism to associate a *Global Transaction ID* with the database state.

In order to enable this feature for backups, you need a script that implements both your preferred backup procedure and the Galera Arbitrator daemon, triggering it in a manner similar to a state snapshot transfer.

```
$ garbd --address gcomm://192.168.1.2?gmcast.listen_addr=tcp://0.0.0.0:4444 \
  --group example_cluster --donor example_donor --sst backup
```

This command triggers the donor node to invoke a script with the name `wsrep_sst_backup.sh`, which it looks for in the `PATH` for the `mysqld` process. When the donor reaches a well-defined point, a point where no changes are happening to the database, it runs the backup script passing the Global Transaction ID corresponding to the current database state.

Note: In the command, ‘`?gmcast.listen_addr=tcp://0.0.0.0:4444`‘ is an arbitrary listen socket address that Galera Arbitrator opens to communicate with the cluster. You only need to specify this in the even that the default socket address, (that is, `0.0.0.0:4567` is busy.

Invoking backups through the state snapshot transfer mechanism has the following benefits:

- The node initiates the backup at a well-defined point.
- The node associates a Global Transaction ID with the backup.
- The node desyncs from the cluster to avoid throttling performance while taking the backup, even if the backup process is blocks the node.
- The cluster knows that the node is performing a backup and won’t choose the node as a donor for another node.

Note: **See Also**: You may find it useful to create your backup script using a modified version of the standard state snapshot transfer scripts. For information on scripts of this kind, see *Scriptable State Snapshot Transfers* (page 111).

Part IV

Deployment

CHAPTER

TWENTYSIX

CLUSTER DEPLOYMENT VARIANTS

An instance of Galera Cluster consists of a series of nodes, preferably three or more. Each node is an instance of MySQL, MariaDB or Percona XtraDB that you convert to Galera Cluster, allowing you to use that node as a cluster base.

Galera Cluster provides synchronous multi-master replication, meaning that you can think of the cluster as a single database server that listens through many interfaces. To give you with an idea of what Galera Cluster is capable of, consider a typical *n*-tier application and the various benefits that would come from deploying it with Galera Cluster.

No Clustering

In the typical *n*-tier application cluster without database clustering, there is no concern for database replication or synchronization.

Internet traffic filters down to your application servers, all of which read and write from the same DBMS server. Given that the upper tiers usually remain stateless, you can start up as many instances as you need to meet the demand from the internet as each instance in turn stores its data in the data tier.

This solution is simple and easy to manage, but suffers a particular weakness in the data tier's lack of redundancy.

For example, should for any reason the DBMS server become unavailable, your application also becomes unavailable. This is the same whether the server crashes or if you need to take it down for maintenance.

Similarly, this deployment also introduces performance concerns. While you can start as many instances as you need to meet the demands on your web and application servers, they can only put so much load on the DBMS server before the load begins to slow down the experience for end users.

Whole Stack Clustering

In the typical *n*-tier application cluster you can avoid the performance bottleneck by building a whole stack cluster.

Internet traffic filters down to the application server, which stores data on its own dedicated DBMS server. Galera Cluster then replicates the data through to the cluster, ensuring that it remains synchronous.

This solution is simple and easy to manage, especially if you can install the whole stack of each node on one physical machine. The direct connection from the application tier to the data tier ensures low latency.

There are, however, certain disadvantages to whole stack clustering:

- **Lack of Redundancy within the Stack** When the database server fails the whole stack fails. This is because the application server uses a dedicated database server, if the database server fails there's no alternative for the application server, so the whole stack goes down.

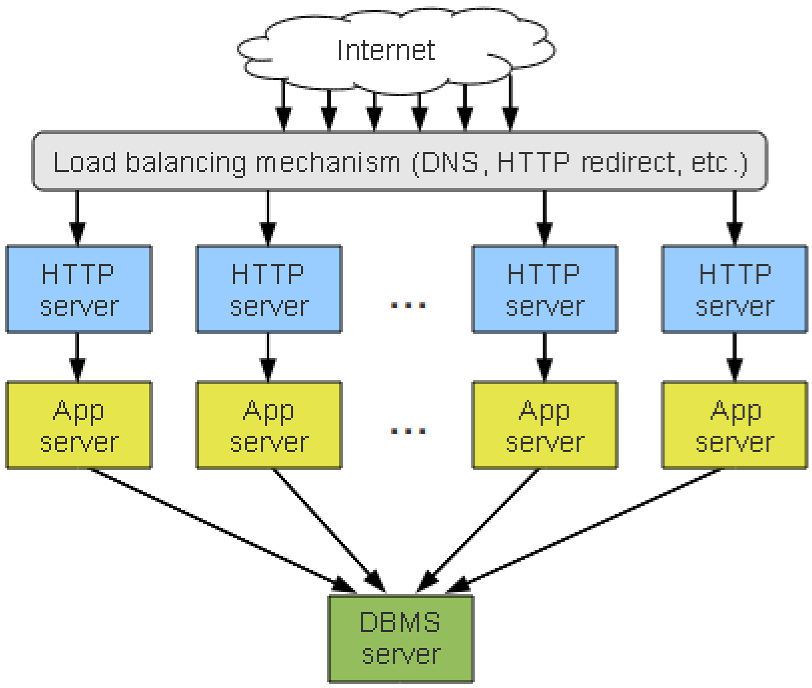


Fig. 26.1: *No Clustering*

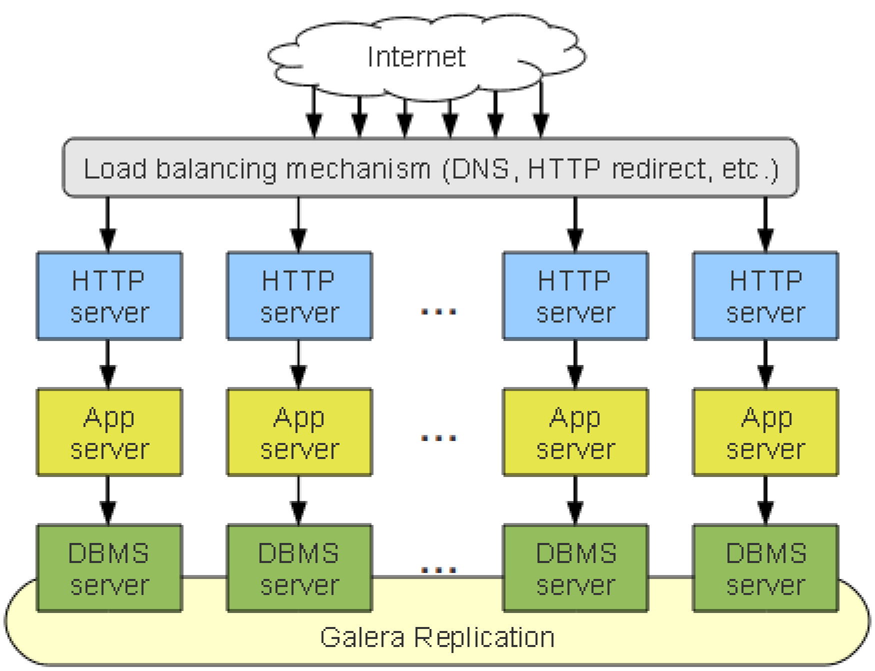


Fig. 26.2: *Whole Stack Cluster*

- **Inefficient Resource Usage** A dedicated DBMS server for each application server is overuse. This is poor resource consolidation. For instance, one server with a 7 GB buffer pool is much faster than two servers with 4 GB buffer pools.
- **Increased Unproductive Overhead** Each server reproduces the work of the other servers in the cluster.
- **Increased Rollback Rate** Given that each application server writes to a dedicated database server, cluster-wide conflicts are more likely, which can increases the likelihood of corrective rollbacks.
- **Inflexibility** There is no way for you to limit the number of master nodes or to perform intelligent load balancing.

Despite the disadvantages, however, this setup can prove very usable for several applications. It depends on your needs.

Data Tier Clustering

To compensate for the shortcomings in whole stack clusters, you can cluster the data tier separate from your web and application servers.

Here, the DBMS servers form a cluster distinct from your *n*-tier application cluster. The application servers treat the database cluster as a single virtual server, making their calls through load balancers to the data tier.

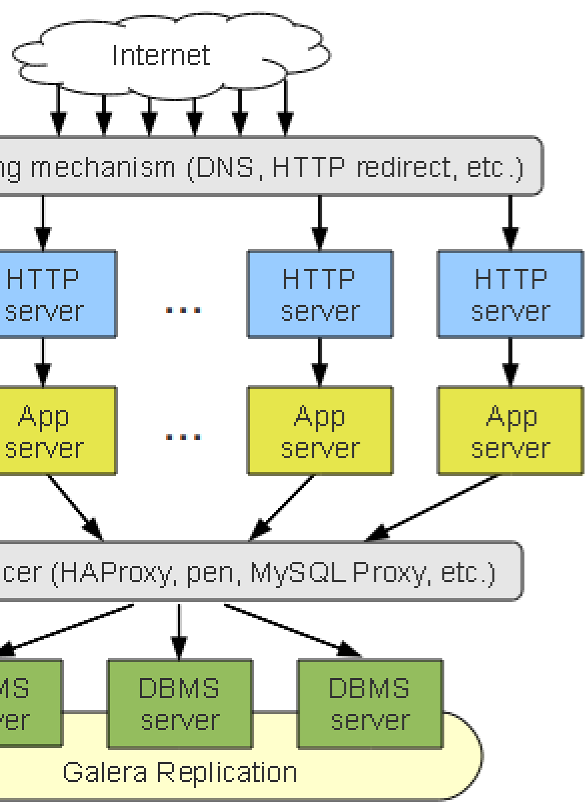


Fig. 26.3: *Data Tier Clustering*

In a data tier cluster, the failure of one node does not effect the rest of the cluster. Furthermore, resources are consolidated better and the setup is flexible. That is, you can assign nodes different roles using intelligent load balancing.

There are, however, certain disadvantages to consider in data tier clustering:

- **Complex Structure** Load balancers are involved and you must back them up in case of failures. This typical means that you have two more servers than you would otherwise, as well as a failover solution between them.
- **Complex Management** You need to configure and reconfigure the load balancers whenever a DBMS server is added to or removed from the cluster.
- **Indirect Connections** The load balancers between the application cluster and the data tier cluster increase the latency for each query. As such, this can easily become a performance bottleneck. You need powerful load balancing servers to avoid this.
- **Scalability** The scheme does not scale well over several datacenters. Attempts to do so may remove any benefits you gain from resource consolidation, given that each datacenter must include at least two DBMS servers.

Data Tier Clustering with Distributed Load Balancing

One solution to the limitations of data tier clustering is to deploy them with distributed load balancing. This scheme roughly follows the standard data tier cluster, but includes a dedicated load balancer installed on each application server.

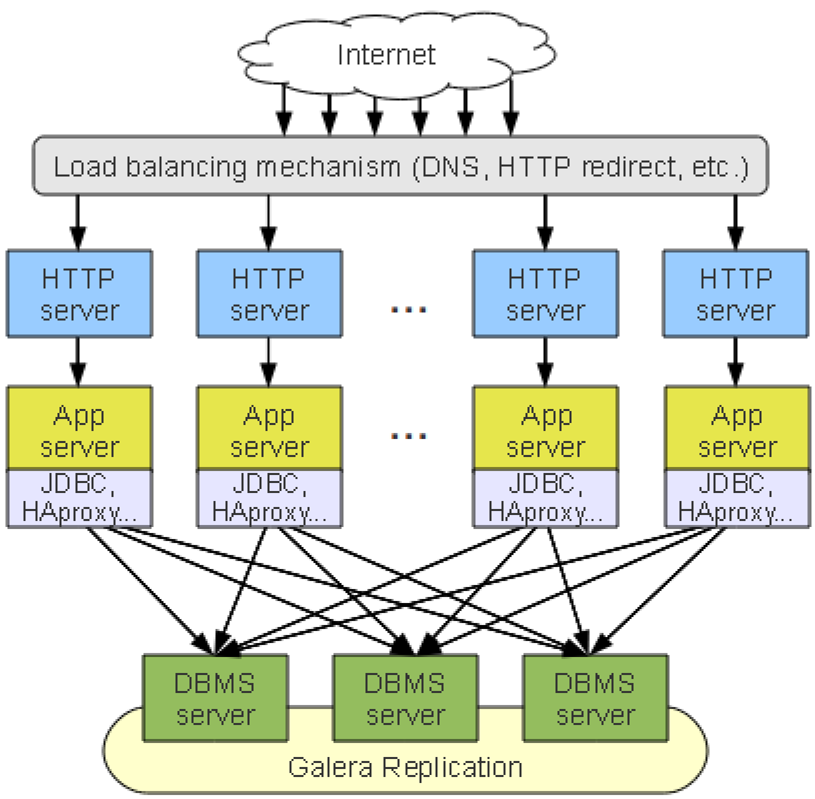


Fig. 26.4: *Data Tier Cluster with Distributed Load Balancing*

In this deployment, the load balancer is no longer a single point of failure. Furthermore, the load balancer scales with the application cluster and thus is unlikely to become a bottleneck. Additionally, it keeps down the client-server communications latency.

Data tier clustering with distributed load balancing has the following disadvantage:

- **Complex Management** Each application server you deploy to meet the needs of your *n*-tier application cluster means another load balancer that you need to set up, manage and reconfigure whenever you change or otherwise update the database cluster configuring.

Aggregated Stack Clustering

In addition to these deployment schemes, you also have the option of a hybrid setup that integrates whole stack and data tier clustering by aggregating several application stacks around single DBMS servers.

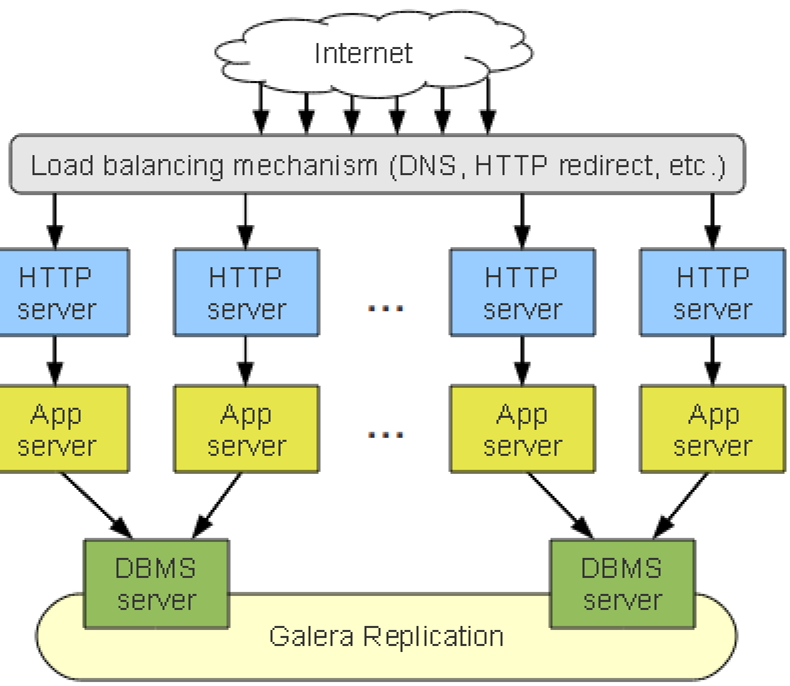


Fig. 26.5: *Aggregated Stack Clustering*

This scheme improves on the resource utilization of the whole stack cluster while maintaining it's relative simplicity and direct DBMS connection benefits. It is also how a data tier cluster with distributed load balancing with look if you were to use only one DBMS server per datacenter.

The aggregated stack cluster is a good setup for sites that are not very big, but still are hosted at more than one datacenter.

CHAPTER

TWENTYSEVEN

LOAD BALANCING

Galera Cluster guarantees node consistency regardless of where and when the query is issued. In other words, you are free to choose a load-balancing approach that best suits your purposes. If you decide to place the load balancing mechanism between the database and the application, you can consider, for example, the following tools:

- **HAProxy** an open source TCP/HTTP load balancer.
- **Pen** another open source TCP/HTTP load balancer. Pen performs better than HAProxy on SQL traffic.
- **Galera Load Balancer** inspired by Pen, but is limited to balancing generic TCP connections only.

Note: For more information or ideas on where to use load balancers in your infrastructure, see *Cluster Deployment Variants* (page 123).

HAProxy

High Availability Proxy, or HAProxy is a single-threaded event-driven non-blocking engine that combines a fast I/O layer with a priority-based scheduler. You can use it to balance the TCP connections between application servers and Galera Cluster.

Installation

HAProxy is available in the software repositories of most Linux distributions and it is the ports tree of FreeBSD. You can install it using the package manager.

- For DEB-based Linux distributions, such as Debian and Ubuntu, run the following command:

```
# apt-get install haproxy
```

- For RPM-based Linux distributions, such as Red Hat, Fedora and CentOS, run the following command:

```
# yum install haproxy
```

- For SUSE-based Linux distributions, such as SUSE Enterprise Linux and openSUSE, instead run this command:

```
# zypper install haproxy
```

- For FreeBSD and similar operating systems, HAProxy is available in the ports tree at */usr/ports/net/haproxy*. Alternatively, you can install it using the package manager:

```
# pkg install net/haproxy
```

This installs HAProxy on your system. In the event that the command for your distribution or operating system does not work as expected, check the your system's documentation or software repository for the correct procedure to install HAProxy.

Configuration

Configuration options for HAProxy are managed through an `haproxy.cfg` configuration file. The above package installations generally places this file in the `/etc/haproxy/` directory, though it may have a different path depending on your distribution or operating system.

To configure HAProxy to work with Galera Cluster, add the following lines to the `haproxy.cfg` configuration file:

```
# Load Balancing for Galera Cluster
listen galera 192.168.1.10:3306
     balance source
     mode tcp
     option tcpka
     option mysql-check user haproxy
     server node1 192.168.1.1:3306 check weight 1
     server node2 192.168.1.2:3306 check weight 1
     server node2 192.168.1.3:3306 check weight 1
```

Create the proxy for Galera Cluster using the `listen` parameter. This gives HAProxy an arbitrary name for the proxy and defines the IP address and port you want it to listen on for incoming connections. Under this parameter, indent and define a series of options to tell HAProxy what you want it to do with these connections.

- `balance` Defines the destination selection policy you want HAProxy to use in choosing which server it routes the incoming connections to.
- `mode tcp` Defines the type of connections it should route. Galera Cluster uses TCP connections.
- `option tcpka` Enables the keepalive function to maintain TCP connections.
- `option mysql-check user <username>` Enables a database server check, to determine whether the node is currently operational.
- `server <server-name> <IP_address> check weight 1` Defines the nodes you want HAProxy to use in routing connections.

Destination Selection Policies

When HAProxy receives a new connection, there are a number of options available to define which algorithm it uses to choose where to route that connection. This algorithm is its destination selection policy. It is defined by the `balance` parameter.

- **Round Robin** Directs new connections to the next destination in a circular order list, modified by the server's weight. Enable it with `balance roundrobin`.
- **Static Round Robin** Directs new connections to the next destination in a circular order list, modified by the server's weight. Unlike the standard implementation of round robin, in static round robin you cannot modify the server weight on the fly. Changing the server weight requires you to restart HAProxy. Enable it with `balance static-rr`.
- **Least Connected** Directs new connections to the server with the smallest number of connections available, which is adjuted for the server's weight. Enable it with `balance leastconn`

- **First** Directs new connections to the first server with a connection slot available. They are chosen from the lowest numeric identifier to the highest. Once the server reaches its maximum connections value, HAProxy moves to the next in the list. Enable it with `balance first`.
- **Source Tracking** Divides the source IP address by the total weight of running servers. Ensures that client connections from the same source IP always reach the same server. Enable it with `balance source`

In the above configuration example, HAProxy is configured to use the source selection policy. For your own implementations, choose the policy that works best with your infrastructure and load.

Enabling Database Server Checks

In addition to routing TCP connections to Galera Cluster, HAProxy can also perform basic health checks on the database server. When enabled, HAProxy attempts to establish a connection with the node and parses its response or any errors to determine if the node is operational.

For HAProxy you can enable this through the `mysql-check` option. However, it requires that you also create a user in the cluster for HAProxy to use when connecting.

```
CREATE USER 'haproxy'@'192.168.1.10';
```

Define the user name as the same as given in the `haproxy.cfg` configuration file for the `mysql-check` option. Replace the IP address with that of the server that runs HAProxy.

Using HAProxy

When you finish configuring HAProxy and the nodes to work with HAProxy, you can start it on the server. For servers that use `init`, run the following command:

```
# service haproxy start
```

For servers that use `systemd`, instead run this command:

```
# systemctl start haproxy
```

The server is now running HAProxy. When new connections are made to this server, it routes them through to nodes in the cluster.

Pen

Pen is a high-scalability, high availability, robust load balancer for TCP- and UDP-based protocols. You can use it to balance connections between your application servers and Galera Cluster.

Installation

Pen is available in the software repositories of most Linux distributions. You can install it using the package manager.

- For DEB-based Linux distributions, such as Debian and Ubuntu, run this command:

  ```
  # apt-get install pen
  ```

- For RPM-based Linux distributions, such as Red Hat, Fedora and CentOS, instead run this command:

```
# yum install pen
```

This installs Pen on your system. In the event that the command for your distribution or operating system does not work as expected, check your system's documentation or software repository for information on the correct procedure to install Pen.

Using Pen

Once you have installed Pen on the load balancing server, you can launch it from the command-line.

```
# pen -l pen.log -p pen.pid localhost:3306 \
      191.168.1.1:3306 \
      191.168.1.2:3306 \
      191.168.1.3:3306
```

When one of the application servers attempts to connect to the Pen server on port `3306`, Pen routes that connection out to one of the Galera Cluster nodes.

Note: For more information on Pen configuration and use, see the manpage.

Server Selection

When Pen receives a new connection from the application servers, it first checks to see where the application was routed on the last connection and attempts to send traffic there. In the event that it cannot establish a connection, it falls back on a round-robin selection policy.

There are a number of options you can use to modify this behavior when you launch Pen.

- **Default Round Robin** Directs all new connections to the next destination in a cirular order list, without looking up which server a client used the last time. Enable it with the `-r` option.
- **Stubborn Selection** In the event that the initial choice is unavailable, Pen closes the client connection. Enable it with the `-s` option.
- **Hash Client IP Address** Pen applies a hash on the client IP address for the initial server selection, making it more predictable where it routes client connections in the future.

Galera Load Balancer

Galera Load Balancer provides simple TCP connection balancing developed with scalability and performance in mind. It draws on Pen for inspiration, but its functionality is limited to only balancing TCP connections.

- Support for configuring back-end servers at runtime.
- Support for draning servers.
- Support for the epoll API for routing performance.
- Support for multithreaded operations.
- Optional watchdog module to monitor destinations and adjust the routing table.

Installation

Unlike Galera Cluster, there is no binary installation available for Galera Load Balancer. Installing it on your system requires that you build it from source. It is available on GitHub at glb.

To build Galera Load Balancer, complete the following steps:

1. From a directory convenient to you for source builds, such as `/opt`, use Git to clone the GitHub repo for Galera Load Balancer.

```
$ git clone https://github.com/codership/glb
```

2. Change into the new `glb/` directory created by Git, then run the bootstrap script.

```
$ cd glb/
$ ./bootstrap.sh
```

3. Configure Make to build on your system.

```
$ ./configure
```

4. Build the application with Make.

```
$ make
```

5. Install the application on your system.

```
# make install
```

Note: Galera Load Balancer installs in `/usr/sbin`. You need to run the above command as root.

Galera Load Balancer is now installed on your system. You can launch it from the command-line, using the `glbd` command.

In addition to the system daemon, you have also installed `libglb`, a shared library for connection balancing with any Linux applications that use the `connect()` call from the C Standard Library.

Service Installation

The above installation procedure only installs Galera Load Balancer to be run manually from the command-line. However, you may find it more useful to run this application as a system service.

In the source directory you cloned from GitHub, navigate into the `files/` directory. Within this directory there is a configuration file and a service script that you need to copy to their relevant locations.

- Place `glbd.sh` into `/etc/init.d` directory under a service name.

```
# cp glbd.sh /etc/init.d/glb
```

- Place `glbd.cfg` into either configuration directory. For Red Hat and its derivatives, this is `/etc/sysconfig/glbd.cfg`. For Debian and its derivatives, use `/etc/default/glbd.cfg`.

```
# cp glbd.cfg /etc/sysconfig/glbd.cfg
```

Note: The `glbd.cfg` configuration file used below refer to the one you have copied into `/etc`.

When you finish this, you can manage Galera Load Balancer through the `service` command. For more information on available commands, see *Using Galera Load Balancer* (page 134).

Configuration

When you run Galera Load Balancer, you can configure its use through the command-line options, which you can reference through the `--help` command. For users that run Galera Load Balancer as a service, you can manage it through the `glbd.cfg` configuration file.

- *LISTEN_ADDR* (page 294) Defines the address that Galera Load Balancer monitors for incoming client connections.
- *DEFAULT_TARGETS* (page 294) Defines the default servers that Galera Load Balancer routes incoming client connections to. For this parameter, use the IP addresses for the nodes in your cluster.
- *OTHER_OPTIONS* (page 294) Defines additional Galera Load Balancer options, such as the balancing policy you want to use. Use the same format as they would appear on the command-line.

For instance,

```
# Galera Load Balancer COnfigurations
LISTEN_ADDR="8010"
DEFAULT_TARGETS="192.168.1.1 192.168.1.2 192.168.1.3"
OTHER_OPTIONS="--random --top 3"
```

Destination Selection Policies

Galera Load Balancer, both the system daemon and the shared library, support five destination selection policies. When you run it from the command-line, you can define these using the command-line arguments, otherwise add the arguments to the *OTHER_OPTIONS* (page 294) parameter in the `glbd.cfg` configuration file.

- **Least Connected** Directs new connections to the server using the smallest number of connections possible, which is adjusted for the server weight. This is the default policy.
- **Round Robin** Directs new connections to the next destination in the circular order list. You can enable it through the *–round* (page 299) option.
- **Single** Directs all connections to the single server with the highest weight of those available. Routing continues to that server until it fails or a server with a higher weight becomes available. You can enable it through the *–single* (page 299) option.
- **Random** Directs connections randomly to available servers. You can enable it through the *–random* (page 299) option
- **Source Tracking** Directs connections originating from the same address to the same server. You can enable it through the *–source* (page 300) option.

Using Galera Load Balancer

In the above section *Service Installation* (page 133), you configured your system to run Galera Load Balancer as a service. This allows you to manage common operations through the `service` command, for instance:

```
# service glb getinfo

Router:
-------------------------------------------
```

```
    Address       : weight   usage  cons
  192.168.1.1:4444 : 1.000    0.000    0
  192.168.1.2:4444 : 1.000    0.000    0
  192.168.1.3:4444 : 1.000    0.000    0
------------------------------------------
Destinations: 3, total connections: 0
```

The `service` script supports the following operations:

- `start`/`stop`/`restart` Commands to start, stop and restart Galera Load Balancer.
- `getinfo` Command provides the current routing information: the servers available, their weight and usage, the number of connections made to them.
- `add`/`remove <IP Address>` Add or remove the designated IP address from the routing table.
- `getstats` Command provides performance statistics.
- `drain <IP Address>` Sets the designated server to drain. That is, Galera Load Balancer does not allocate new connections to the server, but also does not kill existing connections. Instead, it waits for the connections to this server to end gracefully.

When adding an IP address to Galera Load Balancer at runtime, bear in mind that it must follow the convention: `IP Address:port:weight`. When adding through a hostname, the convention is `Hostname:port:weight`.

CHAPTER

TWENTYEIGHT

CONTAINER DEPLOYMENTS

In the standard deployment methods of Galera Cluster, the node runs on a server in the same manner as would an individual standalone instance of MySQL. In container deployments, the node runs in a containerized virtual environment on the server. You may find these methods useful in portable deployments across numerous machines, testing applications that depend on Galera Cluster, process isolation for security, or scripting the installation and configuration process.

For the most part, the configuration for a node running in a containerized environment remains the same as well the node runs in the standard manner. But, there are some parameters that draw their defaults from the base system configurations. These you need to set manually, as the jail is unable to access the host file system.

- *wsrep_node_address* (page 225) The node determines the default address from the IP address on the first network interface. Jails cannot see the network interfaces on the host system. You need to set this parameter to ensure that the cluster is given the correct IP address for the node.
- *wsrep_node_name* (page 226) The node determines the default name from the system hostname. Jails have their own hostnames, distinct from that of the host system.

Bear in mind that the configuration file must be placed within the container `/etc` directory, not that of the host system.

Using Docker

Docker provides an open source platform for automatically deploying applications within software containers.

Galera Cluster can run from within a Docker container. You may find it useful in portable deployment across numerous machines, testing applications that depend on Galera Cluster, or scripting the installation and configuration process.

Note: This guide assumes that you are only running one container node per server. For more information on running multiple nodes per server, see Getting Started Galera with Docker, Part I and Part II.

Configuring the Container

Images are the containers that Docker has available to run. There are a number of base images available through Docker Hub. You can pull these down to your system through the `docker` command-line tool. You can also build new images.

When Docker builds a new image, it sources a `Dockerfile` to determine the steps that it needs to take in order to generate the image that you want to use. What this means that you can script the installation and configuration process: loading the needed configuration files, running updates and installing packages when the image is built through a single command.

```
# Galera Cluster Dockerfile
FROM ubuntu:14.04
MAINTAINER your name <your.user@example.org>

ENV DEBIAN_FRONTEND noninteractive

RUN apt-get update
RUN apt-get install -y  software-properties-common
RUN apt-key adv --keyserver keyserver.ubuntu.com --recv BC19DDBA
RUN add-apt-repository 'deb http://releases.galeracluster.com/ubuntu trusty main'

RUN apt-get update
RUN apt-get install -y galera-3 galera-arbitrator-3 mysql-wsrep-5.6 rsync

COPY my.cnf /etc/mysql/my.cnf
ENTRYPOINT ["mysqld"]
```

The example follows the installation process for running Galera Cluster from within a Docker container based on Ubuntu. When you run the build command, Docker pulls down the Ubuntu 14.04 image from Docker Hub, if it's needed, then it runs each command in the `Dockerfile` to initialize the image for your use.

Configuration File

Before you build the container, you need to write the configuration file for the node. The `COPY` command in the `Dockerfile` above copies `my.cnf` from the build directory into the container.

For the most part, the configuration file for a node running within Docker is the same as when the node is running on a standard Linux server. But, there are some parameters that draw their defaults from the base system. These you need to set manually, as Docker cannot access the host system.

- *wsrep_node_address* (page 225) The node determines the default address from the IP address on the first network interface. Containers cannot see the network interfaces on the host system. You need to set this parameter to ensure that the cluster is given the correct IP address for the node.
- *wsrep_node_name* (page 226) The node determines the default name from the system hostname. Containers have their own hostnames distinct from the host system.

Changing the `my.cnf` file does not propagate into the container. Whenever you need to make changes to the configuration file, run the build again to create a new image with the updated file. Docker caches each step of the build and on rebuild only runs those steps that have changed since the last run. For example, using the above `Dockerfile`, if you rebuild an image after changing `my.cnf`, Docker only runs the last two steps.

Note: If you need Docker to rerun the entire build, use the `--force-rm=true` option.

Building the Container Image

Building the image reduces the node installation, configuration and deployment process to a single command. This creates a server instance where Galera Cluster is already installed, configured and ready to start.

You can build a container node using the `docker` command-line tool.

```
# docker build -t ubuntu:galera-node1 ./
```

When this command runs, Docker looks in the working directory, (here `./`), for the `Dockerfile`. It then follows each command in the `Dockerfile` to build the image you want. When the build is complete, you can view the addition among the available images:

```
# docker images

REPOSITORY   TAG             IMAGE ID      CREATED         SIZE
ubuntu       galera-node-1   53b97c3d7740  2 minutes ago   362.7 MB
ubuntu       14.04           ded7cd95e059  5 weeks ago     185.5 MB
```

You now have a working node image available for use as a container. You can launch it using the `docker run` command. Repeat the build process on each server to create a node container image for Galera Cluster.

Update the container tag to help differentiate between them. That is,

```
[root@node2]# docker build -t ubuntu:galera-node2 ./
[root@node3]# docker build -t ubuntu:galera-node3 ./
```

Deploying the Container

When you finish building the image, you're ready to launch the node container. For each node start the container using the Docker command-line tool with the `run` argument.

```
# docker run -i -d --name Node1 --host node1 \
      -p 3306:3306 -p 4567:4567 -p 4568:4568 -p 4444:4444 \
      -v /var/container_data/mysql:/var/lib/mysql \
      ubuntu:galera-node1
```

In the example, Docker launches a pre-built Ubuntu container tagged as `galera-node1`, which was built using the above `Dockerfile`. The `ENTRYPOINT` parameter is set to `/bin/mysqld`, so the container launches the database server on start.

Update the `--name` option for each node container you start.

Note: The above command starts a container node meant to be attached to an existing cluster. If you are starting the first node in a cluster, append the argument `--wsrep-new-cluster` to the end of the command. For more information, see *Starting the Cluster* (page 33).

Firewall Settings

When you launch the Docker container, (with `docker run` above), the series of `-p` options connect the ports on the host system to those in the container. When the container is launched this way, nodes in the container have the same level of access to the network as the node would when running on the host system.

Use these settings when you only run one container to the server. If you are running multiple containers to the server, you will need a load balancer to dole the incoming connections out to the individual nodes.

For more information on configuring the firewall for Galera Cluster, see *Firewall Settings* (page 163).

Persistent Data

Docker containers are not meant to carry persistent data. When you close the container, the data it carries is lost. To avoid this, you can link volumes in the container with directories on the host file system, using the `-v` option when you launch the container.

In the example, (that is, `docker run` above), the `-v` argument connects the `/var/container_data/mysql/` directory to `/var/lib/mysql/` in the container. This replaces the local datadir inside the container with a symbolic link to a directory on the host system, ensuring that you don't lose data when the container restarts.

Database Client

Once you have the container node running, you can execute additional commands on the container using the `docker exec` command with the container name given above for the `--name` parameter.

For example, if you want access to the database client, run the following command:

```
# docker exec -ti Node1 /bin/mysql -u root -p
```

Using Jails

In FreeBSD, jails provides a platform for securely deploying applications within virtual instances. You may find it useful in portable deployments across numerous machines for testing and security.

Galera Cluster can run from within a jail instance.

Preparing the Server

Jails exist as isolated file systems within, but unaware of, the host server. In order to grant the node running within the jail network connectivity with the cluster, you need to configure the network interfaces and firewall to redirect from the host into the jail.

Network Configuration

To begin, create a second loopback interface for the jail. this allows you to isolate jail traffic from `lo0`, the host loopback interface.

Note: For the purposes of this guide, the jail loopback is called `lo1`, if `lo1` already exists on your system, increment the digit to create one that does not already exist, (for instance, `lo2`).

To create a loopback interface, complete the following steps:

1. Using your preferred text editor, add the loopback interface to `/etc/rc.conf`:

   ```
   # Network Interface
   cloned_interfaces="${cloned_interfaces} lo1"
   ```

2. Create the loopback interface:

   ```
   # service netif cloneup
   ```

This creates `lo1`, a new loopback network interface for your jails. You can view the new interface in the listing using the following command:

```
$ ifconfig
```

Firewall Configuration

FreeBSD provides packet filtering support at the kernel level. Using PF you can set up, maintain and inspect the packet filtering rule sets. For jails, you can route traffic from external ports on the host system to internal ports within the jail's file system. This allows the node running within the jail to have network access as though it were running on the host system.

To enable PF and create rules for the node, complete the following steps:

1. Using your preferred text editor, make the following additions to `/etc/rc.conf`:

```
# Firewall Configuration
pf_enable="YES"
pf_rules="/etc/pf.conf"
pflog_enable="YES"
pflog_logfile="/var/log/pf.log"
```

2. Create the rules files for PF at `/etc/pf.conf`

```
# External Network Interface
ext_if="vtnet0"

# Internal Network Interface
int_if="lo1"

# IP Addresses
external_addr="host_IP_address"
internal_addr="jail_IP_address_range"

# Variables for Galera Cluster
wsrep_ports="{3306,4567,4568,4444}"
table <wsrep_cluster_address> persist {192.168.1.1,192.168.1.2,192.168.1.3}

# Translation
nat on $ext_if from $internal_addr to any -> ($ext_if)

# Redirects
rdr on $ext_if proto tcp from any to $external_addr/32 port 3306 -> jail_IP_
↪address port 3306
rdr on $ext_if proto tcp from any to $external_addr/32 port 4567 -> jail_IP_
↪address port 4567
rdr on $ext_if proto tcp from any to $external_addr/32 port 4568 -> jail_IP_
↪address port 4568
rdr on $ext_if proto tcp from any to $external_addr/32 port 4444 -> jail_IP_
↪address port 4444

pass in proto tcp from <wsrep_cluster_address> to any port $wsrep_ports keep state
```

   Replace `host_IP_address` with the IP address of the host server and `jail_IP_address` with the IP address you want to use for the jail.

3. Using `pfctl`, check for any typos in your PF configurations:

```
# pfctl -v -nf /etc/pf.conf
```

4. If `pfctl` runs without throwing any errors, start PF and PF logging services:

```
# service pf start
# service pflog start
```

The server now uses PF to manage its firewall. Network traffic directed at the four ports Galera Cluster uses is routed to the comparable ports within the jail.

Note: **See Also**: For more information on firewall configurations for FreeBSD, see *Firewall Configuration with PF* (page 166).

Creating the Node Jail

While FreeBSD does provide a manual interface for creating and managing jails on your server, (`jail(8)`), it can prove cumbersome in the event that you have multiple jails running on a server.

The application `ezjail` facilitates this process by automating common tasks and using templates and symbolic links to reduce the disk space usage per jail. It is available for installation through `pkg`. Alternative, you can build it through ports at `sysutils/ezjail`.

To create a node jail with `ezjail`, complete the following steps:

1. Using your preferred text editor, add the following line to `/etc/rc.conf`:

```
ezjail_enable="YES"
```

   This allows you to start and stop jails through the `service` command.

2. Initialize the `ezjail` environment:

```
# ezjail-admin install -sp
```

   This install the base jail system at `/usr/jails/`. It also installs a local build of the ports tree within the jail.

   Note: While the database server is not available for FreeBSD in ports or as a package binary, a port of the *Galera Replication Plugin* is available at `databases/galera`.

3. Create the node jail.

```
# ezjail-admin create galera-node 'lo1|192.168.68.1'
```

   This creates the particular jail for your node and links it to the `lo1` loopback interface and IP address. Replace the IP address with the local IP for internal use on your server. It is the same address as you assigned in the firewall redirects above for `/etc/pf.conf`.

   Note: Bear in mind that in the above command `galera-node` provides the hostname for the jail file system. As Galera Cluster draws on the hostname for the default node name, you need to either use a unique jail name for each node, or manually set *wsrep_node_name* (page 226) in the configuration file to avoid confusion.

4. Copy the `resolve.conf` file from the host file system into the node jail.

```
# cp /etc/resolv.conf /usr/jails/galera-node/etc/
```

   This allows the network interface within the jail to resolve domain names in connecting to the internet.

5. Start the node jail.

```
# ezjail-admin start galera-node
```

The node jail is now running on your server. You can view running jails using the `ezjail-admin` command:

```
# ezjail-admin list
STA JID  IP            Hostname     Root Directory
--- ---- ------------- ------------ ----------------------
DR  2    192.168.68.1  galera-node  /usr/jails/galera-node
```

While on the host system, you can access and manipulate files and directories in the jail file system from `/usr/jails/galera-node/`. Additionally, you can enter the jail directly and manipulate processes running within using the following command:

```
root@FreeBSDHost:/usr/jails # ezjail-admin console galera-node
root@galera-node:~ #
```

When you enter the jail file system, note that the hostname changes to indicate the transition.

Installing Galera Cluster

Regardless of whether you are on the host system or working from within a jail, currently, there is no binary package or port available to fully install Galera Cluster on FreeBSD. You must build the database server from source code.

The specific build process that you need to follow depends on the database server that you want to use:

- *Galera Cluster for MySQL* (page 15)
- *Percona XtraDB Cluster* (page 19)
- *MariaDB Galera Cluster* (page 24)

Due to certain Linux dependencies, the *Galera Replication Plugin* cannot be built from source on FreeBSD. Instead you can use the port at `/usr/ports/databases/galera` or install it from a binary package within the jail:

```
# pkg install galera
```

This install the wsrep Provider file in `/usr/local/lib`. Use this path in the configuration file for the *wsrep_provider* (page 229) parameter.

Configuration File

For the most part, the configuration file for a node running in a jail is the same as when the node runs on a standard FreeBSD server. But, there are some parameters that draw their defaults from the base system. These you need to set manually, as the jail is unable to access the host file system.

- *wsrep_node_address* (page 225) The node determines the default address from the IP address on the first network interface. Jails cannot see the network interfaces on the host system. You need to set this parameter to ensure that the cluster is given the correct IP address for the node.
- *wsrep_node_name* (page 226) The node determines the default name from the system hostname. Jails have their own hostnames, distinct from that of the host system.

```
[mysqld]
user=mysql
#bind-address=0.0.0.0

# Cluster Options
```

```
wsrep_provider=/usr/lib/libgalera_smm.so
wsrep_cluster_address="gcomm://192.168.1.1, 192.168.1.2, 192.16.1.3"
wsrep_node_address="192.168.1.1"
wsrep_node_name="node1"
wsrep_cluster_name="example_cluster"

# InnoDB Options
default_storage_engine=innodb
innodb_autoinc_lock_mode=2
innodb_flush_log_at_trx_commit=0

# SST
wsrep_sst_method=rsync
```

If you are logged into the jail console, place the configuration file at `/etc/my.cnf`. If you are on the host system console, place it at `/usr/jails/galera-node/etc/my.cnf`. Replace `galera-node` in the latter with the name of the node jail.

Starting the Cluster

When running the cluster from within jails, you create and manage the cluster in the same manner as you would in the standard deployment of Galera Cluster on FreeBSD. The exception being that you must obtain console access to the node jail first.

To start the initial cluster node, run the following commands:

```
# ezjail-admin console galera-node
# service mysql start --wsrep-new-cluster
```

To start each additional node, run the following commands:

```
# ezjail-admin console galera-node
# service mysql start
```

Each node you start after the initial will attempt to establish network connectivity with the *Primary Component* and begin syncing their database states into one another.

Part V

Monitor

There are three approaches to monitoring cluster activity and replication health: directly off the database client, using the notification script for Galera Cluster, or through a third-party monitoring application, such as Nagios.

CHAPTER

TWENTYNINE

MONITORING CLUSTER STATUS

From the database client, you can check the status of write-set replication throughout the cluster using standard queries. Status variables that relate to write-set replication have the prefix `wsrep_`, meaning that you can display them all using the following query:

```
SHOW GLOBAL STATUS LIKE 'wsrep_%';

+------------------------+-------+
| Variable_name          | Value |
+------------------------+-------+
| wsrep_protocol_version | 5     |
| wsrep_last_committed   | 202   |
| ...                    | ...   |
| wsrep_thread_count     | 2     |
+------------------------+-------+
```

Note: **See Also**: In addition to checking status variables through the database client, you can also monitor for changes in cluster membership and node status through `wsrep_notify_cmd.sh`. For more information on its use, see *Notification Command* (page 157).

Checking Cluster Integrity

The cluster has integrity when all nodes in it receive and replicate write-sets from all other nodes. The cluster begins to lose integrity when this breaks down, such as when the cluster goes down, becomes partitioned, or experiences a split-brain situation.

You can check cluster integrity using the following status variables:

- *wsrep_cluster_state_uuid* (page 269) shows the cluster *state UUID*, which you can use to determine whether the node is part of the cluster.

```
SHOW GLOBAL STATUS LIKE 'wsrep_cluster_state_uuid';

+--------------------------+--------------------------------------+
| Variable_name            | Value                                |
+--------------------------+--------------------------------------+
| wsrep_cluster_state_uuid | d6a51a3a-b378-11e4-924b-23b6ec126a13 |
+--------------------------+--------------------------------------+
```

  Each node in the cluster should provide the same value. When a node carries a different value, this indicates that it is no longer connected to rest of the cluster. Once the node reestablishes connectivity, it realigns itself with the other nodes.

- *wsrep_cluster_conf_id* (page 268) shows the total number of cluster changes that have happened, which you can use to determine whether or not the node is a part of the *Primary Component*.

```
SHOW GLOBAL STATUS LIKE 'wsrep_cluster_conf_id';

+-----------------------+-------+
| Variable_name         | Value |
+-----------------------+-------+
| wsrep_cluster_conf_id | 32    |
+-----------------------+-------+
```

  Each node in the cluster should provide the same value. When a node carries a different, this indicates that the cluster is partitioned. Once the node reestablish network connectivity, the value aligns itself with the others.

- *wsrep_cluster_size* (page 268) shows the number of nodes in the cluster, which you can use to determine if any are missing.

```
SHOW GLOBAL STATUS LIKE 'wsrep_cluster_size';

+--------------------+-------+
| Variable_name      | Value |
+--------------------+-------+
| wsrep_cluster_size | 15    |
+--------------------+-------+
```

  You can run this check on any node. When the check returns a value lower than the number of nodes in your cluster, it means that some nodes have lost network connectivity or they have failed.

- *wsrep_cluster_status* (page 269) shows the primary status of the cluster component that the node is in, which you can use in determining whether your cluster is experiencing a partition.

```
SHOW GLOBAL STATUS LIKE 'wsrep_cluster_status';

+----------------------+---------+
| Variable_name        | Value   |
+----------------------+---------+
| wsrep_cluster_status | Primary |
+----------------------+---------+
```

  The node should only return a value of `Primary`. Any other value indicates that the node is part of a nonoperational component. This occurs in cases of multiple membership changes that result in a loss of quorum or in cases of split-brain situations.

  Note: **See Also**: In the event that you check all nodes in your cluster and find none that return a value of `Primary`, see *Resetting the Quorum* (page 87).

When these status variables check out and return the desired results on each node, the cluster is up and has integrity. What this means is that replication is able to occur normally on every node. The next step then is *checking node status* (page 151) to ensure that they are all in working order and able to receive write-sets.

Checking the Node Status

In addition to checking cluster integrity, you can also monitor the status of individual nodes. This shows whether nodes receive and process updates from the cluster write-sets and can indicate problems that may prevent replication.

- *wsrep_ready* (page 280) shows whether the node can accept queries.

```
SHOW GLOBAL STATUS LIKE 'wsrep_ready';

+---------------+-------+
| Variable_name | Value |
+---------------+-------+
| wsrep_ready   | ON    |
+---------------+-------+
```

  When the node returns a value of ON it can accept write-sets from the cluster. When it returns the value OFF, almost all queries fail with the error:

```
ERROR 1047 (08501) Unknown Command
```

- *wsrep_connected* (page 270) shows whether the node has network connectivity with any other nodes.

```
SHOW GLOBAL STATUS LIKE 'wsrep_connected';

+-----------------+-------+
| Variable_name   | Value |
+-----------------+-------+
| wsrep_connected | ON    |
+-----------------+-------+
```

  When the value is ON, the node has a network connection to one or more other nodes forming a cluster component. When the value is OFF, the node does not have a connection to any cluster components.

  Note: The reason for a loss of connectivity can also relate to misconfiguration. For instance, if the node uses invalid values for the *wsrep_cluster_address* (page 217) or *wsrep_cluster_name* (page 218) parameters.

  Check the error log for proper diagnostics.

- *wsrep_local_state_comment* (page 278) shows the node state in a human readable format.

```
SHOW GLOBAL STATUS LIKE 'wsrep_local_state_comment';

+---------------------------+--------+
| Variable_name             | Value  |
+---------------------------+--------+
| wsrep_local_state_comment | Joined |
+---------------------------+--------+
```

  When the node is part of the *Primary Component*, the typical return values are Joining, Waiting on SST, Joined, Synced or Donor. In the event that the node is part of a nonoperational component, the return value is Initialized.

  Note: If the node returns any value other than the one listed here, the state comment is momentary and transient. Check the status variable again for an update.

In the event that each status variable returns the desired values, the node is in working order. This means that it is receiving write-sets from the cluster and replicating them to tables in the local database.

Checking the Replication Health

Monitoring cluster integrity and node status can show you issues that may prevent or otherwise block replication. These status variables will help in identifying performance issues and identifying problem areas so that you can get the most from your cluster.

Note: Unlike other the status variables, these are differential and reset on every `SHOW STATUS` command. Execute the query a second time, about a minute after the first to get the current value.

Galera Cluster triggers a feedback mechanism called Flow Control to manage the replication process. When the local received queue of write-sets exceeds a certain threshold, the node engages Flow Control to pause replication while it catches up.

You can monitor the local received queue and Flow Control using the following status variables:

- *wsrep_local_recv_queue_avg* (page 276) shows the average size of the local received queue since the last status query.

```
SHOW STATUS LIKE 'wsrep_local_recv_queue_avg';

+--------------------------+----------+
| Variable_name            | Value    |
+--------------------------+----------+
| wsrep_local_recv_que_avg | 3.348452 |
+--------------------------+----------+
```

  When the node returns a value higher than `0.0` it means that the node cannot apply write-sets as fast as it receives them, which can lead to replication throttling.

  Note: In addition to this status variable, you can also use *wsrep_local_recv_queue_max* (page 276) and *wsrep_local_recv_queue_min* (page 276) to see the maximum and minimum sizes the node recorded for the local received queue.

- *wsrep_flow_control_paused* (page 272) shows the fraction of the time, since the status variable was last called, that the node paused due to Flow Control.

```
SHOW STATUS LIKE 'wsrep_flow_control_paused';

+---------------------------+----------+
| Variable_name             | Value    |
+---------------------------+----------+
| wsrep_flow_control_paused | 0.184353 |
+---------------------------+----------+
```

  When the node returns a value of `0.0`, it indicates that the node did not pause due to Flow Control during this period. When the node returns a value of `1.0`, it indicates that the node spent the entire period paused. When the period between calls is one minute and the node returns `0.25`, it indicates that the node was paused for 15 seconds.

Ideally, the return value should stay as close to `0.0` as possible, since this means the node is not falling behind the cluster. In the event that you find that the node is pausing frequently, you can adjust the *wsrep_slave_threads* (page 232) parameter or you can exclude the node from the cluster.

- *wsrep_cert_deps_distance* (page 267) shows the average distance between the lowest and highest sequence number, or seqno, values that the node can possibly apply in parallel.

```
SHOW STATUS LIKE 'wsrep_cert_deps_distance';

+--------------------------+---------+
| Variable_name            | Value   |
+--------------------------+---------+
| wsrep_cert_deps_distance | 23.8889 |
+--------------------------+---------+
```

This represents the node's potential degree for parallelization. In other words, the optimal value you can use with the *wsrep_slave_threads* (page 232) parameter, given that there is no reason to assign more slave threads than transactions you can apply in parallel.

Detecting Slow Network Issues

While checking the status of Flow Control and the received queue can tell you how the database server copes with incoming write-sets, you can check the send queue to monitor for outgoing connectivity issues.

Note: Unlike other the status variables, these are differential and reset on every `SHOW STATUS` command. Execute the query a second time, about a minute after the first to get the current value.

wsrep_local_send_queue_avg (page 277) show an average for the send queue length since the last status query.

```
SHOW STATUS LIKE 'wsrep_local_send_queue_avg';

+----------------------------+----------+
| Variable_name              | Value    |
+----------------------------+----------+
| wsrep_local_send_queue_avg | 0.145000 |
+----------------------------+----------+
```

Values much greater than `0.0` indicate replication throttling or network throughput issues, such as a bottleneck on the network link. The problem can occur at any layer from the physical components of your server to the configuration of the operating system.

Note: In addition to this status variable, you can also use *wsrep_local_send_queue_max* (page 277) and *wsrep_local_send_queue_min* (page 278) to see the maximum and minimum sizes the node recorded for the local send queue.

CHAPTER

THIRTY

DATABASE SERVER LOGS

Galera Cluster provides the same database server logging features available to MySQL, MariaDB and Percona XtraDB, depending on which you use. By default, it writes errors to a `<hostname>.err` in the data directory. You can change this in the `my.cnf` configuration file using the log_error parameter, or by using the `--log-error` parameter.

Log Parameters

Galera Cluster provides parameters and wsrep Options that allow you to enable error logging on events that are specific to the replication process. If you have a script monitoring the logs, these entires can provide you with information on conflicts occurring in the replication process.

- *wsrep_log_conflicts* (page 223) This parameter enables conflict logging for your error logs, such as when two nodes attempt to write to the same row of the same table at the same time.
- *cert.log_conflicts* (page 246) This wsrep Provider option enables logging of information on certification failures during replication.
- *wsrep_debug* (page 220) This parameter enables debugging information for the database server logs.

Note: **Warning**: In addition to useful debugging information, this parameter also causes the database server to print authentication information, (that is, passwords), to the error logs. Do not enable it in production environments.

You can enable these through the `my.cnf` configuration file.

```
# wsrep Log Options
wsrep_log_conflicts=ON
wsrep_provider_options="cert.log_conflicts=ON"
wsrep_debug=ON
```

Additional Log Files

Whenever the node fails to apply an event on a slave node, the database server creates a special binary log file of the event in the data directory. The naming convention the node uses for the filename is `GRA_*.log`.

CHAPTER

THIRTYONE

NOTIFICATION COMMAND

While you can use the database client to check the status of your cluster, the individual nodes and the health of replication, you may find it counterproductive to log into the client on each node to run these checks. Galera Cluster provides a notification script and interface for customization, allowing you to automate the monitoring process for your cluster.

Notification Command Parameters

When the node registers a change in the cluster or itself that triggers the notification command, it passes a number of parameters in calling the script.

- `--status` The node passes a string indicating it's current state. For a list of the strings it uses, see *Node Status Strings* (page 157) below.
- `--uuid` The node passes a string of either *yes* or *no*, indicating whether it considers itself part of the *Primary Component*.
- `--members` The node passes a list of the current cluster members. For more information on the format of these listings, see *Member List Format* (page 158) below.
- `--index` The node passes a string that indicates its index value in the membership list.

Note: Only those nodes that in the `Synced` state accept connections from the cluster. For more information on node states, see *Node State Changes* (page 58).

Node Status Strings

The notification command passes one of six values with the `--status` parameter to indicate the current status of the node:

- `Undefined` Indicates a starting node that is not part of the Primary Component.
- `Joiner` Indicates a node that is part of the Primary Component that is receiving a state snapshot transfer.
- `Donor` Indicates a node that is part of the Primary Component that is sending a state snapshot transfer.
- `Joined` Indicates a node that is part of the Primary Component that is in a complete state and is catching up with the cluster.
- `Synced` Indicates a node that is syncrhonized with the cluster.
- `Error` Indicates that an error has occurred. This status string may provide an error code with more information on what occurred.

Members List Format

The notification command passes with the `--member` parameter a list containing entries for each node that is connected to the cluster component to which the node belongs. For each entry in the list the node uses this format:

```
<node UUID> / <node name> / <incoming address>
```

- **Node UUID** Refers to the unique identifier the node receives from the wsrep Provider.
- **Node Name** Refers to the node name, as you define it for the *wsrep_node_name* (page 226) parameter, in the configuration file.
- **Incoming Address** Refers to the IP address for client connections, as set for the *wsrep_node_incoming_address* (page 226) parameter, in the configuration file.

Example Notification Script

Nodes can call a notification script when changes happen in the membership of the cluster, that is when nodes join or leave the cluster. You can specify the name of the script the node calls using the *wsrep_notify_cmd* (page 226). While you can use whatever script meets the particular needs of your deployment, you may find it helpful to consider the example below as a starting point.

```
#!/bin/sh -eu

# This is a simple example of wsrep notification script (wsrep_notify_cmd).
# It will create 'wsrep' schema and two tables in it: 'membeship' and 'status'
# and fill them on every membership or node status change.
#
# Edit parameters below to specify the address and login to server.

USER=root
PSWD=rootpass
HOST=<host_IP_address>
PORT=3306

SCHEMA="wsrep"
MEMB_TABLE="$SCHEMA.membership"
STATUS_TABLE="$SCHEMA.status"

BEGIN="
   SET wsrep_on=0;
   DROP SCHEMA IF EXISTS $SCHEMA; CREATE SCHEMA $SCHEMA;
   CREATE TABLE $MEMB_TABLE (
      idx  INT UNIQUE PRIMARY KEY,
      uuid CHAR(40) UNIQUE, /* node UUID */
      name VARCHAR(32),     /* node name */
      addr VARCHAR(256)     /* node address */
   ) ENGINE=MEMORY;
   CREATE TABLE $STATUS_TABLE (
      size   INT,       /* component size   */
      idx    INT,       /* this node index  */
      status CHAR(16), /* this node status */
      uuid   CHAR(40), /* cluster UUID */
      prim   BOOLEAN   /* if component is primary */
   ) ENGINE=MEMORY;
   BEGIN;
```

```
    DELETE FROM $MEMB_TABLE;
    DELETE FROM $STATUS_TABLE;
"
END="COMMIT;"

configuration_change()
{
    echo "$BEGIN;"

    local idx=0

    for NODE in $(echo $MEMBERS | sed s/,/\ /g)
    do
        echo "INSERT INTO $MEMB_TABLE VALUES ( $idx, "
        # Don't forget to properly quote string values
        echo "'$NODE'" | sed  s/\\//\',\'/g
        echo ");"
        idx=$(( $idx + 1 ))
    done

    echo "
        INSERT INTO $STATUS_TABLE
        VALUES($idx, $INDEX,'$STATUS', '$CLUSTER_UUID', $PRIMARY);
    "

    echo "$END"
}

status_update()
{
    echo "
        SET wsrep_on=0;
        BEGIN;
        UPDATE $STATUS_TABLE SET status='$STATUS';
        COMMIT;
    "
}

COM=status_update # not a configuration change by default

while [ $# -gt 0 ]
do
    case $1 in
        --status)
            STATUS=$2
            shift
            ;;
        --uuid)
            CLUSTER_UUID=$2
            shift
            ;;
        --primary)
            [ "$2" = "yes" ] && PRIMARY="1" || PRIMARY="0"
            COM=configuration_change
            shift
            ;;
        --index)
            INDEX=$2
```

```
            shift
            ;;
        --members)
            MEMBERS=$2
            shift
            ;;
            esac
            shift
    done

# Undefined means node is shutting down
if [ "$STATUS" != "Undefined" ]
then
    $COM | mysql -B -u$USER -p$PSWD -h$HOST -P$PORT
fi

exit 0
```

When you finish editing the script to fit your needs, you need to move it into a directory in the `$PATH` environment variable or the binaries directory for your system. On Linux, the binaries directory is typically at `/usr/bin`, while on FreeBSD it is at `/usr/local/bin`.

```
# mv my-wsrep-notify.sh /usr/bin
```

In addition to this, given that the notification command contains your root password, change the ownership to the `mysql` user and make the script executable only to that user.

```
# chown mysql:mysql /usr/bin/my-wsrep-notify.sh
# chmod 700 /usr/bin/my-wsrep-notify.sh.
```

This ensures that only the `mysql` user executes and can read the notification script, preventing all other users from seeing your root password.

Enabling the Notification Command

You can enable the notification command through the *wsrep_notify_cmd* (page 226) parameter in the configuration file.

```
wsrep_notify_cmd=/path/to/wsrep_notify.sh
```

The node then calls the script for each change in cluster membership and node status. You can use these status changes in configuring load balancers, raising alerts or scripting for any other situation where you need your infrastructure to respond to changes to the cluster.

Galera Cluster provides a default script, `wsrep_notify.sh`, for you to use in handling notifications or as a starting point in writing your own custom notification script.

Note: You can also use Nagios for monitoring Galera Cluster. For more information, see Galera Cluster Nagios Plugin.

Part VI

Security

CHAPTER

THIRTYTWO

FIREWALL SETTINGS

Galera Cluster requires a number of ports in order to maintain network connectivity between the nodes. Depending on your deployment, you may require all or some of these ports on each node in the cluster:

- `3306` For MySQL client connections and *State Snapshot Transfer* that use the `mysqldump` method.
- `4567` For Galera Cluster replication traffic, multicast replication uses both UDP transport and TCP on this port.
- `4568` For *Incremental State Transfer*.
- `4444` For all other *State Snapshot Transfer*.

How to open these ports for Galera Cluster can vary depending upon your distribution and what you use to configure the firewall.

Firewall Configuration with `iptables`

Linux provides packet filtering support at the kernel level. Using `iptables` and `ip6tables` you can set up, maintain and inspect tables of IPv4 and IPv6 packet filtering rules.

There are several tables that the kernel uses for packet filtering and within these tables are chains that it match specific kinds of traffic. In order to open the relevant ports for Galera Cluster, you need to append new rules to the `INPUT` chain on the filter table.

Opening Ports for Galera Cluster

Galera Cluster requires four ports for replication. There are two approaches to configuring the firewall to open these `iptables`. The method you use depends on whether you deploy the cluster in a LAN environment, such as an office network, or if you deploy the cluster in a WAN environment, such as on several cloud servers over the internet.

LAN Configuration

When configuring packet filtering rules for a LAN environment, such as on an office network, there are four ports that you need to open to TCP for Galera Cluster and one to UDP transport to enable multicast replication. This means five commands that you must run on each cluster node:

```
# iptables --append INPUT --in-interface eth0 \
   --protocol tcp --match tcp --dport 3306 \
   --source 192.168.0.1/24 --jump ACCEPT
# iptables --append INPUT --in-interface eth0 \
   --protocol tcp --match tcp --dport 4567 \
   --source 192.168.0.1/24 --jump ACCEPT
```

```
# iptables --append INPUT --in-interface eth0 \
   --protocol tcp --match tcp --dport 4568 \
   --source 192.168.0.1/24 --jump ACCEPT
# iptables --append INPUT --in-interface eth0 \
   --protocol tcp --match tcp --dport 4444 \
   --source 192.168.0.1/24 --jump ACCEPT
# iptables --append INPUT --in-interface eth0 \
   --protocol udp --match udp --dport 4567 \
   --source 192.168.0.1/24 --jump ACCEPT
```

These commands open the relevant ports to TCP and UDP transport. It assumes that the IP addresses in your network begin with 192.168.0.

Note: **Warning**: The IP addresses in the example are for demonstration purposes only. Use the real values from your nodes and netmask in your `iptables` configuration.

Galera Cluster can now pass packets through the firewall to the node, but the configuration reverts to default on reboot. In order to update the default firewall configuration, see *Making Firewall Changes Persistent* (page 164).

WAN Configuration

While the configuration shown above for LAN deployments offers the better security, only opening those ports necessary for cluster operation, it does not scale well into WAN deployments. The reason is that in a WAN environment the IP addresses are not in sequence. The four commands to open the relevant ports to TCP would grow to four commands per node on each node. That is, for ten nodes you would need to run four hundred `iptables` commands across the cluster in order to set up the firewall on each node.

Without much loss in security, you can instead open a range of ports between trusted hosts. This reduces the number of commands to one per node on each node. For example, firewall configuration in a three node cluster would look something like:

```
# iptables --append INPUT --protocol tcp \
    --source 64.57.102.34 --jump ACCEPT
# iptables --append INPUT --protocol tcp \
    --source 193.166.3.20  --jump ACCEPT
# iptables --append INPUT --protocol tcp \
    --source 193.125.4.10  --jump ACCEPT
```

When these commands are run on each node, they set the node to accept TCP connections from the IP addresses of the other cluster nodes.

Note: **Warning**: The IP addresses in the example are for demonstration purposes only. Use the real values from your nodes and netmask in your `iptables` configuration.

Galera Cluster can now pass packets through the firewall to the node, but the configuration reverts to default on reboot. In order to update the default firewall configuration, see *Making Firewall Changes Persistent* (page 164).

Making Firewall Changes Persistent

Whether you decide to open ports individually for LAN deployment or in a range between trusted hosts for a WAN deployment, the tables you configure in the above sections are not persistent. When the server reboots, the firewall reverts to its default state.

For systems that use `init`, you can save the packet filtering state with one command:

```
# service save iptables
```

For systems that use `systemd`, you need to save the current packet filtering rules to the path the `iptables` unit reads from when it starts. This path can vary by distribution, but you can normally find it in the `/etc` directory. For example:

- `/etc/sysconfig/iptables`
- `/etc/iptables/iptables.rules`

Once you find where your system stores the rules file, use `iptables-save` to update the file:

```
# iptables-save > /etc/sysconfig/iptables
```

When your system reboots, it now reads this file as the default packet filtering rules.

Firewall Configuration with FirewallD

The firewall daemon, or FirewallD, is an interface for dynamically managing firewalls on Linux operating systems, allowing you to set up, maintain and inspect IPv4 and IPv6 firewall rules.

FirewallD includes support for defining zones, allowing you to set the trust level of a given network connection or interface. For example, when deploying nodes that connect to each other over the internet, rather than a private network, you might configure your firewall around the `public` zone. This assumes that other computers on the network are untrusted and only accepts designated connections.

Note: For more information on FirewallD, see the Documentation.

Opening Ports for Galera Cluster

Galera Cluster requires four ports open for replication over TCP, and, in the event that you want to use multicast replication, one for UDP transport. In order for this to work over FirewallD, you also need to add the database service to your firewall rules.

1. Enable the database service for FirewallD:

   ```
   # firewall-cmd --zone=public --add-service=mysql
   ```

2. Open the TCP ports for Galera Cluster:

   ```
   # firewall-cmd --zone=public --add-port=3306/tcp
   # firewall-cmd --zone=public --add-port=4567/tcp
   # firewall-cmd --zone=public --add-port=4568/tcp
   # firewall-cmd --zone=public --add-port=4444/tcp
   ```

3. Optionally, in the event that you would like to use multicast replication, run this command as well to open UDP transport on `4567`:

   ```
   # firewall-cmd --zone=public --add-port=4567/udp
   ```

These commands dynamically configure FirewallD. Your firewall now permits the rest of the cluster to connect to the node hosted on this server. Repeat the above commands on each server. Bear in mind, these changes are not persistent. When the server reboots, FirewallD returns to its default state.

Making Firewall Changes Persistent

The commands given in the above section allow you to configure FirewallD on a running server and update the firewall rules without restarting. However, these changes are not persistent. When the server restarts, FirewallD reverts to its default configuration. To update the default configuration yourself, a somewhat different approach is required:

1. Enable the database service for FirewallD:

```
# firewall-cmd --zone=public --add-service=mysql \
     --permanent
```

2. Open the TCP ports for Galera Cluster:

```
# firewall-cmd --zone=public --add-port=3306/tcp \
     --permanent
# firewall-cmd --zone=public --add-port=4567/tcp \
     --permanent
# firewall-cmd --zone=public --add-port=4568/tcp \
     --permanent
# firewall-cmd --zone=public --add-port=4444/tcp \
     --permanent
```

3. Optionally, in the event that you would like to use multicast replication, run this command as well to open UDP transport on `4567`:

```
# firewall-cmd --zone=public --add-port=4567/udp \
     --permanent
```

4. Reload the firewall rules, maintaining the current state information:

```
# firewall-cmd --reload
```

These commands modify the default FirewallD settings and then cause the new settings take effect immediately. FirewallD is now configured to allow the rest of the cluster to access this node. The configuration remains in effect across reboots.

Firewall Configuration with PF

FreeBSD provides packet filtering support at the kernel level. Using PF you can set up, maintain and inspect the packet filtering rule sets.

Note: Warning: Different versions of FreeBSD use different versions of PF. Examples here are from FreeBSD 10.1, which uses the same version of PF as OpenBSD 4.5.

Enabling PF

In order to use PF on FreeBSD, you must first set the system up to load its kernel module. Additionally, you need to set the path to the configuration file for PF.

Using your preferred text editor, add the following lines to `/etc/rc.conf`:

```
pf_enable="YES"
pf_rules="/etc/pf.conf"
```

You may also want to enable logging support for PF and set the path for the log file. This can be done by adding the following lines to `/etc/rc.conf`:

```
pflog_enable="YES"
pflog_logfile="/var/log/pflog"
```

FreeBSD now loads the PF kernel module with logging features at boot.

Configuring PF Rules

In the above section, the configuration file for PF was set to `/etc/pf.conf`. This file allows you to set up the default firewall configuration that you want to use on your server. The settings you add to this file are the same for each cluster node.

There are two variables that you need to define for Galera Cluster in the PF configuration file: a list for the ports it needs open for TCP and a table for the IP addresses of nodes in the cluster.

```
# Galera Cluster Macros
wsrep_ports="{ 3306, 4567, 4568,4444}"
table <wsrep_cluster_address> persist {192.168.1.1 192.168.1.2 192.168.1.3}"
```

Once you have these defined, you can add the rule to allow cluster packets to pass through the firewall.

```
# Galera Cluster TCP Filter Rule
pass in proto tcp from <wsrep_cluster_address> to any port $wsrep_ports keep state
```

In the event that you deployed your cluster in a LAN environment, you need to also create on additional rule to open port `4568` to UDP transport for mutlicast replication.

```
# Galera Cluster UDP Filter Rule
pass in proto udp from <wsrep_cluster_address> to any port 4568 keep state
```

This defines the packet filtering rules that Galera Cluster requires. You can test the new rules for syntax errors using `pfctl`, with the `-n` options to prevent it from trying to load the changes.

```
# pfctl -v -nf /etc/pf.conf

wsrep_ports = "{ 3306, 4567, 4568, 4444 }"
table <wsrep_cluster_address> persist { 192.168.1.1 192.168.1.2 192.168.1.3 }
pass in proto tcp from <wsrep_cluster_address> to any port = mysql flags S/A/ keep␣
↪state
pass in proto tcp from <wsrep_cluster_address> to any port = 4567 flags S/SA keep␣
↪state
pass in proto tcp from <wsrep_cluster_address> to any port = 4568 flags S/SA keep␣
↪state
pass in proto tcp from <wsrep_cluster_address> to any port = krb524 falgs S/SA keep␣
↪state
pass in proto udp from <wsrep_cluster_address> to any port = 4568 keep state
```

If there are no syntax errors, `pfctl` prints each of the rules it adds to the firewall, (expanded, as in the example above). If there are syntax errors, it notes the line near where the errors occur.

Note: Warning: The IP addresses in the example are for demonstration purposes only. Use the real values from your nodes and netmask in your PF configuration.

Starting PF

When you finish configuring packet filtering for Galera Cluster and for any other service you may require on your FreeBSD server, you can start the service. This is done with two commands: one to start the service itself and one to start the logging service.

```
# service pf start
# service pflog start
```

In the event that you have PF running already and want to update the rule set to use the settings in the configuration file for PF, (for example, the rules you added for Galera Cluster), you can load the new rules through the `pfctl` command.

```
# pfctl -f /etc/pf.conf
```

CHAPTER THIRTYTHREE

SSL SETTINGS

Galera Cluster supports secure encrypted connections between nodes using SSL (Secure Socket Layer) protocol. This includes both the connections between database clients and servers through the standard SSL support in MySQL as well as encrypting replication traffic particular to Galera Cluster itself.

The SSL implementation is cluster-wide and does not support authentication for replication traffic. You must enable SSL for all nodes in the cluster or none of them.

SSL Certificates

Before you can enable encryption for your cluster, you first need to generate the relevant certificates for the nodes to use. This procedure assumes that you are using OpenSSL.

Note: **See Also**: This chapter only covers certificate generation. For information on its use in Galera Cluster, see *SSL Configuration* (page 171).

Generating Certificates

There are three certificates that you need to create in order to secure Galera Cluster: the Certificate Authority (CA) key and cert; the server certificate, to secure `mysqld` activity and replication traffic; and the client certificate to secure the database client and `stunnel` for state snapshot transfers.

Note: When certificates expire there is no way to update the cluster without a complete shutdown. You can minimize the frequency of this downtime by using large values for the `-days` parameter when generating your certificates.

CA Certificate

The node uses the Certificate Authority to verify the signature on the certificates. As such, you need this key and cert file to generate the server and client certificates.

To create the CA key and cert, complete the following steps:

1. Generate the CA key.

```
# openssl genrsa 2048 > ca-key.pem
```

2. Using the CA key, generate the CA certificate.

```
# openssl req -new -x509 -nodes -days 365000 \
      -key ca-key.pem -out ca-cert.pem
```

This creates a key and certificate file for the Certificate Authority. They are in the current working directory as `ca-key.pem` and `ca-cert.pem`. You need both to generate the server and client certificates. Additionally, each node requires `ca-cert.pem` to verify certificate signatures.

Server Certificate

The node uses the server certificate to secure both the database server activity and replication traffic from Galera Cluster.

1. Create the server key.

```
# openssl req -newkey rsa:2048 -days 365000 \
      -nodes -keyout server-key.pem -out server-req.pem
```

2. Process the server RSA key.

```
# openssl rsa -in server-key.pem -out server-key.pem
```

3. Sign the server certificate.

```
# openssl x509 -req -in server-req.pem -days 365000 \
      -CA ca-cert.pem -CAkey ca-key.pem -set_serial 01 \
      -out server-cert.pem
```

This creates a key and certificate file for the server. They are in the current working directory as `server-key.pem` and `server-cert.pem`. Each node requires both to secure database server activity and replication traffic.

Client Certificate

The node uses the client certificate to secure client-side activity. In the event that you prefer physical transfer methods for state snapshot transfers, `rsync` for instance, the node also uses this key and certificate to secure `stunnel`.

1. Create the client key.

```
# openssl req -newkey rsa:2048 -days 365000 \
      -nodes -keyout client-key.pem -out client-req.pem
```

2. Process client RSA key.

```
# openssl rsa -in client-key.pem -out client-key.pem
```

3. Sign the client certificate.

```
# openssl x509 -req -in client-req.pem -days 365000 \
      -CA ca-cert.pem -CAkey ca-key.pem -set_serial 01 \
      -out client-cert.pem
```

This creates a key and certificate file for the database client. They are in the current working directory as `client-key.pem` and `client-cert.pem`. Each node requires both to secure client activity and state snapshot transfers.

Verifying the Certificates

When you finish creating the key and certificate files, use `openssl` to verify that they were generated correctly:

```
# openssl verify -CAfile ca-cert.pem \
      server-cert.pem client-cert.pem

server-cert.pem: OK
client-cert.pem: OK
```

In the event that this verification fails, repeat the above process to generate replacement certificates.

Once the certificates pass verification, you can send them out to each node. Use a secure method, such as `scp` or `sftp`. The node requires the following files:

- Certificate Authority: `ca-cert.pem`.
- Server Certificate: `server-key.pem` and `server-cert.pem`.
- Client Certificate: `client-key.pem` and `client-cert.pem`.

Place these files in the `/etc/mysql/certs` directory of each node, or a similar location where you can find them later in configuring the cluster to use SSL.

SSL Configuration

When you finish generating the SSL certificates for your cluster, you need to enable it for each node. If you have not yet generated the SSL certificates, see *SSL Certificates* (page 169) for a guide on how to do so.

Note: For Gelera Cluster, SSL configurations are not dynamic. Since they must be set on every node in the cluster, if you are enabling this feature with a running cluster you need to restart the entire cluster.

Enabling SSL

There are three vectors that you can secure through SSL: traffic between the database server and client, replication traffic within Galera Cluster, and the *State Snapshot Transfer*.

Note: The configurations shown here cover the first two. The procedure for securing state snapshot transfers through SSL varies depending on the SST method you use. For more information, see *SSL for State Snapshot Transfers* (page 173).

Securing the Database

For securing database server and client connections, you can use the internal MySQL SSL support. In the event that you use logical transfer methods for state snapshot transfer, such as `mysqldump`, this is the only step you need to take in securing your state snapshot transfers.

In the configuration file, (`my.cnf`), add the follow parameters to each unit:

```
# MySQL Server
[mysqld]
ssl-ca = /path/to/ca-cert.pem
ssl-key = /path/to/server-key.pem
ssl-cert = /path/to/server-cert.pem

# MySQL Client Configuration
[mysql]
ssl-ca = /path/to/ca-cert.pem
ssl-key = /path/to/client-key.pem
ssl-cert = /path/to/client-cert.pem
```

These parameters tell the database server and client which files to use in encrypting and decrypting their interactions through SSL. The node will begin to use them once it restarts.

Securing Replication Traffic

In order to enable SSL on the internal node processes, you need to define the paths to the key, certificate and certificate authority files that you want the node to use in encrypting replication traffic.

- *socket.ssl_key* (page 263) The key file.
- *socket.ssl_cert* (page 262) The certificate file.
- *socket.ssl_ca* (page 262) The certificate authority file.

You can configure these options through the *wsrep_provider_options* (page 230) parameter in the configuration file, (that is, `my.cnf`).

```
wsrep_provider_options="socket.ssl_key=/path/to/server-key.pem;socket.ssl_cert=/path/
↪to/server-cert.pem;socket.ssl_ca=/path/to/cacert.pem"
```

This tells Galera Cluster which files to use in encrypting and decrypting replication traffic through SSL. The node will begin to use them once it restarts.

Configuring SSL

In the event that you want or need to further configure how the node uses SSL, Galera Cluster provides some additional parameters, including defining the cyclic redundancy check and setting the cryptographic cipher algorithm you want to use.

Note: **See Also**: For a complete list of available configurations available for SSL, see the options with the `socket.` prefix at *Galera Parameters* (page 243).

Configuring the Socket Checksum

Using the *socket.checksum* (page 262) parameter, you can define whether or which cyclic redundancy check the node uses in detecting errors. There are three available settings for this parameter, which are defined by an integer:

- `0` Disables the checksum.
- `1` Enables the CRC-32 checksum.
- `2` Enables the CRC-32C checksum.

The default configuration for this parameter is `1` or `2` depending upon your version. CRC-32C is optimized for and potentially hardware accelerated on Intel CPU's.

```
wsrep_provider_options = "socket.checksum=2"
```

Configuring the Encryption Cipher

Using the *socket.ssl_cipher* (page 262) parameter, you define which cipher the node uses in encrypting replication traffic. Galera Cluster uses whatever ciphers are available to the SSL implementation installed on the nodes. For instance, if you install OpenSSL on your node, Galera Cluster can use any cryptographic algorithms OpenSSL uses in ciphers.

The SSL configuration for Galera Cluster defaults to AES128-SHA, as this setting is considerably faster and no less secure than AES256.

```
wsrep_provider_options = "socket.ssl_cipher=AES128-SHA"
```

SSL for State Snapshot Transfers

When you finish generating the SSL certificates for your cluster, you can begin configuring the node for their use. Where *SSL Configuration* (page 171) covers how to enable SSL for replication traffic and the database client, this page covers enabling it for *State Snapshot Transfer* scripts.

The particular method you use to secure the State Snapshot Transfer through SSL depends upon the method you use in state snapshot transfers: `mysqldump` or `xtrabackup`.

Note: For Gelera Cluster, SSL configurations are not dynamic. Since they must be set on every node in the cluster, if you want to enable this feature with an existing cluster you need to restart the entire cluster.

Enabling SSL for `mysqldump`

The procedure for securing `mysqldump` is fairly similar to that of securing the database server and client through SSL. Given that `mysqldump` connects through the database client, you can use the same SSL certificates you created for replication traffic.

Before you shut down the cluster, you need to create a user for `mysqldump` on the database server and grant it privileges through the cluster. This ensures that when the cluster comes back up, the nodes have the correct privileges to execute the incoming state snapshot transfers. In the event that you use the *Total Order Isolation* online schema upgrade method, you only need to execute the following commands on a single node.

1. From the database client, check that you use Total Order Isolation for online schema upgrades.

   ```
   SHOW VARIABLES LIKE 'wsrep_OSU_method';

   +------------------+-------+
   | Variable_name    | Value |
   +------------------+-------+
   | wsrep_OSU_method | TOI   |
   +------------------+-------+
   ```

   If *wsrep_OSU_method* (page 228) is set to *Rolling Schema Upgrade*, or `ROI`, then you need to execute the following commands on each node individually.

2. Create a user for mysqldump.

```
CREATE USER 'sst_user'$'%' IDENTIFIED BY PASSWORD 'sst_password';
```

   Bear in mind that, due to the manner in which the SST script is called, the user name and password must be the same on all nodes.

3. Grant privileges to this user and require SSL.

```
GRANT ALL ON *.* TO 'sst_user'@'%' REQUIRE SSL;
```

4. From the database client on a different node, check to ensure that the user has replicated to the cluster.

```
SELECT User, Host, ssl_type FROM mysql.user WHERE User='sst_user';

+----------+------+----------+
| User     | Host | ssl_type |
+----------+------+----------+
| sst_user | %    | Any      |
+----------+------+----------+
```

This configures and enables the mysqldump user for the cluster.

Note: In the event that you find, *wsrep_OSU_method* (page 228) set to ROI, you need to manually create the user on each node in the cluster. For more information on rolling schema upgrades, see *Schema Upgrades* (page 99).

With the user now on every node, you can shut the cluster down to enable SSL for mysqldump State Snapshot Transfers.

1. Using your preferred text editor, update the my.cnf configuration file to define the parameters the node requires to secure state snapshot transfers.

```
# MySQL Server
[mysqld]
ssl-ca = /path/to/ca-cert.pem
ssl-key = /path/to/server-key.pem
ssl-cert = /path/to/server-cert.pem

# MySQL Client Configuration
[client]
ssl-ca = /path/to/ca-cert.pem
ssl-key = /path/to/client-key.pem
ssl-cert = /path/to/client-cert.pem
```

2. Additionally, configure *wsrep_sst_auth* (page 234) with the SST user authentication information.

```
[mysqld]
# mysqldump SST auth
wsrep_sst_auth = sst_user:sst_password
```

This configures the node to use mysqldump for state snapshot transfers over SSL. When all nodes are updated to SSL, you can begin restarting the cluster. For more information on how to do this, see *Starting the Cluster* (page 33).

Enabling SSL for `xtrabackup`

The *Physical State Transfer Method* for state snapshot transfers, uses an external script to copy the physical data directly from the file system on one cluster node into another. Unlike `rsync`, `xtrabackup` includes support for SSL encryption built in.

Configurations for `xtrabackup` are handled through the `my.cnf` configuration file, in the same as the database server and client. Use the `[sst]` unit to configure SSL for the script. You can use the same SSL certificate files as the node uses on the database server, client and with replication traffic.

```
# xtrabackup Configuration
[sst]
encrypt = 3
tca = /path/to/ca.pem
tkey = /path/to/key.pem
tcert = /path/to/cert.pem
```

When you finish editing the configuration file, restart the node to apply the changes. `xtrabackup` now sends and receives state snapshot transfers through SSL.

Note: In order to use SSL with `xtrabackup`, you need to set *wsrep_sst_method* (page 235) to `xtrabackup-v2`, instead of `xtrabackup`.

CHAPTER

THIRTYFOUR

SELINUX CONFIGURATION

Security-Enhanced Linux, or SELinux, is a kernel module for improving security of Linux operating systems. It integrates support for access control security policies, including mandatory access control (MAC), that limit user applications and system daemons access to files and network resources. Some Linux distributions, such as Fedora, ship with SELinux enabled by default.

In the context of Galera Cluster, systems with SELinux may block the database server, keeping it from starting or preventing the node from establishing connections with other nodes in the cluster. To prevent this, you need to configure SELinux policies to allow the node to operate.

Generating an SELinux Policy

In order to create an SELinux policy for Galera Cluster, you need to first open ports and set SELinux to permissive mode. Then, after generating various replication events, state transfers and notifications, create a policy from the logs of this activity and reset SELinux from to enforcing mode.

Setting SELinux to Permissive Mode

When SELinux registers a system event, there are three modes that define its response: enforcing, permissive and disabled. While you can set it to permit all activity on the system, this is not a good security practice. Instead, set SELinux to permit activity on the relevant ports and to ignore the database server.

To set SELinux to permissive mode, complete the following steps:

1. Using `semanage`, open the relevant ports:

   ```
   # semanage port -a -t mysqld_port_t -p tcp 4567
   # semanage port -a -t mysqld_port_t -p tcp 4568
   # semanage port -a -t mysqld_port_t -p tcp 4444
   ```

   SELinux already opens the standard MySQL port `3306`. In the event that you use UDP in your cluster, you also need to open `4567` to those connections.

   ```
   # semanage port -a -t mysqld_port_t -p udp 4567
   ```

2. Set SELinux to permissive mode for the database server.

   ```
   # semanage permissive -a mysqld_t
   ```

SELinux now permits the database server to function on the server and no longer blocks the node from network connectivity with the cluster.

Defining the SELinux Policy

While SELinux remains in permissive mode, it continues to log activity from the database server. In order for it to understand normal operation for the database, you need to start the database and generate routine events for SELinux to see.

For servers that use `init`, start the database with the following command:

```
# service mysql start
```

For servers that use `systemd`, instead run this command:

```
# systemctl mysql start
```

You can now begin to create events for SELinux to log. There are many ways to go about this, including:

- Stop the node, then make changes on another node before starting it again. Not being that far behind, the node updates itself using an *Incremental State Transfer*.
- Stop the node, delete the `grastate.dat` file in the data directory, then restart the node. This forces a *State Snapshot Transfer*.
- Restart the node, to trigger the notification command as defined by *wsrep_notify_cmd* (page 226).

When you feel you have generated sufficient events for the log, you can begin work creating the policy and turning SELinux back on.

Note: In order to for your policy to work you must generate both State Snapshot and Incremental State transfers.

Enabling an SELinux Policy

Generating an SELinux policy requires that you search log events for the relevant information and pipe it to the `audit2allow` utility, creating a `galera.te` file to load into SELinux.

To generate and load an SELinux policy for Galera Cluster, complete the following steps:

1. Using `fgrep` and `audit2allow`, create a textease file with the policy information.

   ```
   # fgrep "mysqld" /var/log/audit/audit.log | audit2allow -m MySQL_galera -o galera.
   ↪te
   ```

   This creates a `galera.te` file in your working directory.

2. Compile the audit logs into an SELinux policy module.

   ```
   # checkmodule -M -m galera.te -o galera.mod
   ```

   This creates a `galera.mod` file in your working directory.

3. Package the compiled policy module.

   ```
   # semodule_package -m galera.mod -o galera.pp.
   ```

   This creates a `galera.pp` file in your working directory.

4. Load the package into SELinux.

```
semodule -i galera.pp
```

5. Disable permissive mode for the database server.

```
# semanage permissive -d mysql_t
```

SELinux returns to enforcement mode, now using new policies that work with Galera Cluster.

Part VII

Migration

Bear in mind that there are certain key differences between how a standalone instance of the MySQL server works and the Galera Cluster wsrep database server. This is especially important if you plan to install Galera Cluster over an existing MySQL server, preserving its data for replication.

CHAPTER

THIRTYFIVE

DIFFERENCES FROM A STANDALONE MYSQL SERVER

Although Galera Cluster is built on providing write-set replication to MySQL and related database systems, there are certain key differences between how it handles and the standard standalone MySQL server.

Server Differences

Using a server with Galera Cluster is not the same as one with MySQL. Galera Cluster does not support the same range of operating systems as MySQL, and there are differences in how it handles binary logs and character sets.

Operating System Support

Galera Cluster requires that you use Linux or a similar UNIX-like operating system. Binary packages are not supplied for FreeBSD, Solaris and Mac OS X. There is no support available for Microsoft Windows.

Binary Log Support

Do not use the `binlog-do-db` and `binlog-ignore-db` options.

These binary log options are only supported for DML (Data Manipulation Language) statements. They provide no support for DDL statements. This creates a discrepancy in the binary logs and will cause replication to abort.

Unsupported Character Sets

Do not use the `character_set_server` with UTF-16, UTF-32 or UCS-2.

When you use `rsync` for *State Snapshot Transfer*, the use of these unsupported character sets can cause the server to crash.

Note: This is also a problem when you use automatic donor selection in your cluster, as the cluster may choose to use `rsync` on its own.

Differences in Table Configurations

There are certain features and configurations available in MySQL that do not work as expected in Galera Cluster, such as storage engine support, certain queries and the query cache.

Storage Engine Support

Galera Cluster requires the InnoDB storage engine. Writes made to tables of other types, including the system `mysql-*` tables, do not replicate to the cluster.

That said, DDL statements do replicate at the statement level, meaning that changes made to the `mysql-*` tables do replicate that way.

What this means is that if you were to issue a statement like

```
CREATE USER 'stranger'@'localhost'
  IDENTIFIED BY 'password';
```

or, like

```
GRANT ALL ON strangedb.* TO 'stranger'@'localhost';
```

the changes made to the `mysql-*` tables would replicate to the cluster. However, if you were to issue a statement like

```
INSERT INTO mysql.user (Host, User, Password)
   VALUES ('localhost', 'stranger', 'password');
```

the changes would not replicate.

Note: In general, non-transactional storage engines cannot be supported in multi-master replication.

Tables without Primary Keys

Do not use tables without a primary key.

When tables lack a primary key, rows can appear in different order on different nodes in your cluster. As such, queries like `SELECT...LIMIT...` can return different results. Additionally, on such tables the `DELETE` statement is unsupported.

Note: If you have a table without a primary key, it is always possible to add an `AUTO_INCREMENT` column to the table without breaking your application.

Table Locking

Galera Cluster does not support table locking, as they conflict with multi-master replication. As such, the `LOCK TABLES` and `UNLOCK TABLES` queries are not supported. This also applies to lock functions, such as `GET_LOCK()` and `RELEASE_LOCK()...` for the same reason.

Query Logs

You cannot direct query logs to a table. If you would like to enable query logging in Galera Cluster, you must forward the logs to a file.

```
log_output = FILE
```

Use `general_log` and `general_log_file` to choose query logging and to set the filename for your log file.

Differences in Transactions

There are some differences in how Galera Cluster handles transactions from MySQL, such as XA (eXtended Architecture) transactions and limitations on transaction size.

Distributed Transaction Processing

The standard MySQL server provides support for distributed transaction processing using the Open Group XA standard. This feature is *not* available for Galera Cluster, given that it can lead to possible rollbacks on commit.

Transaction Size

Although Galera Cluster does not explicitly limit the transaction size, the hardware you run it on does impose a size limitation on your transactions. Nodes process write-sets in a single memory-resident buffer. As such, extremely large transactions, such as `LOAD DATA` can adversely effect node performance.

You can avoid situations of this kind using the *wsrep_max_ws_rows* (page 224) and the *wsrep_max_ws_size* (page 224) parameters. Limit the transaction rows to 128 KB and the transaction size to 1 GB.

If necessary, you can increase these limits.

Transaction Commits

Galera Cluster uses at the cluster-level optimistic concurrency control, which can result in transactions that issue a `COMMIT` aborting at that stage.

For example, say that you have two transactions that will write to the same rows, but commit on separate nodes in the cluster and that only one of them can successfully commit. The commit that fails is aborted, while the successful one replicates.

When aborts occur at the cluster level, Galera Cluster gives a deadlock error.

```
code (Error: 1213 SQLSTATE: 40001 (ER_LOCK_DEADLOCK)
```

If you receive this error, restart the failing transaction. It will then issue on its own, without another to put it into conflict.

CHAPTER

THIRTYSIX

MIGRATING TO GALERA CLUSTER

For systems that already have instances of the standalone versions of MySQL, MariaDB or Percona XtraDB, the Galera Cluster installation replaces the existing database server with a new one that includes the *wsrep API* patch. This only affects the database server, not the data.

When upgrading from a standalone database server, you must take some additional steps in order to subsequently preserve and use your data with Galera Cluster.

Note: See Also: For more information on installing Galera Cluster, see *Installation* (page 9).

Upgrading System Tables

When you finish upgrading a standalone database server to Galera Cluster, but before you initialize your own cluster, you need to update the system tables to take advantage of the new privileges and capabilities. You can do this with `mysql_upgrade`.

In order to use `mysql_upgrade`, you need to first start the database server, but start it without initializing replication. For systems that use `init`, run the following command:

```
# service mysql start --wsrep_on=OFF
```

For servers that use `systemd`, instead use this command:

```
# systemctl start mysql --wsrep_on=OFF
```

The command starts `mysqld` with the *wsrep_on* (page 228) parameter set to `OFF`, which disables replication. With the database server running, you can update the system tables:

```
# mysql_upgrade
```

If this command generates any errors, check the MySQL Reference Manual for more information related to the particular error message. Typically, these errors are not critical and you can usually ignore them, unless they relate to specific functionality that your system requires.

When you finish upgrading the system tables, you need to stop the `mysqld` process until you are ready to initialize the cluster. For servers that use `init`, run the following command:

```
# service mysql stop
```

For servers that use `systemd`, instead use this command:

```
# systemctl stop mysql
```

Running this command stops database server. When you are ready to initialize your cluster, choose this server as your starting node.

Note: **See Also**: For more information on initializing and adding nodes to a cluster, see *Starting the Cluster* (page 33).

Migrating from MySQL to Galera Cluster

In the event that you have an existing database server that uses the MyISAM storage engine or the stock MySQL master-slave replication, there are some additional steps that you need to take. The *Galera Replication Plugin* requires a transactional storage engine in order to function. As MyISAM is non-transactional, you need to migrate your data to InnoDB, in addition to installing the new software packages.

There are three types of database servers referred to in this guide:

- **Master Server** Refers to the MySQL master server.
- **Slave Server** Refers to a MySQL slave server.
- **Cluster Node** Refers to a node in Galera Cluster.

For the sake of simplicity, slave servers and cluster nodes are referenced collectively, rather than individually. In production, you may have several slave servers and must have at least three cluster nodes.

Infrastructure Preparation

For your existing infrastructure, you have a MySQL master server as well as several slave servers that form a master-slave cluster. Before you can begin migration, you first need to prepare your infrastructure for the change.

1. Launch at least three new servers, outside of and unconnected to your existing database infrastructure.
2. On each new server, install Galera Cluster. For information on how to do this, see *Installation* (page 9).
3. Configure the database server. In addition to the IP addresses of each node, on the *wsrep_cluster_address* (page 217) parameter, include the IP addresses of the MySQL master server and each instance of the slave servers.

   For more information on configuring Galera Cluster, see *System Configuration* (page 28) and *Replication Configuration* (page 30).
4. When you finish the installation and configuration, start the cluster. For more information on how to start the cluster, see *Starting the Cluster* (page 33).

To check that it is running properly, log into one of the database clients and run the *wsrep_cluster_size* (page 268) status variable:

```
SHOW STATUS LIKE 'wsrep_cluster_size';

+--------------------+-------+
| Varialbe_name      | Value |
+--------------------+-------+
| wsrep_cluster_size | 3     |
+--------------------+-------+
```

Galera Cluster is now running in parallel to your MySQL master-slave cluster. It contains no data and remains unused by your application servers. You can now begin migrating your data.

Data Migration

In order to migrate data from a MySQL master-slave cluster to Galera Cluster, you need to manually transfer it from your existing infrastructure to the new one.

1. Stop the load of the master server.
2. On the master server, run `mysqldump`:

   ```
   $ mysqldump -u root -p --skip-create-options --all-databases > migration.sql
   ```

   The `--skip-create-options` ensures that the database server uses the default storage engine when loading the data, instead of MyISAM.
3. Transfer the `migration.sql` output file to one of your new cluster nodes.

   ```
   $ scp migration.sql user@galera-node-IP
   ```

4. On the cluster node, load the data from the master server.

   ```
   mysql -u root -p < migration.sql
   ```

5. Restart the load from the application servers, this time directing it towards your cluster nodes instead of the master server.

Your application now uses Galera Cluster, instead of your previous MySQL master-slave cluster.

Note: Bear in mind that your application will experience downtime at this stage of the process. The length of the downtime varies depending on the amount of data you have to migrate, specifically how long it takes `mysqldump` to create a snapshot of the master server, then transfer and upload it onto a cluster node.

Database Migration

With your application server now using the new cluster nodes, you now need to migrate your master and slave servers from stock MySQL to Galera Cluster.

1. Using the same process described in *Installation* (page 9), install and configure Galera Cluster on the server.
2. Start the node with replication disabled. For servers that use `init`, run the following command:

   ```
   # service mysql start --wsrep-on=OFF
   ```

   For servers that use `systemd`, instead run this command:

   ```
   # systemctl start mysql --wsrep-on=OFF
   ```

3. From the database client, manually switch the storage engine on each table from MyISAM to InnoDB:

   ```
   ALTER TABLE table_name ENGINE = InnoDB;
   ```

4. Update the system tables:

```
# mysql_upgrade
```

Note: For more information, see *Upgrading System Tables* (page 189).

5. From one of the running Galera Cluster nodes, copy the `grastate.dat` file into the data directory of the former MySQL master server.

```
$ scp grastate.dat user@server-master-ip:/path/to/datadir
```

6. Using your preferred text editor, on the former MySQL master server update the sequence number (that is, the seqno) in the `grastate.dat` file from `-1` to `0`.

7. Restart the master and slave servers. For servers that use `init`, run the following command:

```
# service mysql restart
```

For servers that use `systemd`, instead run this command:

```
# systemctl restart mysql
```

8. Resume load on these servers.

When the former MySQL master and slave servers come back after restarting, they establish network connectivity with the cluster and begin catching up with recent changes. All of the servers now function as nodes in Galera Cluster.

Note: **See Also**: For more information on the installation and basic management of Galera Cluster, see the *Getting Started Guide* (page 5).

Part VIII

Support

CHAPTER

THIRTYSEVEN

TROUBLESHOOTING

Frequently Asked Questions

This chapter lists a number of frequently asked questions on Galera Cluster and other related matters.

What is Galera Cluster?

Galera Cluster is a write-set replication service provider in the form of the dlopenable library. It provides synchronous replication and supports multi-master replication. Galera Cluster is capable of unconstrained parallel applying (that is, "parallel replication"), multicast replication and automatic node provisioning.

The primary focus of Galera Cluster is data consistency. Transactions are either applied to every node or not at all. Galera Cluster is not a cluster manager, a load balancer or a cluster monitor. What it does it keep databases synchronized provided that they were properly configured and synchronized in the beginning.

What is Galera?

The word *galera* is the Italian word for *galley*. The galley is a class of naval vessel used in the Mediterranean Sea from the 2nd millennium B.C.E. until the Renaissance. Although they used sails when the winds were favorable, their principal method of propulsion came from banks of oars.

In order to manage the vessel effectively, rowers had to act synchronously, lest the oars become intertwined and get blocked. Captains could scale the crew up to hundreds of rowers, making the galleys faster and more maneuverable in combat.

Note: See Also: For more information on galleys, see Wikipedia.

How Do I Manage Failover?

Galera Cluster is a true synchronous multi-master replication system, which allows the use of any or all of the nodes as master at any time without any extra provisioning. What this means is that there is no failover in the traditional MySQL master-slave sense.

The primary focus of Galera Cluster is data consistency across the nodes. This does not allow for any modifications to the database that may compromise consistency. For instance, the node blocks or rejects write requests until the joining node syncs with the cluster and is ready to process requests.

The results of this is that you can safely use your favorite approach to distribute or migrate connections between the nodes without the risk of causing inconsistency.

Note: **See Also**: For more information on connection distribution, see *Cluster Deployment Variants* (page 123).

How Do I Upgrade the Cluster?

Periodically, updates will become available for Galera Cluster, (for the database server itself or the *Galera Replication Plugin*). To update the software for the node, complete the following steps:

1. Stop the node.
2. Upgrade the software.
3. Restart the node.

In addition to this, you also need to transfer client connections from node you want to upgrade to another node for the duration of the migration.

Note: **See Also**: For more information on upgrade process, see *Upgrading Galera Cluster* (page 107).

What InnoDB Isolation Levels does Galera Cluster Support?

You can use all isolation levels. Locally, in a given node, transaction isolation works as it does natively with InnoDB.

That said, globally, with transactions processing in separate nodes, Galera Cluster implements a transaction-level called `SNAPSHOT ISOLATION`. The `SNAPSHOT ISOLATION` level is between the `REPEATABLE READ` and `SERIALIZABLE` levels.

The `SERIALIZABLE` level cannot be guaranteed in the multi-master use case, because Galera Cluster replication does not carry a transaction read set. Also, `SERIALIZABLE` transaction is vulnerable to multi-master conflicts. It holds read locks and any replicated write to read locked row will cause the transaction to abort. Hence, it is recommended not to use it in Galera Cluster.

Note: **See Also**: For more information, see *Isolation Levels* (page 51).

How are DDL's Handled by Galera Cluster?

For DDL statements and similar queries, Galera Cluster has two modes of execution:

- *Total Order Isolation* Where the query is replicated in a statement before executing on the master. The node waits for all preceding transactions to commit and then all nodes simultaneously execute the transaction in isolation.
- *Rolling Schema Upgrade* Where the schema upgrades run locally, blocking only the node on which they are run. The changes do not replicate to the rest of the cluster.

Note: **See Also**: For more information, see *Schema Upgrades* (page 99).

What if connections give an `Unknown command` error?

Your cluster experiences a temporary split, during which a portion of the nodes loses connectivity to the *Primary Component*. When they reconnect, nodes from the former nonoperational component drop their client connections. New connections to the database client return `Unknown command` errors.

What's happening is that the node does not consider yet itself a part of the Primary Component. While it has restored network connectivity, it still has to resynchronize itself with the cluster. MySQL does not have an error code for the node lacking Primary status and defaults to an `Unknown command` message.

Nodes in a nonoperational component must regain network connectivity with the Primary Component, process a state transfer and catch up with the cluster before they can resume normal operation.

Is GCache a Binlog?

The *Write-set Cache*, which is also called GCache, is a memory allocator for write-sets. Its primary purpose is to minimize the write-set footprint in RAM. It is not a log of events, but rather a cache.

- GCache is not persistent.
- Not every entry in GCache is a write-set.
- Not every write-set in GCache will be committed.
- Write-sets in GCache are not allocated in commit order.
- Write-sets are not an optimal entry for the binlog, since they contain extra information.

That said, it is possible to construct a binlog out of the write-set cache.

What if the node crashes during `rsync` SST

You can configure *wsrep_sst_method* (page 235) to use `rsync` for *State Snapshot Transfer*. If the node crashes before the state transfer is complete, it may cause the `rsync` process to hang forever, occupying the port and not allowing you to restart the node. In the event that this occurs, the error logs for the database server show that the port is in use.

To correct the issue, kill the orphaned `rsync` process . For instance, if you find the process had a pid of `501`, you might run the following command:

```
# kill 501
```

Once you kill the orphaned process, it frees up the relevant ports and allows you to restart the node.

Server Error Log

`Node 0 (XXX) requested state transfer from '*any*'. Selected 1 (XXX) as donor.`

The node is attempting to initiate a *State Snapshot Transfer*.

In the event that you do not explicitly set the donor node through *wsrep_sst_donor* (page 234), the Group Communication module selects a donor based on the information available about the node states.

Group Communication monitors node states for the purposes of flow control, state transfers and quorum calculations. That is, to ensure that a node that shows as `JOINING` does not count towards flow control and quorum.

The node can serve as a donor when it is in the SYNCED state. The joiner node selects a donor from the available synced nodes. It shows preference to synced nodes that have the same *gmcast.segment* (page 257) wsrep Provider option or it selects the first in the index. When the donor node is chosen its state changes immediately to DONOR, meaning that it is no longer available for requests.

If the node can find no free nodes that show as SYNCED, the joining node reports:

```
Requesting state transfer failed: -11(Resource temporarily
unavailable).  Will keep retrying every 1 second(s).
```

The joining node continues to retry the state transfer request.

SQL SYNTAX Errors

When a *State Snapshot Transfer* fails using mysqldump for any reason, the node writes a SQL SYNTAX message into the server error logs.

This is a pseudo-statement. You can find the actual error message the state transfer returned within the SQL SYNTAX entry. It provides the information you need to correct the problem.

Commit failed for reason: 3

When you have *wsrep_debug* (page 220) turned ON, you may occasionally see a message noting that a commit has failed due to reason 3. For example:

```
110906 17:45:01 [Note] WSREP: BF kill (1, seqno: 16962377), victim:  (140588996478720
↪4) trx: 35525064
110906 17:45:01 [Note] WSREP: Aborting query: commit
110906 17:45:01 [Note] WSREP: kill trx QUERY_COMMITTING for 35525064
110906 17:45:01 [Note] WSREP: commit failed for reason: 3, seqno: -1
```

When attempting to apply a replicated write-set, slave threads occasionally encounter lock conflicts with local transactions, which may already be in the commit phase. In such cases, the node aborts the local transaction, allowing the slave thread to proceed.

This is a consequence of optimistic transaction execution. The database server executes transaction under the expectation that there will be no row conflicts. It is an expected issue in a multi-master configuration.

To mitigate such conflicts:

- Use the cluster in a master-slave configuration. Direct all writes to a single node.
- Use the same approaches as for master-slave read/write splitting.

Unknown Command Errors

Every query returns the Unknown command error.

Situation

For example, you log into a node and try to run a query from the database client. Every query you run generates the same error:

```
SELECT * FROM example_table;

ERROR: Unknown command '\\'
```

The reason for the error is that the node considers itself out of sync with the global state of the cluster. It is unable to serve SQL requests except for `SET` and `SHOW`.

This occurs when you have explicitly set the wsrep Provider (through the *wsrep_provider* (page 229) parameter), but the wsrep Provider rejects service. For example, this happens in cases where the node is unable to connect to the *Primary Component*, such as when the *wsrep_cluster_address* (page 217) parameter becomes unset or due to networking issues.

Solution

Using the *wsrep_on* (page 228) parameter dynamically, you can bypass the wsrep Provider check. This disables replication.

```
SET wsrep_on=OFF;
```

This command tells `mysqld` to ignore the *wsrep_provider* (page 229) setting and behave as a standard standalone database server. Doing this can lead to data inconsistency with the rest of the cluster, but that may be the desired result for modifying the "local" tables.

In the event that you know or suspect that your cluster does not have a *Primary Component*, you need to bootstrap a new one. On each node in the cluster, run the following queries:

1. Using the *wsrep_cluster_status* (page 269) status variable, confirm that the node is not part the Primary Component:

   ```
   SHOW STATUS LIKE 'wsrep_cluster_status';

   +----------------------+-------------+
   | Variable_name        | Value       |
   +----------------------+-------------+
   | wsrep_cluster_status | Non_primary |
   +----------------------+-------------+
   ```

   If the query returns `Primary`, the node is part of the Primary Component. If the query returns any other value, it indicates that the node is part of a nonoperational component.

2. Using the *wsrep_last_committed* (page 274) status variable, find the sequence number of the last committed transaction.

   ```
   SHOW STATUS LIKE 'wsrep_last_committed';

   +----------------------+--------+
   | Variable_name        | Value  |
   +----------------------+--------+
   | wsrep_last_committed | 409745 |
   +----------------------+--------+
   ```

In the event that none of the nodes show as the Primary Component, you need to bootstrap a new one. The node that returns the largest sequence number is the most advanced in the cluster. On that node, run the following command:

```
SET GLOBAL wsrep_provider_options='pc.bootstrap=YES';
```

The node now operates as the starting point in a new Primary Component. Nodes that are part of nonoperational components that have network connectivity attempt to initiate a state transfer to bring their own databases up-to-date with this node. The cluster begins accepting SQL requests again.

User Changes not Replicating

User changes do not replicate to the cluster.

Situation

You have made some changes to database users, but on inspection find that these changes are only present on the node in which you made them and have not replicated to the cluster.

For instance, say that you want to add a new user to your cluster. You log into a node and use an `INSERT` statement to update the `mysql.user` table.

```
INSERT INTO mysql.user (User,Host, Password)
   VALUES ('user1','localhost', password('my_password'));
```

When finished, you check your work by running a `SELECT` query, to make sure that `user1` does in fact exist on the node:

```
SELECT User, Host, Password FROM mysql.user WHERE User='user1';

+-------+-------------+-----------------------------------------+
| User  | Host        | Password                                |
+-------+-------------+-----------------------------------------+
| user1 | localhost   | *00A60C0186D8740829671225B7F5694EA5C08EF5 |
+-------+-------------+-----------------------------------------+
```

This checks out fine. However, when you run the same query on a different node, you receive different results:

```
SELECT User, Host, Password FROM mysql.user WHERE User='user1';

Empty set (0.00 sec)
```

The changes you made to the `mysql.user` table on the first node do not replicate to the others. The new user you created can only function when accessing the database on the node where you created it.

Replication currently only works with the InnoDB and XtraDB storage engines. Multi-master replication cannot support non-transactional storage engines, such as MyISAM. Writes made to tables that use non-transactional storage engines do not replicate.

The system tables use MyISAM. This means that any changes you make to the system tables directly, such as in the above example with an `INSERT` statement, remain on the node in which they were issued.

Solution

While direct modifications to the system tables do not replicate, DDL statements replicate at the statement level. Meaning, changes made to the system tables in this manner are made to the entire cluster.

For instance, consider the above example where you added a user to node. If instead of `INSERT` you used `CREATE USER` or `GRANT` you would get very different results:

```
CREATE USER user1 IDENTIFIED BY 'my_password';
```

This creates `user1` in a way that replicates through the cluster. If you run `SELECT` query to check the `mysql.user` table on any node, it returns the same results:

```
SELECT User, Host, Password FROM mysql.user WHERE User='user1';

+-------+-------------+-----------------------------------------+
| User  | Host        | Password                                |
+-------+-------------+-----------------------------------------+
| user1 | localhost   | *00A60C0186D8740829671225B7F5694EA5C08EF5 |
+-------+-------------+-----------------------------------------+
```

You can now `user1` on any node in the cluster.

Cluster Stalls on ALTER

The cluster stalls when you run an `ALTER` query on an unused table.

Situation

You attempt to run an `ALTER` command on one node. The command takes a long time to execute. During that period all other nodes stall leading to performance issues throughout the cluster.

What's happening is a side effect of a multi-master cluster with several appliers. The cluster needs to control when a DDL statement ends in relation to other transactions, in order to deterministically detect conflicts and schedule parallel appliers. Effectively, the DDL statement must execute in isolation.

Galera Cluster has a 65K window of tolerance for transactions applied in parallel, but the cluster must wait when `ALTER` commands take too long.

Solution

Given that this is a consequence of something intrinsic to how replication works in Galera Cluster, there is no direct solution to the problem. However, you can implement a workaround.

In the event that you can guarantee that no other session will try to modify the table *and* that there are no other DDL statements running, you can shift the schema upgrade method from *Total Order Isolation* to *Rolling Schema Upgrade* for the duration of the `ALTER` statement. This applies the changes to each node individually, without affecting cluster performance.

To run an `ALTER` statement in this manner, on each node run the following queries:

1. Change the Schema Upgrade method to Rolling Schema Upgrade.

   ```
   SET wsrep_OSU_method='RSU';
   ```

2. Run the `ALTER` statement.
3. Reset the Schema Upgrade method back to Total Order Isolation.

   ```
   SET wsrep_OSU_method='TOI';
   ```

The cluster now runs with the desired updates.

Detecting a Slow Node

By design, the performance of the cluster cannot be higher than the performance of the slowest node on the cluster. Even if you have one node only, its performance can be considerably lower when compared with running the same server in a standalone mode (without a wsrep Provider).

This is particularly true for big transactions even if they were within the transaction size limits. This is why it is important to be able to detect a slow node on the cluster.

Finding Slow Nodes

There are two status variables used in finding slow nodes:

- *wsrep_flow_control_sent* (page 273) Provides the number of times the node sent a pause event due to flow control since the last status query.

```
SHOW STATUS LIKE 'wsrep_flow_control_sent';

+-------------------------+-------+
| Variable_name           | Value |
+-------------------------+-------+
| wsrep_flow_control_sent | 7     |
+-------------------------+-------+
```

- *wsrep_local_recv_queue_avg* (page 276) Provides an average of the received queue length since the last status query.

```
SHOW STATUS LIKE 'wsrep_local_recv_queue_avg';

+----------------------------+---------+
| Variable_name              | Value   |
+----------------------------+---------+
| wsrep_local_recv_queue_avg | 3.34852 |
+----------------------------+---------+
```

  Nodes that return values much higher than `0.0` inidcates that it cannot apply write-sets as fast as they are received and can generate replication throttling.

Check these status variables on each node in your cluster. The node that returns the highest value is the slowest node. Lower values are preferable.

Dealing with Multi-Master Conflicts

The type of conflicts that you need to address in multi-master database environments are typically row conflicts on different nodes.

Consider a situation in a multi-master replication system. Users can submit updates to any database node. In turn two nodes can attempt to change the same database row with different data. Galera Cluster copes with situations such as this by using certification-based replication.

Note: **See Also**: For more information, see *Certification-based Replication* (page 45).

Diagnosing Multi-Master Conflicts

There are a few techniques available to you in logging and monitoring for problems that may indicate multi-master conflicts.

- *wsrep_debug* (page 220) tells the node to include additional debugging information in the server output log. You can enable it through the configuration file:

```
# Enable Debugging Output to Server Error Log
wsrep_debug=ON
```

  Once you turn debugging on, you can use your preferred monitoring software to watch for row conflicts.

```
110906 17:45:01 [Note] WSREP: BF kill (1, seqno: 16962377), victim: 
↪(140588996478720 4) trx: 35525064
110906 17:45:01 [Note] WSREP: Aborting query: commit
110906 17:45:01 [Note] WSREP: kill trx QUERY_COMMITTING for 35525064
110906 17:45:01 [Note] WSREP: commit failed for reason: 3, seqno: -1
```

  Note: **Warning**: In addition to useful debugging information, this parameter also causes the database server to print authentication information, (that is, passwords), to the error logs. Do not enable it in production environments.

- In the event that you are developing your own notification system, you can use status variables to watch for conflicts:

```
SHOW STATUS LIKE 'wsrep_local_bf_aborts';

+-----------------------+-------+
| Variable_name         | Value |
+-----------------------+-------+
| wsrep_local_bf_aborts | 333   |
+-----------------------+-------+

SHOW STATUS LIKE 'wsrep_local_cert_failures';

+---------------------------+-------+
| Variable_name             | Value |
+---------------------------+-------+
| wsrep_local_cert_failures | 333   |
+---------------------------+-------+
```

  wsrep_local_bf_aborts (page 274) gives the total number of local transactions aborted by slave transactions while in execution. *wsrep_local_cert_failures* (page 274) gives the total number of transactions that have failed certification tests.

- Lastly, you can enable conflict logging features through *wsrep_log_conflicts* (page 223) and *cert.log_conflicts* (page 246).

```
# Enable Conflict Logging
wsrep_log_conflicts=ON
wsrep_provider_options="cert.log_conflicts=YES"
```

  These parameters enable different forms of conflict logging on the database server. When turned on, the node logs additional information about the conflicts it encounters, such as the name of the table and schema where the conflict occurred and the actual values for the keys that produced the conflict.

```
7:51:13 [Note] WSREP: trx conflict for key (1,FLAT8)056eac38 0989cb96:
source: cdeae866-d4a8-11e3-bd84-479ea1a1e941 version: 3 local: 1 state:
MUST_ABORT flags: 1 conn_id: 160285 trx_id: 29755710 seqnos (l: 643424,
g: 8749173, s: 8749171, d: 8749171, ts: 12637975935482109) <--X-->
source: 5af493da-d4ab-11e3-bfe0-16ba14bdca37 version: 3 local: 0 state:
APPLYING flags: 1 conn_id: 157852 trx_id: 26224969 seqnos (l: 643423,
g: 8749172, s: 8749171, d: 8749170, ts: 12637839897662340)
```

Auto-committing Transactions

When two transactions come into conflict, the later of the two is rolled back by the cluster. The client application registers this rollback as a deadlock error. Ideally, the client application *should* retry the deadlocked transaction, but not all client applications have this logic built in.

In the event that you encounter this problem, you can set the node to attempt to auto-commit the deadlocked transactions on behalf of the client application, using the *wsrep_retry_autocommit* (page 232) parameter.

```
wsrep_retry_autocommit=4
```

When a transaction fails the certification test due to a cluster-wide conflict, this tells the node how many times you want it to retry the transaction before returning a deadlock error.

Note: Retrying only applies to auto-commit transactions, as retrying is not safe for multi-statement transactions.

Working Around Multi-Master Conflicts

While Galera Cluster resolves multi-master conflicts automatically, there are steps you can take to minimize the frequency of their occurrence.

- Analyze the hot-spot and see if you can change the application logic to catch deadlock exceptions.
- Enable retrying logic at the node level using, *wsrep_retry_autocommit* (page 232).
- Limit the number of master nodes or switch to a master-slave model.

Note: If you can filter out the access to the hot-spot table, it is enough to treat writes only to the hot-spot table as master-slave.

Two-Node Clusters

In a two-node cluster, a single-node failure causes the other to stop working.

Situation

You have a cluster composed of only two nodes. One of the nodes leaves the cluster *ungracefully*. That is, instead of being shut down through `init` or `systemd`, it crashes or suffers a loss of network connectivity. The node that remains becomes nonoperational. It remains so until some additional information is provided by a third party, such as a human operator or another node.

If the node remained operational after the other left the cluster ungracefully, there would be the risk that each of the two nodes will think itself as being the *Primary Component*. To prevent this, the node becomes nonoperational.

Solutions

There are two solutions available to you:

- You can bootstrap the surviving node to form a new *Primary Component*, using the *pc.boostrap* (page 258) wsrep Provider option. To do so, log into the database client and run the following command:

  ```
  SET GLOBAL wsrep_provider_options='pc.bootstrap=YES';
  ```

  This bootstraps the surviving node as a new Primary Component. When the other node comes back online or regains network connectivity with this node, it will initiate a state transfer and catch up with this node.

- In the event that you want the node to continue to operate, you can use the *pc.ignore_sb* (page 259) wsrep Provider option. To do so, log into the database client and run the following command:

  ```
  SET GLOBAL wsrep_provider_options='pc.ignore_sb=TRUE';
  ```

  The node resumes processing updates and it will continue to do so, even in the event that it suspects a split-brain situation.

  Note: Warning: Enabling *pc.ignore_sb* (page 259) is dangerous in a multi-master setup, due to the aforementioned risk for split-brain situations. However, it does simplify things in master-slave clusters, (especially in cases where you only use two nodes).

In addition to the solutions provided above, you can avoid the situation entirely using Galera Arbitrator. Galera Arbitrator functions as an odd node in quorum calculations. Meaning that, if you enable Galera Arbitrator on one node in a two-node cluster, that node remains the Primary Component, even if the other node fails or loses network connectivity.

CHAPTER

THIRTYEIGHT

TUTORIALS

Performance

Write-set Caching during State Transfers

Under normal operations, nodes do not consume much more memory than the regular standalone MySQL database server. The certification index and uncommitted write-sets do cause some additional usage, but in typical applications this is not usually noticeable.

Write-set caching during state transfers is the exception.

When a node receives a state transfer, it cannot process or apply incoming write-sets as it does not yet have a state to apply them to. Depending on the state transfer method, (`mysqldump`, for instance), the sending node may also be unable to apply write-sets.

The Write-set Cache, (or GCache), caches write-sets on memory-mapped files to disk and Galera Cluster allocates these files as needed. In other words, the only limit for the cache is the available disk space. Writing to disk in turn reduces memory consumption.

Note: **See Also**: For more information on configuring write-set caching to improve performance, see *Configuring Flow Control* (page 92).

Customizing the Write-set Cache Size

You can define the size of the write-set cache using the *gcache.size* (page 253) parameter. The set the size to one less than that of the data directory.

If you have storage issues, there are some guidelines to consider in adjusting this issue. For example, your preferred state snapshot method. `rsync` and `xtrabackup` copy the InnoDB log files, while `mysqldump` does not. So, if you use `mysqldump` for state snapshot transfers, you can subtract the size of the log files from your calculation of the data directory size.

Note: Incremental State Transfers (IST) copies the database five times faster over `mysqldump` and about 50% faster than `xtrabackup`. Meaning that your cluster can handle relatively large write-set caches. However, bear in mind that you cannot provision a server with Incremental State Transfers.

As a general rule, start with the data directory size, including any possible links, then subtract the size of the ring buffer storage file, which is called `galera.cache` by default.

In the event that storage remains an issue, you can further refine these calculations with the database write rate. The write rate indicates the tail length that the cluster stores in the write-set cache.

You can calculate this using the *wsrep_received_bytes* (page 281) status variable.

1. Determine the size of the write-sets the node has received from the cluster:

```
SHOW STATUS LIKE 'wsrep_received_bytes';

+------------------------+-----------+
| Variable name          | Value     |
+------------------------+-----------+
| wsrep_received_bytes   | 6637093   |
+------------------------+-----------+
```

   Note the value and time, respective as $recv_1$ and $time_1$.

2. Run the same query again, noting the value and time, respectively, as $recv_2$ and $time_2$.

3. Apply these values to the following equation:

$$writerate = \frac{recv_2 - recv_1}{time_2 - time_1}$$

From the write rate you can determine the amount of time the cache remains valid. When the cluster shows a node as absent for a period of time less than this interval, the node can rejoin the cluster through an incremental state transfer. Node that remains absent for longer than this interval will likely require a full state snapshot transfer to rejoin the cluster.

You can determine the period of time the cache remains valid using this equation:

$$period = \frac{cachesize}{writerate}$$

Conversely, if you already know the period in which you want the write-set cache to remain valid, you can use instead this equation:

$$cachesize = writerate \times time$$

This equation can show how the size of the write-set cache can improve performance. For instance, say you find that cluster nodes frequently request state snapshot transfers. Increasing the *gcache.size* (page 253) parameter extends the period in which the write-set remains valid, allowing the nodes to update instead through incremental state transfers.

Note: Consider these configuration tips as guidelines only. For example, in cases where you must avoid state snapshot transfers as much as possible, you may end up using a much larger write-set cache than suggested above.

Setting Parallel Slave Threads

There is no rule about how many slave threads you need for replication. Parallel threads do not guarantee better performance. But, parallel applying does not impair regular operation performance and may speed up the synchronization of new nodes with the cluster.

You should start with four slave threads per CPU core:

```
wsrep_slave_threads=4
```

The logic here is that, in a balanced system, four slave threads can typically saturate a CPU core. However, I/O performance can increase this figure several times over. For example, a single-core ThinkPad R51 with a 4200 RPM drive can use thirty-two slave threads.

Parallel applying requires the following settings:

```
innodb_autoinc_lockmode=2
innodb_locks_unsafe_For_binlog=1
```

You can use the *wsrep_cert_deps_distance* (page 267) status variable to determine the maximum number of slave threads possible. For example:

```
SHOW STATUS LIKE 'wsrep_cert_deps_distance';

+----------------------------+-----------+
| Variable name              | Value     |
+----------------------------+-----------+
| wsrep_cert_deps_distance   | 23.88889  |
+----------------------------+-----------+
```

This value essentially determines the number of write-sets that the node can apply in parallel on average.

Note: **Warning**: Do not use a value for *wsrep_slave_threads* (page 232) that is higher than the average given by the *wsrep_cert_deps_distance* (page 267) status variable.

Dealing with Large Transactions

Large transactions, for instance the transaction caused by a `DELETE` query that removes millions of rows from a table at once, can lead to diminished performance. If you find that you must perform frequently transactions of this scale, consider using `pt-archiver` from the Percona Toolkit.

For example, if you want to delete expired tokens from their table on a database called `keystone` at `dbhost`, you might run something like this:

```
$ pt-archiver --source h=dbhost,D=keystone,t=token \
   --purge --where "expires < NOW()" --primary-key-only \
   --sleep-coef 1.0 --txn-size 500
```

This allows you to delete rows efficiently from the cluster.

Note: **See Also**: For more information on `pt-archiver`, its syntax and what else it can do, see the manpage.

Configuration Tips

This chapter contains some advanced configuration tips.

WAN Replication

When running the cluster over WAN, you may frequently experience transient network connectivity failures. To prevent this from partitioning the cluster, you may want to increase the keepalive timeouts.

The following parameters can tolerate 30 second connectivity outages.

```
wsrep_provider_options = "evs.keepalive_period = PT3S;
      evs.suspect_timeout = PT30S;
      evs.inactive_timeout = PT1M;
      evs.install_timeout = PT1M"
```

In configuring these parameters, consider the following:

- You want *evs.suspect_timeout* (page 251) parameter set as high as possible to help avoid partitions. Given that partitions cause state transfers, which can effect performance.
- You must set the *evs.inactive_timeout* (page 249) parameter to a value higher than *evs.suspect_timeout* (page 251).
- You must set the *evs.install_timeout* (page 249) parameter to a value higher than the *evs.inactive_timeout* (page 249).

Dealing with WAN Latency

When using Galera Cluster over a WAN, bear in mind that WAN links can have exceptionally high latency. You can correct for this by taking Round-Trip Time (RTT) measurements between cluster nodes and adjust all temporal parameters.

To take RTT measurements, use `ping` on each cluster node to ping the others. For example, if you were to log in to the node at `192.168.1.1`:

```
$ ping -c 3 192.168.1.2
  PING 192.168.1.2 (192.168.1.2) 58(84) bytes of data.
  64 bytes from 192.168.1.2: icmp_seq=1 ttl=64 time=0.736 ms
  64 bytes from 192.168.1.2: icmp_seq=2 ttl=64 time=0.878 ms
  64 bytes from 192.168.1.2: icmp_seq=3 ttl=64 time=12.7 ms

  --- 192.168.1.2 ---
  3 packets transmitted, 3 received, 0% packet loss, time 2002ms
  rtt min/avg/max/mdev = 0.736/4.788/12.752/5.631 ms
```

Take RTT measurements on each node in your cluster and note the highest value among them.

Parameters that relate to periods and timeouts, such as *evs.join_retrans_period* (page 250). They must all use values that exceed the highest RTT measurement in your cluster.

```
wsrep_provider_options="evs.join_retrans_period=PT0.5S"
```

This allows the cluster to compensate for the latency issues of the WAN links between your cluster nodes.

Multi-Master Setup

A master is a node that can simultaneously process writes from clients.

The more masters you have in the cluster the higher the probability of certification conflicts. This can lead to undesirable rollbacks and performance degradation.

If you find you experience frequent certification conflicts, consider reducing the number of nodes your cluster uses as masters.

Single Master Setup

In the event that your cluster uses only one node as a master, there are certain requirements, such as the slave queue size, that can be relaxed.

To relax flow control, use the settings below:

```
wsrep_provider_options = "gcs.fc_limit = 256;
    gcs.fc_factor = 0.99;
    gcs.fc_master_slave = YES"
```

By reducing the rate of flow control events, these settings may improve replication performance.

Note: You can also use this setting as suboptimal in a multi-master setup.

Using Galera Cluster with SELinux

When you first enable Galera Cluster on a node that runs SELinux, SELinux prohibits all cluster activities. In order to enable replication on the node, you need a policy so that SELinux can recognize cluster activities as legitimate.

To create a policy for Galera Cluster, set SELinux to run in permissive mode. Permissive mode does not block cluster activity, but it does log the actions as warnings. By collecting these warnings, you can iteratively create a policy for Galera Cluster.

Once SELinux no longer registers warnings from Galera Cluster, you can switch it back into enforcing mode. SELinux then uses the new policy to allow the cluster access to the various ports and files it needs.

Note: Almost all Linux distributions ship with a MySQL policy for SELinux. You can use this policy as a starting point for Galera Cluster and extend it, using the above procedure.

Using Synchronization Functions

Occasionally, your application may need to perform a critical read. Critical reads are queries that require that the local database reaches the most up to date state possible before the query is executed.

In versions of Galera Cluster prior to 4.x, you could manage critical reads using the *wsrep_sync_wait* (page 238) session variable. This would cause the node to enable causality checks, holding new queries until the database server catches up with all updates that were made prior to the start of the current transaction. While this method does ensure that the node reaches the most up-to-date state before executing the query, it also means that the node may waits to receive updates that may have nothing to do with the query at hand.

Beginning with Galera Cluster 4.0, you can use synchronization functions. This allows you to tie the synchronization process to specific transactions so that the node waits only until a specific transaction is applied before executing the query. For example,

1. On `node1`, begin a transaction.

   ```
   START TRANSACTION;
   ```

2. Update the database with various changes and additions. When you're done, commit the transaction.

   ```
   COMMIT;
   ```

3. Using the *WSREP_LAST_WRITTEN_GTID()* (page 241) function, obtain the *Global Transaction ID* of the transaction, save it to the `$transaction_1_gtid` variable.

```
$transaction_1_gtid = SELECT WSREP_LAST_WRITTEN_GTID();
```

4. On `node2`, set it to wait until it replicates and applies the transaction from `node1` before starting a new transaction:

```
SELECT WSREP_SYNC_WAIT_UPTO_GTID($transaction_1_gtid);
START TRANSACTION;
```

5. Execute your critical reads.

Using the *WSREP_SYNC_WAIT_UPTO_GTID()* (page 241) function, the node waits until it has replicated and applied the given Global Transaction ID before starting a new transaction.

Note: Synchronization Functions were introduced in Galera Cluster 4. If you have an older version, you won't be able to use these features. To find out what version you have, run the *wsrep_provider_version* (page 280) status variable, and use the second decimal position. For instance,

```
SHOW STATUS LIKE 'wsrep_provider_version';

+-------------------------+----------------------+
| Variable_name           | Value                |
+-------------------------+----------------------+
| wsrep_provider_version  | 25.3.5-wheezy(rXXXX) |
+-------------------------+----------------------+
```

This install uses Galera Cluster, version 3.5, which does not feature synchronization functions.

Part IX

Reference

CHAPTER

THIRTYNINE

MYSQL WSREP OPTIONS

These are MySQL system variables introduced by wsrep API patch v0.8. All variables are global except where marked by an **S**, for session variables.

Option	Default	Support	Dynamic
wsrep_auto_increment_control (page 216)	`ON`	1+	
wsrep_causal_reads (page 216) [S]	`OFF`	1 - 3.6	
wsrep_certify_nonPK (page 217)	`ON`	1+	
wsrep_cluster_address (page 217)		1+	
wsrep_cluster_name (page 218)	`example_cluster`	1+	
wsrep_convert_LOCK_to_trx (page 218)	`OFF`	1+	
wsrep_data_home_dir (page 219)	`/path/to/data_home`	1+	
wsrep_dbug_option (page 219)		1+	
wsrep_debug (page 220)	`OFF`	1+	
wsrep_desync (page 220)	`OFF`	1+	
wsrep_dirty_reads (page 221)	`OFF`		Yes
wsrep_drupal_282555_workaround (page 222)	`ON`	1+	
wsrep_forced_binlog_format (page 222)	`NONE`	1+	
wsrep_load_data_splitting (page 223)	`ON`	1+	
wsrep_log_conflicts (page 223)	`OFF`	1+	
wsrep_max_ws_rows (page 224)	`128K`	1+	
wsrep_max_ws_size (page 224)	`1G`	1+	
wsrep_node_address (page 225)	*host address:default port*	1+	
wsrep_node_incoming_address (page 226)	*host address:mysqld port*	1+	
wsrep_node_name (page 226)	`<hostname>`	1+	
wsrep_notify_cmd (page 226)		1+	
wsrep_on (page 228) [S]	`ON`	1+	
wsrep_OSU_method (page 228) [S]	`TOI`	3+	
wsrep_preordered (page 229)	`OFF`	1+	
wsrep_provider (page 229)	`NONE`	1+	
wsrep_provider_options (page 230)		1+	
wsrep_reject_queries (page 230)	`NONE`		Yes
wsrep_restart_slave (page 231)	`OFF`	1+	Yes
wsrep_retry_autocommit (page 232)	`1`	1+	
wsrep_slave_FK_checks (page 232)	`ON`	1+	Yes
wsrep_slave_threads (page 232)	`1`	1+	
wsrep_slave_UK_checks (page 233)	`OFF`	1+	Yes
wsrep_sst_auth (page 234)		1+	
wsrep_sst_donor (page 234)		1+	
wsrep_sst_donor_rejects_queries (page 235)	`OFF`	1+	

Continued on next page

Table 39.1 – continued from previous page

Option	Default	Support	Dynamic
wsrep_sst_method (page 235)	mysqldump	1+	
wsrep_sst_receive_address (page 237)	*node IP address*	1+	
wsrep_start_position (page 237)	*see reference entry*	1+	
wsrep_sync_wait (page 238)	0	3.6+	Yes
wsrep_trx_fragment_size (page 239)	0	4+	Yes
wsrep_trx_fragment_unit (page 239)	bytes	4+	Yes
wsrep_ws_persistency (page 240)		1	

wsrep_auto_increment_control

Enables the automatic adjustment of auto increment system variables with changes in cluster membership.

Command-line Format	--wsrep-auto-increment-control	
System Variable	*Name:*	wsrep_auto_increment_control
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	Boolean
	Default Value:	ON
Support	*Introduced:*	1

The node manages auto-increment values in your table using two variables: `auto_increment_increment` and `auto_increment_offset`. The first relates to the value auto-increment rows count from and the second to the offset it should use in moving to the next position.

The *wsrep_auto_increment_control* (page 216) parameter enables additional calculations to this process, using the number of nodes connected to the *Primary Component* to adjust the increment and offset. This is done to reduce the likelihood that two nodes will attempt to write the same auto-increment value to a table.

It significantly reduces the rate of certification conflicts for `INSERT` commands.

```
SHOW VARIABLES LIKE 'wsrep_auto_increment_control';

 +------------------------------+-------+
 | Variable_name                | Value |
 +------------------------------+-------+
 | wsrep_auto_increment_control | ON    |
 +------------------------------+-------+
```

wsrep_causal_reads

Enables the enforcement of strict cluster-wide `READ COMMITTED` semantics on non-transactional reads. Results in larger read latencies.

Command-line Format	--wsrep-causal-reads	
System Variable	*Name:*	wsrep_causal_reads
	Variable Scope:	Session
	Dynamic Variable:	
Permitted Values	*Type:*	Boolean
	Default Value:	OFF
Support	*Introduced:*	1
	Deprecated:	3.6

```
SHOW VARIABLES LIKE 'wsrep_causal_reads';
```

Note: **Warning**: This feature has been **deprecated**. It has been replaced by *wsrep_sync_wait* (page 238).

wsrep_certify_nonPK

Defines whether the node should generate primary keys on rows without them for the purposes of certification.

Command-line Format	`--wsrep-certify-nonpk`	
System Variable	*Name:*	`wsrep_certify_nonpk`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	Boolean
	Default Value:	`ON`
Support	*Introduced:*	1

Galera Cluster requires primary keys on all tables. The node uses the primary key in replication to allow for the parallel applying of transactions to the table. This parameter tells the node that when it encounters a row without a primary key, that it should create one for replication purposes. However, as a rule do not use tables without primary keys.

```
SHOW VARIABLES LIKE 'wsrep_certify_nonpk';

+---------------------+-------+
| Variable_name       | Value |
+---------------------+-------+
| wsrep_certify_nonpk | ON    |
+---------------------+-------+
```

wsrep_cluster_address

Defines the back-end schema, IP addresses, ports and options the node uses in connecting to the cluster.

Command-line Format	`--wsrep-cluster-address`	
System Variable	*Name:*	`wsrep_cluster_address`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	String
	Default Value:	
Support	*Introduced:*	1

Galera Cluster uses this parameter to determine the IP addresses for the other nodes in the cluster, the back-end schema you want it to use and additional options it should use in connecting to and communicating with those nodes. Currently, the only back-end schema supported for production is `gcomm`.

The syntax for node addresses uses the following pattern:

```
<backend schema>://<cluster address>[?option1=value1[&option2=value2]]
```

For example:

```
wsrep_cluster_address="gcomm://192.168.0.1:4567?gmcast.listen_addr=0.0.0.0:5678"
```

Changing this variable in runtime will cause the node to close connection to the current cluster (if any), and reconnect to the new address. (However, doing this at runtime may not be possible for all SST methods.) As of Galera Cluster 23.2.2, it is possible to provide a comma separated list of other nodes in the cluster as follows:

```
gcomm://node1:port1,node2:port2,...[?option1=value1&...]
```

Using the string `gcomm://` without any address will cause the node to startup alone, thus initializing a new cluster (that the other nodes can join to). Using `--wsrep-new-cluster` is the newer, preferred way.

Note: **Warning**: Never use an empty `gcomm://` string in the `my.cnf` configuration file. If a node restarts, that will cause the node to not join back to the cluster that it was part of, rather it will initialize a new one node cluster and cause a split brain. To bootstrap a cluster, you should only pass the `--wsrep-new-cluster` string, (instead of using `--wsrep-cluster-address="gcomm://"`) on the command line. For more information, see *Starting the Cluster* (page 33).

```
SHOW VARIABLES LIKE 'wsrep_cluster_address';

+-----------------------+---------------------------------------------+
| Variable_name         | Value                                       |
+-----------------------+---------------------------------------------+
| wsrep_cluster_address | gcomm://192.168.1.1,192.168.1.2,192.168.1.3 |
+-----------------------+---------------------------------------------+
```

wsrep_cluster_name

Defines the logical cluster name for the node.

Command-line Format	`--wsrep-cluster-name`	
System Variable	*Name:*	`wsrep_cluster_name`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	String
	Default Value:	`exmaple_cluster`
Support	*Introduced:*	1

This parameter allows you to define the logical name the node uses for the cluster. When a node attempts to connect to a cluster, it checks the value of this parameter against that of the cluster. The connection is only made if the names match. If they do not, the connection fails. So, the cluster name must be the same on all nodes.

```
SHOW VARIABLES LIKE 'wsrep_cluster_name';

+--------------------+-----------------+
| Variable_name      | Value           |
+--------------------+-----------------+
| wsrep_cluster_name | example_cluster |
+--------------------+-----------------+
```

wsrep_convert_lock_to_trx

Defines whether the node converts `LOCK/UNLOCK TABLES` statements into `BEGIN/COMMIT` statements.

Command-line Format	`--wsrep-convert-lock-to-trx`	
System Variable	*Name:*	`wsrep_convert_lock_to_trx`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	Boolean
	Default Value:	`OFF`
Support	*Introduced:*	1

This parameter determines how the node handles `LOCK/UNLOCK TABLES` statements, specifically whether or not you want it to convert these statements into `BEGIN/COMMIT` statements. In other words, it tells the node to implicitly convert locking sessions into transactions within the database server. By itself, this is not the same as support for locking sections, but it does prevent the database from ending up in a logically inconsistent state.

Sometimes this parameter may help to get old applications working in a multi-master setup.

Note: Loading a large database dump with `LOCK` statements can result in abnormally large transactions and cause an out-of-memory condition.

```
SHOW VARIABLES LIKE 'wsrep_convert_lock_to_trx';

+---------------------------+-------+
| Variable_name             | Value |
+---------------------------+-------+
| wsrep_convert_lock_to_trx | OFF   |
+---------------------------+-------+
```

`wsrep_data_home_dir`

Defines the directory the wsrep Provider uses for its files.

System Variable	*Name:*	`wsrep_data_home_dir`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	Directory
	Default Value:	/path/to/mysql_datahome
Support	*Introduced:*	1

During operation, the wsrep Provider needs to save various files to disk that record its internal state. This parameter defines the path to the directory that you want it to use. It defaults the MySQL `datadir` path.

```
SHOW VARIABLES LIKE 'wsrep_data_home_dir';

+---------------------+----------------+
| Variable_name       | Value          |
+---------------------+----------------+
| wsrep_data_home_dir | /var/lib/mysql |
+---------------------+----------------+
```

`wsrep_dbug_option`

Defines debug options to pass to the wsrep Provider.

Command-line Format	--wsrep-dbug-option	
System Variable	*Name:*	wsrep_dbug_option
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	String
	Default Value:	
Support	*Introduced:*	1

```
SHOW VARIABLES LIKE 'wsrep_dbug_option';

+-------------------+-------+
| Variable_name     | Value |
+-------------------+-------+
| wsrep_dbug_option |       |
+-------------------+-------+
```

wsrep_debug

Enables additional debugging output for the database server error log.

Command-line Format	--wsrep-debug	
System Variable	*Name:*	wsrep_debug
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	Boolean
	Default Value:	OFF
Support	*Introduced:*	1

Under normal operation, error events are logged to an error log file for the database server. By default, the name of this file is the server hostname with the `.err` extension. You can define a custom path using the log_error parameter. When you enable *wsrep_debug* (page 220), the database server logs additional events surrounding these errors to help you in identifying and correcting problems.

Note: **Warning**: In addition to useful debugging information, this parameter also causes the database server to print authentication information, (that is, passwords), to the error logs. Do not enable it in production environments.

```
SHOW VARIABLES LIKE 'wsrep_debug';

+---------------+-------+
| Variable_name | Value |
+---------------+-------+
| wsrep_debug   | OFF   |
+---------------+-------+
```

wsrep_desync

Defines whether or not the node participates in Flow Control.

System Variable	*Name:*	`wsrep_desync`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	Boolean
	Default Value:	`OFF`
Support	*Introduced:*	1

When a node receives more write-sets than it can apply, the transactions are placed in a received queue. In the event that the node falls too far behind, it engages Flow Control. The node takes itself out of sync with the cluster and works through the received queue until it reaches a more manageable size.

Note: **See Also**: For more information on what Flow Control is and how to configure and manage it in your cluster, see *Flow Control* (page 57) and *Managing Flow Control* (page 91).

When set to `ON`, this parameter disables Flow Control for the node. The node continues to receive write-sets and fall further behind the cluster. The cluster does not wait for desynced nodes to catch up, even if it reaches the `fc_limit` value.

```
SHOW VARIABLES LIKE 'wsrep_desync';

+---------------+-------+
| Variable_name | Value |
+---------------+-------+
| wsrep_desync  | OFF   |
+---------------+-------+
```

wsrep_dirty_reads

Defines whether the node accepts read queries when in a non-operational state.

Command-line Format	`--wsrep-dirty-reads`	
System Variable	*Name:*	`wsrep_dirty_reads`
	Variable Scope:	Global, Session
	Dynamic Variable:	Yes
Permitted Values	*Type:*	Boolean
	Default Value:	`OFF`
Support	*Introduced:*	

When a node loses its connection to the *Primary Component*, it enters a non-operational state. Given that it cannot keep its data current while in this state, it rejects all queries with an `ERROR: Unknown command` message. This parameter determines whether or not the node permits reads while in a non-operational state.

Note: Remember that by its nature, data reads from nodes in a non-operational state are stale. Current data in the Primary Component remains inaccessible to these nodes until they rejoin the cluster.

When enabling this parameter the node only permits reads, it still rejects any command that modifies or updates the database. When in this state, the node allows `USE`, `SELECT`, `LOCK TABLE` and `UNLOCK TABLES`. It does not allow DDL statements. It also rejects DML statements, such as `INSERT`, `DELETE` and `UPDATE`.

You must set the *wsrep_sync_wait* (page 238) parameter to `0` when using this parameter, else it raises a deadlock error.

```
SHOW VARIABLES LIKE 'wsrep_dirty_reads';
```

```
+-------------------+-------+
| Variable_name     | Value |
+-------------------+-------+
| wsrep_dirty_reads | ON    |
+-------------------+-------+
```

Note: This is a MySQL wsrep parameter. It was introduced in version 5.6.29.

wsrep_drupal_282555_workaround

Enables workaround for a bug in MySQL InnoDB that affect Drupal installations.

Command-line Format	`--wsrep-drupal-282555-workaround`	
System Variable	*Name:*	`wsrep_drupal_282555_workaround`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	Boolean
	Default Value:	`ON`
Support	*Introduced:*	1

Drupal installations using MySQL are subject to a bug in InnoDB, tracked as MySQL Bug 41984 and Drupal Issue 282555. Specifically, it is where inserting a *DEFAULT* value into an *AUTO_INCREMENT* column may return duplicate key errors.

This parameter enables a workaround for the bug on Galera Cluster.

```
SHOW VARIABLES LIKE 'wsrep_drupal_28255_workaround';

+-------------------------------+-------+
| Variable_name                 | Value |
+-------------------------------+-------+
| wsrep_drupal_28255_workaround | ON    |
+-------------------------------+-------+
```

wsrep_forced_binlog_format

Defines the binary log format for all transactions.

Command-line Format	`--wsrep-forced-binlog-format`	
System Variable	*Name:*	`wsrep_forced_binlog_format`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	enumeration
	Default Value:	`NONE`
	Valid Values:	`ROW`
		`STATEMENT`
		`MIXED`
		`NONE`
Support	*Introduced:*	1

When set to a value other than `NONE`, this parameter forces all transactions to use a given binary log format. The node uses the format given by this parameter regardless of the client session variable binlog_format. Valid choices for this parameter are: ROW, STATEMENT, and MIXED. Additionally, there is the special value NONE, which means that there is no forced format in effect for the binary logs.

This variable was introduced to support STATEMENT format replication during *Rolling Schema Upgrade*. In most cases, however, ROW format replication is valid for asymmetric schema replication.

```
SHOW VARIABLES LIKE 'wsrep_forced_binlog_format';

+----------------------------+-------+
| Variable_name              | Value |
+----------------------------+-------+
| wsrep_forced_binlog_format | NONE  |
+----------------------------+-------+
```

wsrep_load_data_splitting

Defines whether the node splits large LOAD DATA commands into more manageable units.

Command-line Format	--wsrep-load-data-splitting	
System Variable	*Name:*	wsrep_load_data_splitting
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	Boolean
	Default Value:	ON
Support	*Introduced:*	1

When loading huge data loads creates problems for Galera Cluster, in that they eventually reach a size that is too large for the node to completely roll the operation back in the event of a conflict and whatever gets committed stays committed.

This parameter tells the node to split LOAD DATA commands into transactions of 10,000 rows or less, making the data more manageable for the cluster. This deviates from the standard behavior for MySQL.

In Galera 4.x, this variable has no effect for statements where *Streaming Replication* is in effect.

```
SHOW VARIABLES LIKE 'wsrep_load_data_splitting';

+---------------------------+-------+
| Variable_name             | Value |
+---------------------------+-------+
| wsrep_load_data_splitting | ON    |
+---------------------------+-------+
```

wsrep_log_conflicts

Defines whether the node logs additional information about conflicts.

Command-line Format	--wsrep-log-conflicts	
System Variable	*Name:*	wsrep_log_conflicts
	Variable Scope:	Global
	Dynamic Variable:	No
Permitted Values	*Type:*	Boolean
	Default Value:	OFF
Support	*Introduced:*	1

In Galera Cluster, the database server uses the standard logging features of MySQL, MariaDB or Percona XtraDB. This parameter enables additional information for the logs pertaining to conflicts, which you may find useful in troubleshooting problems.

Note: **See Also**: You can also log conflict information with the wsrep Provider option *cert.log_conflicts* (page 246).

The additional information includes the table and schema where the conflict occurred, as well as the actual values for the keys that produced the conflict.

```
SHOW VARIABLES LIKE 'wsrep_log_conflicts';

+---------------------+-------+
| Variable_name       | Value |
+---------------------+-------+
| wsrep_log_conflicts | OFF   |
+---------------------+-------+
```

wsrep_max_ws_rows

Defines the maximum number of rows the node allows in a write-set.

Command-line Format	`--wsrep-max-ws-rows`	
System Variable	*Name:*	`wsrep_max_ws_rows`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	string
	Default Value:	`128k`
Support	*Introduced:*	1

This parameter sets the maximum number of rows that the node allows in a write-set. Currently, this value limits the supported size of transactions and of `LOAD DATA` statements.

```
SHOW VARIABLES LIKE 'wsrep_max_ws_rows';

+-------------------+-------+
| Variable_name     | Value |
+-------------------+-------+
| wsrep_max_ws_rows | 128k  |
+-------------------+-------+
```

wsrep_max_ws_size

Defines the maximum size the node allows for write-sets.

Command-line Format	`--wsrep-max-ws-size`	
System Variable	*Name:*	`wsrep_max_ws_size`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	string
	Default Value:	`1G`
Support	*Introduced:*	1

This parameter sets the maximum size that the node allows for a write-set. Currently, this value limits the supported size of transactions and of `LOAD DATA` statements.

The maximum allowed write-set size is 2G.

```
SHOW VARIABLES LIKE 'wsrep_max_ws_size';

+-------------------+-------+
| Variable_name     | Value |
+-------------------+-------+
| wsrep_max_ws_size | 1G    |
+-------------------+-------+
```

wsrep_node_address

Defines the IP address and port of the node.

Command-line Format	--wsrep-node-address	
System Variable	*Name:*	wsrep_node_address
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	string
	Default Value:	server IP address, port 4567
Support	*Introduced:*	1

The node passes its IP address and port number to the *Galera Replication Plugin*, where it gets used as the base address in cluster communications. By default, the node pulls the address of the first network interface on your system and the default port for Galera Cluster. Typically, this is the address of eth0 or enp2s0 on port 4567.

While the default behavior is often sufficient, there are situations where this auto-guessing function produces unreliable results. For instance,

- Servers with multiple network interfaces.
- Servers that run multiple nodes.
- Network Address Translation (NAT).
- Clusters with nodes in more than one region.
- Container deployments, such as with Docker and jails.
- Cloud deployments, such as with Amazon EC2 and OpenStack.

In these cases, you need to provide an explicit value for this parameter, given that the auto-guess of the IP address does not produce the correct result.

Note: See Also: In addition to defining the node address and port, this parameter also provides the default values for the *wsrep_sst_receive_address* (page 237) parameter and the *ist.recv_addr* (page 257) option.

In some cases, you may need to provide a different value. For example, Galera Cluster running on Amazon EC2 requires that you use the global DNS name instead of the local IP address.

```
SHOW VARIABLES LIKE 'wsrep_node_address';

+--------------------+-------------+
| Variable_name      | Value       |
+--------------------+-------------+
| wsrep_node_address | 192.168.1.1 |
+--------------------+-------------+
```

wsrep_node_incoming_address

Defines the IP address and port from which the node expects client connections.

Command-line Format	`--wsrep-node-incoming-address`	
System Variable	*Name:*	`wsrep_node_incoming_address`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	String
	Default Value:	
Support	*Introduced:*	1

This parameter defines the IP address and port number at which the node expects to receive client connections. It is intended for integration with load balancers and, for now, otherwise unused by the node.

```
SHOW VARIABLES LIKE 'wsrep_node_incoming_address';

+-----------------------------+------------------+
| Variable_name               | Value            |
+-----------------------------+------------------+
| wsrep_node_incoming_address | 192.168.1.1:3306 |
+-----------------------------+------------------+
```

wsrep_node_name

Defines the logical name that the node uses for itself.

Command-line Format	`--wsrep-node-name`	
System Variable	*Name:*	`wsrep_node_name`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	string
	Default Value:	server hostname
Support	*Introduced:*	1

This parameter defines the logical name that the node uses when referring to itself in logs and to the cluster. It is for convenience, to help you in identifying nodes in the cluster by means other than the node address.

By default, the node uses the server hostname. In some situations, you may need to set it explicitly, such as in container deployments with Docker or FreeBSD jails, where the node uses the name of the container rather than the hostname.

```
SHOW VARIABLES LIKE 'wsrep_node_name';

+-----------------+-------------+
| Variable_name   | Value       |
+-----------------+-------------+
| wsrep_node_name | GaleraNode1 |
+-----------------+-------------+
```

wsrep_notify_cmd

Defines the command the node runs whenever cluster membership or the state of the node changes.

Command-line Format	`--wsrep-notify-cmd`	
System Variable	*Name:*	`wsrep_notify_cmd`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	string
	Default Value:	
Support	*Introduced:*	1

Whenever the node registers changes in cluster membership or its own state, this parameter allows you to send information about that change to an external script defined by the value. You can use this to reconfigure load balancers, raise alerts and so on, in response to node and cluster activity.

Note: **See Also**: For an example script that updates two tables on the local node, with changes taking place at the cluster level, see the *Notification Command* (page 157).

When the node calls the command, it passes one or more arguments that you can use in configuring your custom notification script and how it responds to the change. The options are:

--status <status str> The status of this node. The possible statuses are:

- `Undefined` The node has just started up and is not connected to any *Primary Component*.
- `Joiner` The node is connected to a primary component and now is receiving state snapshot.
- `Donor` The node is connected to primary component and now is sending state snapshot.
- `Joined` The node has a complete state and now is catching up with the cluster.
- `Synced` The node has synchronized itself with the cluster.
- `Error(<error code if available>)` The node is in an error state.

--uuid <state UUID> The cluster state UUID.

--primary <yes/no> Whether the current cluster component is primary or not.

--members <list> A comma-separated list of the component member UUIDs. The members are presented in the following syntax:

- `<node UUID>` A unique node ID. The wsrep Provider automatically assigns this ID for each node.
- `<node name>` The node name as it is set in the `wsrep_node_name` option.
- `<incoming address>` The address for client connections as it is set in the `wsrep_node_incoming_address` option.

--index The index of this node in the node list.

```
SHOW VARIABLES LIKE 'wsrep_notify_cmd';

+------------------+-------------------------+
| Variable_name    | Value                   |
+------------------+-------------------------+
```

```
| wsrep_notify_cmd | /usr/bin/wsrep_notify.sh |
+------------------+-------------------------+
```

wsrep_on

Defines whether replication takes place for updates from the current session.

System Variable	*Name:*	`wsrep_on`
	Variable Scope:	Session
	Dynamic Variable:	
Permitted Values	*Type:*	Boolean
	Default Value:	`ON`
Support	*Introduced:*	1

This parameter defines whether or not updates made in the current session replicate to the cluster. It does not cause the node to leave the cluster and the node continues to communicate with other nodes. Additionally, it is a session variable. Defining it through the `SET GLOBAL` syntax also affects future sessions.

```
SHOW VARIABLES LIKE 'wsrep_on';

+---------------+-------+
| Variable_name | Value |
+---------------+-------+
| wsrep_on      | ON    |
+---------------+-------+
```

wsrep_OSU_method

Defines the Online Schema Upgrade method the node uses to replicate DDL statements.

Command-line Format	`--wsrep-OSU-method`	
System Variable	*Name:*	`wsrep_OSU_method`
	Variable Scope:	Global, Session
	Dynamic Variable:	Yes
Permitted Values	*Type:*	enumeration
	Default Value:	`TOI`
	Valid Values:	`TOI`
		`ROI`
		`NBO`
Support	*Introduced:*	Patch v. 3 (5.5.17-22.3)

DDL statements are non-transactional and as such do not replicate through write-sets. There are three methods available that determine how the node handles replicating these statements:

- `TOI` In the *Total Order Isolation* method, the cluster runs the DDL statement on all nodes in the same total order sequence, blocking other transactions from committing while the DDL is in progress.
- `RSU` In the *Rolling Schema Upgrade* method, the node runs the DDL statements locally, thus blocking only the one node where the statement was made. While processing the DDL statement, the node is not replicating and may be unable to process replication events due to a table lock. Once the DDL operation is complete, the node catches up and syncs with the cluster to become fully operational again. The DDL statement or its effects are not replicated; the user is responsible for manually executing this statement on each node in the cluster.
- `NBO` In the *Non-Blocking Operation* method, metadata locks on the table are acquired on all nodes before executing an `ALTER` statement. The statement is then executed using a separate applier thread on each node.

This allows transactions against other tables to continue to be processed while the DDL statement is in progress, while preserving data consistency.

Note: **See Also**: For more information on DDL statements and OSU methods, see *Schema Upgrades* (page 99).

```
SHOW VARIABLES LIKE 'wsrep_OSU_method';

+------------------+-------+
| Variable_name    | Value |
+------------------+-------+
| wsrep_OSU_method | TOI   |
+------------------+-------+
```

wsrep_preordered

Defines whether the node uses transparent handling of preordered replication events.

Command-line Format	`--wsrep-preordered`	
System Variable	*Name:*	`wsrep_preordered`
	Variable Scope:	Global
	Dynamic Variable:	Yes
Permitted Values	*Type:*	Boolean
	Default Value:	`OFF`
Support	*Introduced:*	1

This parameter enables transparent handling of preordered replication events, such as replication events arriving from traditional asynchronous replication. When this option is `ON`, such events will be applied locally first before being replicated to the other nodes of the cluster. This could increase the rate at which they can be processed which would be otherwise limited by the latency between the nodes in the cluster.

Preordered events should not interfere with events that originate on the local node. Therefore, you should not run local update queries on a table that is also being updated through asynchronous replication.

```
SHOW VARIABLES LIKE 'wsrep_preordered';

+------------------+-------+
| Variable_name    | Value |
+------------------+-------+
| wsrep_preordered | OFF   |
+------------------+-------+
```

wsrep_provider

Defines the path to the *Galera Replication Plugin*.

Command-line Format	`--wsrep-provider`	
System Variable	*Name:*	`wsrep_provider`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	File
	Default Value:	
Support	*Introduced:*	1

When the node starts, it needs to load the wsrep Provider in order to enable replication functions. The path defined in this parameter tells it what file it needs to load and where to find it. In the event that you do not define this path or you give it an invalid value, the node bypasses all calls to the wsrep Provider and behaves as a standard standalone instance of MySQL.

```
SHOW VARIABLES LIKE 'wsrep_provider';

+----------------+----------------------------------+
| Variable_name  | Value                            |
+----------------+----------------------------------+
| wsrep_provider | /usr/lib/galera/libgalera_smm.so |
+----------------+----------------------------------+
```

wsrep_provider_options

Defines optional settings the node passes to the wsrep Provider.

Command-line Format	--wsrep-provider-options	
System Variable	*Name:*	wsrep_provider_options
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	String
	Default Value:	
Support	*Introduced:*	1

When the node loads the wsrep Provider, there are several configuration options available that affect how it handles certain events. These allow you to fine tune how it handles various situations.

For example, you can use *gcache.size* (page 253) to define how large a write-set cache the node keeps or manage group communications timeouts.

Note: See Also: For more information on the wsrep Provider options, see *Galera Parameters* (page 243).

```
SHOW VARIABLES LIKE 'wsrep_provider_options';

+------------------------+-----------------------------------------------+
| Variable_name          | Value                                         |
+------------------------+-----------------------------------------------+
| wsrep_provider_options | ... evs.user_send_window=2,gcache.size=128Mb  |
|                        | evs.auto_evict=0,debug=OFF, evs.version=0 ... |
+------------------------+-----------------------------------------------+
```

wsrep_reject_queries:

Defines whether the node rejects client queries while participating in the cluster.

System Variable	*Name:*	`wsrep_reject_queries`
	Variable Scope:	Global
	Dynamic Variable:	Yes
Permitted Values	*Type:*	array
	Default Value:	`NONE`
	Valid Values:	`NONE`
		`ALL`
		`ALL_KILL`
Support	*Introduced:*	

When in use, this parameter causes the node to reject queries from client connections. The node continues to participate in the cluster and apply write-sets, but client queries generate `Unknown command` errors. For instance,

```
SELECT * FROM my_table;

Error 1047: Unknown command
```

You may find this parameter useful in certain maintenance situations. In enabling it, you can also decide whether or not the node maintains or kills any current client connections.

- `NONE` The node disables this feature.
- `ALL` The node enables this feature. It rejects all queries, but maintains any existing client connections.
- `ALL_KILL` The node enables this feature. It rejects all queries and kills existing client connections without waiting, including the current connection.

```
SHOW VARIABLES LIKE 'wsrep_reject_queries';

+----------------------+-------+
| Variable_name        | Value |
+----------------------+-------+
| wsrep_reject_queries | NONE  |
+----------------------+-------+
```

Note: This is a MySQL wsrep parameter. It was introduced in version 5.6.29.

`wsrep_restart_slave`

Defines whether the replication slave restarts when the node joins the cluster.

Command-line Format	`--wsrep-restart-slave`	
System Variable	*Name:*	`wsrep_restart_slave`
	Variable Scope:	Global
	Dynamic Variable:	Yes
Permitted Values	*Type:*	boolean
	Default Value:	`OFF`
Support	*Introduced:*	

Enabling this parameter tells the node to restart the replication slave when it joins the cluster.

```
SHOW VARIABLES LIKE 'wsrep_restart_slave';

+---------------------+-------+
| Variable_name       | Value |
+---------------------+-------+
```

```
| wsrep_restart_slave | OFF    |
+---------------------+--------+
```

wsrep_retry_autocommit

Defines the number of retries the node attempts when an autocommit query fails.

Command-line Format	--wsrep-retry-autocommit	
System Variable	*Name:*	wsrep_retry_autocommit
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	integer
	Default Value:	1
Support	*Introduced:*	1

When an autocommit query fails the certification test due to a cluster-wide conflict, the node can retry it without returning an error to the client. This parameter defines how many times the node retries the query. It is analogous to rescheduling an autocommit query should it go into deadlock with other transactions in the database lock manager.

```
SHOW VARIABLES LIKE 'wsrep_retry_autocommit';

+------------------------+-------+
| Variable_name          | Value |
+------------------------+-------+
| wsrep_retry_autocommit | 1     |
+------------------------+-------+
```

wsrep_slave_FK_checks

Defines whether the node performs foreign key checking for applier threads.

Command-line Format	--wsrep-slave-FK-checks	
System Variable	*Name:*	wsrep_slave_FK_checks
	Variable Scope:	Global
	Dynamic Variable:	Yes
Permitted Values	*Type:*	boolean
	Default Value:	ON
Support	*Introduced:*	

This parameter enables foreign key checking on applier threads.

```
SHOW VARIABLES LIKE 'wsrep_slave_FK_checks';

+-----------------------+-------+
| Variable_name         | Value |
+-----------------------+-------+
| wsrep_slave_FK_checks | ON    |
+-----------------------+-------+
```

wsrep_slave_threads

Defines the number of threads to use in applying slave write-sets.

Command-line Format	`--wsrep-slave-threads`	
System Variable	*Name:*	`wsrep_slave_threads`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	integer
	Default Value:	`1`
Support	*Introduced:*	1

This parameter allows you to define how many threads the node uses when applying slave write-sets. Performance on the underlying system and hardware, the size of the database, the number of client connections, and the load your application puts on the server all factor in the need for threading, but not in a way that makes the scale of that need easy to predict. Because of this, there is no strict formula to determine how many slave threads your node actually needs.

Instead of concrete recommendations, there are some general guidelines that you can use as a starting point in finding the value that works best for your system:

- It is rarely beneficial to use a value that is less than twice the number of CPU cores on your system.
- Similarly, it is rarely beneficial to use a value that is more than one quarter the total number of client connections to the node. While it is difficult to predict the number of client connections, being off by as much as 50% over or under is unlikely to make a difference.
- From the perspective of resource utilization, it's recommended that you keep to the lower end of slave threads.

```
SHOW VARIABLES LIKE 'wsrep_slave_threads';

+---------------------+-------+
| Variable_name       | Value |
+---------------------+-------+
| wsrep_slave_threads | 1     |
+---------------------+-------+
```

wsrep_slave_UK_checks

Defines whether the node performs unique key checking on applier threads.

Command-line Format	`--wsrep-slave-UK-checks`	
System Variable	*Name:*	`wsrep_slave_UK_checks`
	Variable Scope:	Global
	Dynamic Variable:	Yes
Permitted Values	*Type:*	boolean
	Default Value:	`OFF`
Support	*Introduced:*	

This parameter enables unique key checking on applier threads.

```
SHOW VARIABLES LIKE 'wsrep_slave_UK_checks';

+-----------------------+-------+
| Variable_name         | Value |
+-----------------------+-------+
| wsrep_slave_UK_checks | OFF   |
+-----------------------+-------+
```

wsrep_sst_auth

Defines the authentication information to use in *State Snapshot Transfer*.

Command-line Format	`--wsrep-sst-auth`	
System Variable	*Name:*	`wsrep_sst_auth`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	string
	Default Value:	
	Valid Values:	username:password
Support	*Introduced:*	1

When the node attempts a state snapshot transfer using the *Logical State Transfer Method*, the transfer script uses a client connection to the database server in order to obtain the data it needs to send. This parameter provides the authentication information, (that is, the username and password), that the script uses to access the database servers of both sending and receiving nodes.

Note: Galera Cluster only uses this parameter for State Snapshot Transfers that use the Logical transfer method. Currently, the only method to use the Logical transfer method is `mysqldump`. For all other methods, the node doesn't need this parameter.

Format this value to the pattern: `username:password`.

```
SHOW VARIABLES LIKE 'wsrep_sst_auth'

+----------------+--------------------------+
| Variable_name  | Value                    |
+----------------+--------------------------+
| wsrep_sst_auth | wsrep_sst_user:mypassword |
+----------------+--------------------------+
```

wsrep_sst_donor

Defines the name of the node that this node uses as a donor in state transfers.

Command-line Format	`--wsrep-sst-donor`	
System Variable	*Name:*	`wsrep_sst_donor`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	string
	Default Value:	
Support	*Introduced:*	1

When the node requires a state transfer from the cluster, it looks for the most appropriate one available. The group communications module monitors the node state for the purposes of Flow Control, state transfers and quorum calculations. The node can be a donor if it is in the `SYNCED` state. The first node in the `SYNCED` state in the index becomes the donor and is made unavailable for requests while serving as such.

If there are no free `SYNCED` nodes at the moment, the joining node reports in the logs:

```
Requesting state transfer failed: -11(Resource temporarily unavailable).
 Will keep retrying every 1 second(s)
```

It continues retrying the state transfer request until it succeeds. When the state transfer request does succeed, the node makes the following entry in the logs:

```
Node 0 (XXX) requested state transfer from '*any*'. Selected 1 (XXX) as donor.
```

Using this parameter, you can tell the node which cluster node it should use instead for state transfers. The name given to the receiving node with this parameter must match the name given for *wsrep_node_name* (page 226) on the donor node.

```
SHOW VARIABLES LIKE 'wsrep_sst_donor';

+-----------------+---------------+
| Variable_name   | Value         |
+-----------------+---------------+
| wsrep_sst_donor | my_donor_node |
+-----------------+---------------+
```

wsrep_sst_donor_rejects_queries

Defines whether the node rejects blocking client sessions on a node when it is serving as a donor in a blocking state transfer method, such as `mysqldump` and `rsync`.

Command-line Format	`--wsrep-sst-donor-rejects-queries`	
System Variable	*Name:*	`wsrep_sst_donor_rejects_queries`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	Boolean
	Default Value:	`OFF`
Support	*Introduced:*	1

This parameter determines whether the node rejects blocking client sessions while it is sending state transfers using methods that block it as the donor. In these situations, all queries return the error `ER_UNKNOWN_COM_ERROR`, that is they respond with `Unknown command`, just like the joining node does.

Given that a *State Snapshot Transfer* is scriptable, there is no way to tell whether the requested method is blocking or not. You may also want to avoid querying the donor even with non-blocking state transfers. As a result, when this parameter is enabled the donor node rejects queries regardless the state transfer and even if the initial request concerned a blocking-only transfer, (meaning, it also rejects during `xtrabackup`).

Note: Warning: The `mysqldump` state transfer method does not work with this setting, given that `mysqldump` runs queries on the donor and there is no way to differentiate its session from the regular client session.

```
SHOW VARIABLES LIKE 'wsrep_sst_donor_rejects_queries';

+---------------------------------+-------+
| Variable_name                   | Value |
+---------------------------------+-------+
| wsrep_sst_donor_rejects_queries | OFF   |
+---------------------------------+-------+
```

wsrep_sst_method

Defines the method or script the node uses in a *State Snapshot Transfer*.

Command-line Format	`--wsrep-sst-method`	
System Variable	*Name:*	`wsrep_sst_method`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	string
	Default Value:	`mysqldump`
Support	*Introduced:*	1

When the node makes a state transfer request it calls on an external shell script to establish a connection a with the donor node and transfer the database state onto the local database server. This parameter allows you to define what script the node uses in requesting state transfers.

Galera Cluster ships with a number of default scripts that the node can use in state snapshot transfers. The supported methods are:

- `mysqldump` This is slow, except for small data-sets, but is the most tested option.
- `rsync` This option is much faster than `mysqldump` on large data-sets.

  Note: You can only use `rsync` when anode is starting. You cannot use it with a running InnoDB storage engine.

- `rsync_wan` This option is almost the same as `rsync`, but uses the `delta-xfer` algorithm to minimize network traffic.
- `xtrabackup` This option is a fast and practically non-blocking state transfer method based on the Percona `xtrabackup` tool. If you want to use it, the following settings must be present in the `my.cnf` configuration file on all nodes:

```
[mysqld]
wsrep_sst_auth=YOUR_SST_USER:YOUR_SST_PASSWORD
wsrep_sst_method=xtrabackup
datadri=/path/to/datadir

[client]
socket=/path/to/socket
```

In addition to the default scripts provided and supported by Galera Cluster, you can also define your own custom state transfer script. The naming convention that the node expects is for the value of this parameter to match `wsrep_%.sh`. For instance, giving the node a transfer method of `MyCustomSST` causes it to look for `wsrep_MyCustomSST.sh` in `/usr/bin`.

Bear in mind, the cluster uses the same script to send and receive state transfers. If you want to use a custom state transfer script, you need to place it on every node in the cluster.

Note: **See Also**: For more information on scripting state snapshot transfers, see *Scriptable State Snapshot Transfers* (page 111).

```
SHOW VARIABLES LIKE 'wsrep_sst_method';

+------------------+-----------+
| Variable_name    | Value     |
+------------------+-----------+
| wsrep_sst_method | mysqldump |
+------------------+-----------+
```

wsrep_sst_receive_address

Defines the address from which the node expects to receive state transfers.

Command-line Format	--wsrep-sst-receive-address	
System Variable	*Name:*	wsrep_sst_receive_address
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	string
	Default Value:	*wsrep_node_address* (page 225)
Support	*Introduced:*	1

This parameter defines the address from which the node expects to receive state transfers. It is dependent on the *State Snapshot Transfer* method the node uses.

For example, `mysqldump` uses the address and port on which the node listens, which by default is set to the value of *wsrep_node_address* (page 225).

Note: Check that your firewall allows connections to this address from other cluster nodes.

```
SHOW VARIABLES LIKE 'wsrep_sst_receive_address';

+---------------------------+-------------+
| Variable_name             | Value       |
+---------------------------+-------------+
| wsrep_sst_receive_address | 192.168.1.1 |
+---------------------------+-------------+
```

wsrep_start_position

Defines the node start position.

Command-line Format	--wsrep-start-position	
System Variable	*Name:*	wsrep_start_position
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	string
	Default Value:	00000000-0000-0000-0000-000000000000:-1
Support	*Introduced:*	1

This parameter defines the node start position. It exists for the sole purpose of notifying the joining node of the completion of a state transfer.

Note: **See Also**: For more information on scripting state snapshot transfers, see *Scriptable State Snapshot Transfers* (page 111).

```
SHOW VARIABLES LIKE 'wsrep_start_position';

+----------------------+-----------------------------------------+
| Variable_name        | Value                                   |
+----------------------+-----------------------------------------+
| wsrep_start_position | 00000000-0000-0000-0000-000000000000:-1 |
+----------------------+-----------------------------------------+
```

wsrep_sync_wait

Defines whether the node enforces strict cluster-wide causality checks.

Command-line Format	`--wsrep-sync-wait`	
System Variable	*Name:*	`wsrep_sync_wait`
	Variable Scope:	Session
	Dynamic Variable:	Yes
Permitted Values	*Type:*	bitmask
	Default Value:	`0`
Support	*Introduced:*	3.6

When you enable this parameter, the node triggers causality checks in response to certain types of queries. During the check, the node blocks new queries while the database server catches up with all updates made in the cluster to the point where the check was begun. Once it reaches this point, the node executes the original query.

Note: Causality checks of any type can result in increased latency.

This value of this parameter is a bitmask, which determines the type of check you want the node to run.

Bitmask	Checks
`0`	Disabled.
`1`	Checks on `READ` statements, including `SELECT`, `SHOW`, and `BEGIN` / `START TRANSACTION`.
`2`	Checks made on `UPDATE` and `DELETE` statements.
`3`	Checks made on `READ`, `UPDATE` and `DELETE` statements.
`4`	Checks made on `INSERT` and `REPLACE` statements.

For example, say that you have a web application. At one point in its run, you need it to perform a critical read. That is, you want the application to access the database server and run a `SELECT` query that must return the most up to date information possible.

```
SET SESSION wsrep_sync_wait=1;
SELECT * FROM example WHERE field = "value";
SET SESSION wsrep_sync_wait=0
```

In the example, the application first runs a `SET` command to enable *wsrep_sync_wait* (page 238) for `READ` statements, then it makes a `SELECT` query. Rather than running the query, the node initiates a causality check, blocking incoming queries while it catches up with the cluster. When the node finishes applying the new transaction, it executes the `SELECT` query and returns the results to the application. The application, having finished the critical read, disables *wsrep_sync_wait* (page 238), returning the node to normal operation.

Note: Setting *wsrep_sync_wait* (page 238) to `1` is the same as *wsrep_causal_reads* (page 216) to `ON`. This deprecates *wsrep_causal_reads* (page 216).

```
SHOW VARIABLES LIKE 'wsrep_sync_wait';

+-----------------+-------+
| Variable_name   | Value |
+-----------------+-------+
| wsrep_sync_wait | 0     |
+-----------------+-------+
```

wsrep_trx_fragment_size

Defines the number of replication units needed to generate a new fragment in Streaming Replication.

Command-line Format	`--wsrep-trx-fragment-size`	
System Variable	*Name:*	`wsrep_trx_fragment_size`
	Variable Scope:	Session
	Dynamic Variable:	Yes
Permitted Values	*Type:*	integer
	Default Value:	`0`
Support	*Introduced:*	4.0

In *Streaming Replication*, the node breaks transactions down into fragments, then replicates and certifies them while the transaction is in progress. Once certified, a fragment can no longer be aborted due to conflicting transactions. This parameter determines the number of replication units to include in a fragment. To define what these units represent, use *wsrep_trx_fragment_unit* (page 239). A value of `0` indicates that streaming replication will not be used.

```
SHOW VARIABLE LIKE 'wsrep_trx_fragment_size';

+-------------------------+-------+
| Variable_name           | Value |
+-------------------------+-------+
| wsrep_trx_fragment_size | 5     |
+-------------------------+-------+
```

wsrep_trx_fragment_unit

Defines the replication unit type to use in Streaming Replication.

Command-line Format	`--wsrep-trx-fragment-unit`	
System Variable	*Name:*	`wsrep_trx_fragment_unit`
	Variable Scope:	Session
	Dynamic Variable:	Yes
Permitted Values	*Type:*	string
	Default Value:	`bytes`
	Valid Values:	`bytes`
		`events`
		`rows`
		`statements`
Support	*Introduced:*	4.0

In *Streaming Replication*, the node breaks transactions down into fragments, then replicates and certifies them while the transaction is in progress. Once certified, a fragment can no longer be aborted due to conflicting transactions. This parameter determines the unit to use in determining the size of the fragment. To define the number of replication units to use in the fragment, use *wsrep_trx_fragment_size* (page 239).

Supported replication units are:

- **bytes**: Refers to the fragment size in bytes.
- **events**: Refers to the number of binary log events in the fragment.
- **rows**: Refers to the number of rows updated in the fragment.
- **statements**: Refers to the number of SQL statements in the fragment.

```
SHOW VARIABLE LIKE 'wsrep_trx_fragment_unit';

+-------------------------+--------+
| Variable_name           | Value  |
+-------------------------+--------+
| wsrep_trx_fragment_unit | bytes  |
+-------------------------+--------+
```

wsrep_ws_persistency

Defines whether the node stores write-sets locally for debugging.

Command-line Format	`--wsrep-ws-persistency`	
System Variable	*Name:*	`wsrep_ws_persistency`
	Variable Scope:	Global
	Dynamic Variable:	
Permitted Values	*Type:*	string
	Default Value:	
Support	*Introduced:*	
	Deprecated:	0.8

This parameter defines whether the node stores write-sets locally for debugging purposes.

```
SHOW VARIABLES LIKE 'wsrep_ws_persistency';

+----------------------+-------+
| Variable_name        | Value |
+----------------------+-------+
| wsrep_ws_persistency | ON    |
+----------------------+-------+
```

CHAPTER

FORTY

MYSQL WSREP FUNCTIONS

Function	Arguments	Support
WSREP_LAST_SEEN_GTID() (page 241)		4+
WSREP_LAST_WRITTEN_GTID() (page 241)		4+
WSREP_SYNC_WAIT_UPTO_GTID() (page 241)	`gtid [timeout]`	4+

WSREP_LAST_SEEN_GTID()

Returns the *Global Transaction ID* of the last write transaction observed by the client.

Function	`WSREP_LAST_SEEN_GTID()`
Arguments	None
Support	4+

This function returns the Global Transaction ID of the last write transaction observed by the client. You may find it useful in combination with *WSREP_SYNC_WAIT_UPTO_GTID()* (page 241), using this parameter to identify the transaction it should wait on before unblocking the client.

```
SELECT WSREP_LAST_SEEN_GTID();
```

WSREP_LAST_WRITTEN_GTID()

Returns the *Global Transaction ID* of the last write transaction made by the client.

Function	`WSREP_LAST_WRITTEN_GTID()`
Arguments	None
Support	4+

This function returns the Global Transaction ID of the last write transaction made by the client. You may find it useful in combination with *WSREP_SYNC_WAIT_UPTO_GTID()* (page 241), using this parameter to identify the transaction it should wait on before unblocking the client.

```
BEGIN;
UPDATE table_name SET id = 0 WHERE field = 'example';
COMMIT;
SELECT WSREP_LAST_WRITTEN_GTID();
```

WSREP_SYNC_WAIT_UPTO_GTID()

Blocks the client until the node applies and commits the given transaction.

<table>
<tr><td>Function</td><td colspan="2"><code>WSREP_LAST_WRITTEN_GTID()</code></td></tr>
<tr><td rowspan="2">Arguments</td><td>Required Arguments</td><td>Global Transaction ID</td></tr>
<tr><td>Optional Arguments</td><td>timeout</td></tr>
<tr><td>Support</td><td colspan="2">4+</td></tr>
</table>

This function blocks the client until the node applies and commits the given *Global Transaction ID*. If you don't provide a timeout, it defaults to the value of *repl.causal_read_timeout* (page 261).

The function uses the following return values:

- When the node applies and commits the given Global Transaction ID, it returns the value `1`.
- When the function times out before the node can apply the transaction, it returns an `ER_LOCAL_WAIT_TIMEOUT` error.
- When the function is given an incorrect Global Transaction ID, it returns an `ER_WRONG_ARGUMENTS` error.

```
$transaction_gtid = SELECT WSREP_LAST_SEEN_GTID();
...
SELECT WSREP_SYNC_WAIT_UPTO_GTID($transaction_gtid);
```

CHAPTER

FORTYONE

GALERA PARAMETERS

As of version 0.8, Galera Cluster accepts parameters as semicolon-separated key value pair lists, such as `key1 = value1; key2 = value2`. In this way, you can configure an arbitrary number of Galera Cluster parameters in one call. A key consists of parameter group and parameter name:

```
<group>.<name>
```

Where `<group>` roughly corresponds to some Galera module.

Table legend:

- **Numeric values** Galera Cluster understands the following numeric modifiers: `K`, `M`, `G`, `T` standing for 2^{10}, 2^{20}, 2^{30} and 2^{40} respectively.
- **Boolean values** Galera Cluster accepts the following boolean values: `0`, `1`, `YES`, `NO`, `TRUE`, `FALSE`, `ON`, `OFF`.
- Time periods must be expressed in the ISO8601 format. See also the examples below.
- **T** indicates parameters that are strictly for use in troubleshooting problems. You should not implement these in production environments.

Parameter	Default	Support	Dynamic
base_host (page 246)	detected network address	1+	
base_port (page 246)	`4567`	1+	
cert.log_conflicts (page 246)	`NO`	2+	Yes
debug (page 246)	`NO`	2+	Yes
evs.auto_evict (page 246)	`0`	3.8+	No
evs.causal_keepalive_period (page 247)		1+	No
evs.consensus_timeout (page 247) T	`PT30S`	1 - 2	No
evs.debug_log_mask (page 247)	`0x1`	1+	Yes
evs.delayed_keep_period (page 247)	`PT30S`	3.8+	No
evs.delayed_margin (page 248)	`PT1S`	3.8+	No
evs.evict (page 248)		3.8	No
evs.inactive_check_period (page 248)	`PT1S`	1+	No
evs.inactive_timeout (page 249)	`PT15S`	1+	No
Continued on next page			

Table 41.1 – continued from previous page

Parameter	Default	Support	Dynamic
evs.info_log_mask (page 249)	`0`	1+	No
evs.install_timeout (page 249)	`PT15S`	1+	Yes
evs.join_retrans_period (page 250)	`PT1S`	1+	Yes
evs.keepalive_period (page 250)	`PT1S`	1+	No
evs.max_install_timeouts (page 250)	`1`	1+	No
evs.send_window (page 250)	`4`	1+	Yes
evs.stats_report_period (page 251)	`PT1M`	1+	No
evs.suspect_timeout (page 251)	`PT5S`	1+	No
evs.use_aggregate (page 251)	`TRUE`	1+	No
evs.user_send_window (page 251)	`2`	1+	Yes
evs.view_forget_timeout (page 252)	`PT5M`	1+	No
evs.version (page 252) [T]	`0`	1+	No
gcache.dir (page 252)	working directory	1.0	No
gcache.name (page 253)	`galera.cache`	1+	No
gcache.keep_pages_size (page 253)	`0`	1+	No
gcache.page_size (page 253)	`128Mb`	1+	No
gcache.size (page 253)	`128Mb`	1+	No
gcomm.thread_prio (page 254)		3+	No
gcs.fc_debug (page 254)	`0`	1+	No
gcs.fc_factor (page 254)	`0.5`	1+	Yes
gcs.fc_limit (page 254)	`16`	1+	Yes
gcs.fc_master_slave (page 255)	`NO`	1+	No
gcs.max_packet_size (page 255)	`32616`	1+	No
gcs.max_throttle (page 255)	`0.25`	1+	No
gcs.recv_q_hard_limit (page 255)	`LLONG_MAX`	1+	No
gcs.recv_q_soft_limit (page 255)	`0.25`	1+	No
gcs.sync_donor (page 256)	`NO`	1+	No
gmcast.listen_addr (page 256)	`tcp://0.0.0.0:4567`	1+	No

Continued on next page

Table 41.1 – continued from previous page

Parameter	Default	Support	Dynamic
gmcast.mcast_addr (page 256)		1+	No
gmcast.mcast_ttl (page 256)	`1`	1+	No
gmcast.peer_timeout (page 256)	`PT3S`	1+	No
gmcast.segment (page 257)	`0`	3+	No
gmcast.time_wait (page 257)	`PT5S`	1+	No
gmcast.version (page 257) T	n/a		
ist.recv_addr (page 257)		1+	No
ist.recv_bind (page 257)		3+	No
pc.recovery (page 258)	`TRUE`	3+	No
pc.bootstrap (page 258)	n/a	2+	Yes
pc.announce_timeout (page 258)	`PT3S`	2+	No
pc.checksum (page 258)	`TRUE`	1+	No
pc.ignore_sb (page 259)	`FALSE`	1+	Yes
pc.ignore_quorum (page 259)	`FALSE`	1+	Yes
pc.linger (page 259)	`PT2S`	1+	No
pc.npvo (page 259)	`FALSE`	1+	No
pc.wait_prim (page 259)	`FALSE`	1+	No
pc.wait_prim_timeout (page 260)	`P30S`	2+	No
pc.weight (page 260)	`1`	2.4+	Yes
pc.version (page 260) T	n/a	1+	
protonet.backend (page 260)	`asio`	1+	No
protonet.version (page 260) T	n/a	1+	
repl.commit_order (page 260)	`3`	1+	No
repl.causal_read_timeout (page 261)	`PT30S`	1+	No
repl.key_format (page 261)	`FLAT8`	3+	No
repl.max_ws_size (page 261)	`2147483647`	3+	No
repl.proto_max (page 261)	`5`	2+	No
socket.ssl_ca (page 262)		1+	No
socket.ssl_cert (page 262)		1+	No
socket.checksum (page 262)	`1` (for version 2) `2` (for version 3+)	2+	No
socket.ssl_cipher (page 262)	`AES128-SHA`	1+	No

Continued on next page

Table 41.1 – continued from previous page

Parameter	Default	Support	Dynamic
socket.ssl_compression (page 263)	`YES`	1+	No
socket.ssl_key (page 263)		1+	No
socket.ssl_password_file (page 263)		1+	No

`base_host`

Global variable for internal use.

Note: **Warning**: Do not manually set this variable.

Default Values	Dynamic	Introduced | Deprecated	
detected network address			

`base_port`

Global variable for internal use.

Note: **Warning**: Do not manually set this variable.

Default Value	Dynamic	Introduced	Deprecated
`4567`			

`cert.log_conflicts`

Log details of certification failures.

```
wsrep_provider_options="cert.log_conflicts=NO"
```

Default Value	Dynamic	Introduced	Deprecated
`NO`	Yes	2.0	

`debug`

Enable debugging.

```
wsrep_provider_options="debug=NO"
```

Default Value	Dynamic	Introduced	Deprecated
`NO`	Yes	2.0	

`evs.auto_evict`

Defines how many entries the node allows for given a delayed node before it triggers the Auto Eviction protocol.

```
wsrep_provider_options="evs.auto_evict=5"
```

Each cluster node monitors the group communication response times from all other nodes. When the cluster registers delayed response from a given node, it adds an entry for that node to its delayed list. If the majority of the cluster nodes show the node as delayed, the node is permanently evicted from the cluster.

This parameter determines how many entries a given node can receive before it triggers Auto Eviction.

When this parameter is set to 0, it disables the Auto Eviction protocol for this node. Even when you disable Auto Eviction, though; the node continues to monitor response times from the cluster.

Note: See Also: For more information on the Auto Eviction process, see *Auto Eviction* (page 95).

Default Value	Dynamic	Introduced	Deprecated
0	No	3.8	

evs.causal_keepalive_period

For developer use only. Defaults to evs.keepalive_period.

Default Value	Dynamic	Introduced	Deprecated
	No	1.0	

evs.consensus_timeout

Timeout on reaching the consensus about cluster membership.

```
wsrep_provider_options="evs.consensus_timeout=PT30S"
```

This variable is mostly used for troubleshooting purposes and should not be implemented in a production environment.

Note: See Also: This feature has been **deprecated**. It is succeeded by *evs.install_timeout* (page 249).

Default Value	Dynamic	Introduced	Deprecated
PT30S	No	1.0	2.0

evs.debug_log_mask

Control EVS debug logging, only effective when wsrep_debug is in use.

```
wsrep_provider_options="evs.debug_log_mask=0x1"
```

Default Value	Dynamic	Introduced	Deprecated
0x1	Yes	1.0	

evs.delayed_keep_period

Defines how long this node requires a delayed node to remain responsive before it removes an entry from the delayed list.

```
wsrep_provider_options="evs.delayed_keep_period=PT45S"
```

Each cluster node monitors the group communication response times from all other nodes. When the cluster registered delayed responses from a given node, it adds an entry for that node to its delayed list. Nodes that remain on the delayed list can trigger Auto Eviction, which removes them permanently from the cluster.

This parameter determines how long a node on the delayed list must remain responsive before it removes one entry. The number of entries on the delayed list and how long it takes before the node removes all entries depends on how long the delayed node was unresponsive.

Note: **See Also**: For more information on the delayed list and the Auto Eviction process, see *Auto Eviction* (page 95).

Default Value	Dynamic	Introduced	Deprecated
PT30S	No	3.8	

evs.delayed_margin

Defines how long the node allows response times to deviate before adding an entry to the delayed list.

```
wsrep_provider_options="evs.delayed_margin=PT5S"
```

Each cluster node monitors group communication response times from all other nodes. When the cluster registers a delayed response from a given node, it adds an entry for that node to its delayed list. Delayed nodes can trigger Auto Eviction, which removes them permanently from the cluster.

This parameter determines how long a delay can run before the node adds an entry to the delayed list. You must set this parameter to a value higher than the round-trip delay time (RTT) between the nodes.

Note: **See Also**: For more information on the delayed list and the Auto Eviction process, see *Auto Eviction* (page 95).

Default Value	Dynamic	Introduced	Deprecated
PT1S	No	3.8	

evs.evict

Defines the point at which the cluster triggers manual eviction to a certain node value. Setting this parameter as an empty string causes it to clear the eviction list on the node where it is set.

Note: **See Also**: For more information on the eviction and Auto Eviction process, see *Auto Eviction* (page 95).

Default Value	Dynamic	Introduced	Deprecated
	No	3.8	

evs.inactive_check_period

Defines how often you want the node to check for peer inactivity.

```
wsrep_provider_options="evs.inactive_check_period=PT1S"
```

Each cluster node monitors group communication response times from all other nodes. When the cluster registers a delayed response from a given node, it adds an entry for that node to its delayed list, which can lead to the delayed node's eviction from the cluster.

This parameter determines how often you want the node to check for delays in the group communication responses from other cluster nodes.

Default Value	Dynamic	Introduced	Deprecated
`PT1S`	No	1.0	

`evs.inactive_timeout`

Defines a hard limit on node inactivity.

Hard limit on the inactivity period, after which the node is pronounced dead.

```
wsrep_provider_options="evs.inactive_timeout=PT15S"
```

Each cluster node monitors group communication response times from all other nodes. When the cluster registers a delayed response from a given node, it add an entry for that node to its delayed list, which can lead tot he delayed node's eviction from the cluster.

This parameter sets a hard limit for node inactivity. If a delayed node remains unresponsive for longer than this period, the node pronounces the delayed node as dead.

Default Value	Dynamic	Introduced	Deprecated
`PT15S`	No	1.0	

`evs.info_log_mask`

Defines additional logging options for the EVS Protocol.

```
wsrep_provider_options="evs.info_log_mask=0x4"
```

The EVS Protocol monitors group communication response times and controls the node eviction and auto eviction processes. This parameter allows you to enable additional logging options, through a bitmask value.

- `0x1` Provides extra view change info.
- `0x2` Provides extra state change info
- `0x4` Provides statistics
- `0x8` Provides profiling (only in builds with profiling enabled)

Default Value	Dynamic	Introduced	Deprecated
`0`	No	1.0	

`evs.install_timeout`

Defines the timeout for install message acknowledgments.

```
wsrep_provider_options="evs.install_timeout=PT15S"
```

Each cluster node monitors group communication response times from all other nodes, checking whether they are responsive or delayed. This parameter determines how long you want the node to wait on install message acknowledgments.

Note: **See Also**: This parameter replaces *evs.consensus_timeout* (page 247).

Default Value	Dynamic	Introduced	Deprecated
PT15S	Yes	1.0	

evs.join_retrans_period

Defines how often the node retransmits EVS join messages when forming cluster membership.

```
wsrep_provider_options="evs.join_retrans_period=PT1S"
```

Default Value	Dynamic	Introduced	Deprecated
PT1S	Yes	1.0	

evs.keepalive_period

Defines how often the node emits keepalive signals.

```
wsrep_provider_options="evs.keepalive_period=PT1S"
```

Each cluster node monitors group communication response times from all other nodes. When there is no traffic going out for the cluster to monitor, nodes emit keepalive signals so that other nodes have something to measure. This parameter determines how often the node emits a keepalive signal, absent any other traffic.

Default Value	Dynamic	Introduced	Deprecated
PT1S	No	1.0	

evs.max_install_timeouts

Defines the number of membership install rounds to try before giving up.

```
wsrep_provider_options="evs.max_install_timeouts=1"
```

This parameter determines the maximum number of times that the node tries for a membership install acknowledgment, before it stops trying. The total number of rounds it tries is this value plus 2.

Default Value	Dynamic	Introduced	Deprecated
1	No	1.0	

evs.send_window

Defines the maximum number of packets at a time in replication.

```
wsrep_provider_options="evs.send_window=4"
```

This parameter determines the maximum number of packets the node uses at a time in replication. For clusters implemented over WAN, you can set this value considerably higher, (for example, 512), than for clusters implemented over LAN.

You must use a value that is greater than *evs.user_send_window* (page 251). The recommended value is double *evs.user_send_window* (page 251).

Default Value	Dynamic	Introduced	Deprecated
4	Yes	1.0	

evs.stats_report_period

Control period of EVS statistics reporting. The node is pronounced dead.

```
wsrep_provider_options="evs.stats_report_period=PT1M"
```

Default Value	Dynamic	Introduced	Deprecated
PT1M	No	1.0	

evs.suspect_timeout

Defines the inactivity period after which a node is *suspected* as dead.

```
wsrep_provider_options="evs.suspect_timeout=PT5S"
```

Each node in the cluster monitors group communications from all other nodes in the cluster. This parameter determines the period of inactivity before the node suspects another of being dead. If all nodes agree on that, the cluster drops the inactive node.

Default Value	Dynamic	Introduced	Deprecated
PT5S	No	1.0	

evs.use_aggregate

Defines whether the node aggregates small packets into one when possible.

```
wsrep_provider_options="evs.use_aggregate=TRUE"
```

Default Value	Dynamic	Introduced	Deprecated
TRUE	No	1	

evs.user_send_window

Defines the maximum number of data packets at a time in replication.

```
wsrep_provider_options="evs.user_send_window=2"
```

This parameter determines the maximum number of data packets the node uses at a time in replication. For clusters implemented over WAN, you can set this to a value considerably higher than cluster implementations over LAN, (for example, 512).

You must use a value that is smaller than *evs.send_window* (page 250). The recommended value is half *evs.send_window* (page 250).

Note: **See Also**: *evs.send_window* (page 250).

Default Value	Dynamic	Introduced	Deprecated
`2`	Yes	1.0	

evs.view_forget_timeout

Defines how long the node saves past views from the view history.

```
wsrep_provider_options="evs.view_forget_timeout=PT5M"
```

Each node maintains a history of past views. This parameter determines how long you want the node to save past views before dropping them from the table.

Default Value	Dynamic	Introduced	Deprecated
`PT5M`	No	1.0	

evs.version

Defines the EVS Protocol version.

```
wsrep_provider_options="evs.version=1"
```

This parameter determines which version of the EVS Protocol the node uses. In order to ensure backwards compatibility, the parameter defaults to `0`. Certain EVS Protocol features, such as Auto Eviction, require you to upgrade to more recent versions.

Note: **See Also**: For more information on the procedure to upgrade from one version to another, see *Upgrading the EVS Protocol* (page 96).

Default Value	Dynamic	Introduced	Deprecated
`0`	No	1.0	

gcache.dir

Defines the directory where the write-set cache places its files.

```
wsrep_provider_options="gcache.dir=/usr/share/galera"
```

When nodes receive state transfers they cannot process incoming write-sets until they finish updating their state. Under certain methods, the node that sends the state transfer is similarly blocked. To prevent the database from falling further behind, GCache saves the incoming write-sets on memory mapped files to disk.

This parameter determines where you want the node to save these files for write-set caching. By default, GCache uses the working directory for the database server.

Default Value	Dynamic	Introduced	Deprecated
`/path/to/working_dir`	No	1.0	

gcache.keep_pages_size

Total size of the page storage pages to keep for caching purposes. If only page storage is enabled, one page is always present.

```
wsrep_provider_options="gcache.keep_pages_size=0"
```

Default Value	Dynamic	Introduced	Deprecated
0	No	1.0	

gcache.name

Defines the filename for the write-set cache.

```
wsrep_provider_options="gcache.name=galera.cache"
```

When nodes receive state transfers they cannot process incoming write-sets until they finish updating their state. Under certain methods, the node that sends the state transfer is similarly blocked. To prevent the database from falling further behind, GCache saves the incoming write-sets on memory-mapped files to disk.

This parameter determines the name you want the node to use for this ring buffer storage file.

Default Value	Dynamic	Introduced	Deprecated
galera.cache	No	1.0	

gcache.page_size

Size of the page files in page storage. The limit on overall page storage is the size of the disk. Pages are prefixed by `gcache.page`.

```
wsrep_provider_options="gcache.page_size=128Mb"
```

Default Value	Dynamic	Introduced	Deprecated
128M	No	1.0	

gcache.size

Defines the disk space you want to node to use in caching write-sets.

```
wsrep_provider_options="gcache.size=128Mb"
```

When nodes receive state transfers they cannot process incoming write-sets until they finish updating their state. Under certain methods, the node that sends the state transfer is similarly blocked. To prevent the database from falling further behind, GCache saves the incoming write-sets on memory-mapped files to disk.

This parameter defines the amount of disk space you want to allocate for the present ring buffer storage. The node allocates this space when it starts the database server.

Note: See Also: For more information on customizing the write-set cache, see *Performance* (page 207).

Default Value	Dynamic	Introduced	Deprecated
128M	No	1.0	

gcomm.thread_prio

Defines the policy and priority for the gcomm thread.

Using this option, you can raise the priority of the gcomm thread to a higher level than it normally uses. You may find this useful in situations where Galera Cluster threads do not receive sufficient CPU time, due to competition with other MySQL threads. In these cases, when the thread scheduler for the operating system does not run the Galera threads frequently enough, timeouts may occur, causing the node to drop from the cluster.

The format for this option is: `<policy>:<priority>`. The priority value is an integer. The policy value supports the following options:

- `other` Designates the default time-sharing scheduling in Linux. They can run until they are blocked by an I/O request or preempted by higher priorities or superior scheduling designations.
- `fifo` Designates first-in out scheduling. These threads always immediately preempt any currently running other, batch or idle threads. They can run until they are either blocked by an I/O request or preempted by a FIFO thread of a higher priority.
- `rr` Designates round-robin scheduling. These threads always preempt any currently running other, batch or idle threads. The scheduler allows these threads to run for a fixed period of a time. If the thread is still running when this time period is exceeded, they are stopped and moved to the end of the list, allowing another round-robin thread of the same priority to run in their place. They can otherwise continue to run until they are blocked by an I/O request or are preempted by threads of a higher priority.

Default Value	Dynamic	Introduced	Deprecated
	No	3.0	

gcs.fc_debug

Post debug statistics about SST flow every this number of writesets.

```
wsrep_provider_options="gcs.fc_debug=0"
```

Default Value	Dynamic	Introduced	Deprecated
0	No	1.0	

gcs.fc_factor

Resume replication after recv queue drops below this fraction of `gcs.fc_limit`.

```
wsrep_provider_options="gcs.fc_factor=0.5"
```

Default Value	Dynamic	Introduced	Deprecated
0.5	Yes	1.0	

gcs.fc_limit

Pause replication if recv queue exceeds this number of writesets. For master-slave setups this number can be increased considerably.

```
wsrep_provider_options="gcs.fc_limit=16"
```

Default Value	Dynamic	Introduced	Deprecated
16	Yes	1.0	

gcs.fc_master_slave

Defines whether there is only one master node in the group.

```
wsrep_provider_options="gcs.fc_master_slave=NO"
```

Default Value	Dynamic	Introduced	Deprecated
NO	No	1.0	

gcs.max_packet_size

All writesets exceeding that size will be fragmented.

```
wsrep_provider_options="gcs.max_packet_size=32616"
```

Default Value	Dynamic	Introduced	Deprecated
32616	No	1.0	

gcs.max_throttle

How much to throttle replication rate during state transfer (to avoid running out of memory). Set the value to 0.0 if stopping replication is acceptable for completing state transfer.

```
wsrep_provider_options="gcs.max_throttle=0.25"
```

Default Value	Dynamic	Introduced	Deprecated
0.25	No	1.0	

gcs.recv_q_hard_limit

Maximum allowed size of recv queue. This should normally be half of (RAM + swap). If this limit is exceeded, Galera Cluster will abort the server.

```
wsrep_provider_options="gcs.recv_q_hard_limit=LLONG_MAX"
```

Default Value	Dynamic	Introduced	Deprecated
LLONG_MAX	No	1.0	

gcs.recv_q_soft_limit

The fraction of *gcs.recv_q_hard_limit* (page 255) after which replication rate will be throttled.

```
wsrep_provider_options="gcs.recv_q_soft_limit=0.25"
```

The degree of throttling is a linear function of recv queue size and goes from 1.0 (`full rate`) at *gcs.recv_q_soft_limit* (page 255) to *gcs.max_throttle* (page 255) at *gcs.recv_q_hard_limit* (page 255) Note that `full rate`, as estimated between 0 and *gcs.recv_q_soft_limit* (page 255) is a very imprecise estimate of a regular replication rate.

Default Value	Dynamic	Introduced	Deprecated
0.25	No	1.0	

gcs.sync_donor

Should the rest of the cluster keep in sync with the donor? YES means that if the donor is blocked by state transfer, the whole cluster is blocked with it.

```
wsrep_provider_options="gcs.sync_donor=NO"
```

If you choose to use value YES, it is theoretically possible that the donor node cannot keep up with the rest of the cluster due to the extra load from the SST. If the node lags behind, it may send flow control messages stalling the whole cluster. However, you can monitor this using the *wsrep_flow_control_paused* (page 272) status variable.

Default Value	Dynamic	Introduced	Deprecated
NO	No	1.0	

gmcast.listen_addr

Address at which *Galera Cluster* listens to connections from other nodes. By default the port to listen at is taken from the connection address. This setting can be used to overwrite that.

```
wsrep_provider_options="gmcast.listen_addr=tcp://0.0.0.0:4567"
```

Default Value	Dynamic	Introduced	Deprecated
tcp://0.0.0.0"4567	No	1.0	

gmcast.mcast_addr

If set, UDP multicast will be used for replication, for example:

```
wsrep_provider_options="gmcast.mcast_addr=239.192.0.11"
```

The value must be the same on all nodes.

If you are planning to build a large cluster, we recommend using UDP.

Default Value	Dynamic	Introduced	Deprecated
	No	1.0	

gmcast.mcast_ttl

Time to live value for multicast packets.

```
wsrep_provider_options="gmcast.mcast_ttl=1"
```

Default Value	Dynamic	Introduced	Deprecated
1	No	1.0	

gmcast.peer_timeout

Connection timeout to initiate message relaying.

```
wsrep_provider_options="gmcast.peer_timeout=PT3S"
```

Default Value	Dynamic	Introduced	Deprecated
PT3S	No	1.0	

gmcast.segment

Define which network segment this node is in. Optimisations on communication are performed to minimise the amount of traffic between network segments including writeset relaying and IST and SST donor selection. The *gmcast.segment* (page 257) value is an integer from 0 to 255. By default all nodes are placed in the same segment (0).

```
wsrep_provider_options="gmcast.segment=0"
```

Default Value	Dynamic	Introduced	Deprecated
0	No	3.0	

gmcast.time_wait

Time to wait until allowing peer declared outside of stable view to reconnect.

```
wsrep_provider_options="gmcast.time_wait=PT5S"
```

Default Value	Dynamic	Introduced	Deprecated
PT5S	No	1.0	

gmcast.version

This status variable is used to check which gmcast protocol version is used.

This variable is mostly used for troubleshooting purposes and should not be implemented in a production environment.

Default Value	Dynamic	Introduced	Deprecated
	No	1.0	

ist.recv_addr

Address to listen on for Incremental State Transfer. By default this is the <address>:<port+1> from *wsrep_node_address* (page 225).

```
wsrep_provider_options="ist.recv_addr=192.168.1.1"
```

Default Value	Dynamic	Introduced	Deprecated
	No	2.0	

ist.recv_bind

Defines the address that the node binds on for receiving an *Incremental State Transfer*.

```
wsrep_provider_options="ist.recv_bind=192.168.1.1"
```

This option defines the address to which the node will bind in order to receive Incremental State Transfers. When this option is not set, it takes its value from *ist.recv_addr* (page 257) or, in the event that that is also not set, from *wsrep_node_address* (page 225). You may find it useful when the node runs behind a NAT or in similar cases where the public and private addresses differ.

Default Value	Dynamic	Introduced	Deprecated
	No	3.16	

pc.recovery

When set to TRUE, the node stores the Primary Component state to disk, in the gvwstate.dat file. The Primary Component can then recover automatically when all nodes that were part of the last saved state reestablish communications with each other.

```
wsrep_provider_options="pc.recovery=TRUE"
```

This allows for:

- Automatic recovery from full cluster crashes, such as in the case of a data center power outage.
- Graceful full cluster restarts without the need for explicitly bootstrapping a new Primary Component.

Note: In the event that the wsrep position differs between nodes, recovery also requires a full State Snapshot Transfer.

Default Value	Dynamic	Introduced	Deprecated
TRUE	No	3.0	

pc.bootstrap

If you set this value to TRUE is a signal to turn a NON-PRIMARY component into PRIMARY.

```
wsrep_provider_options="pc.bootstrap=TRUE"
```

Default Value	Dynamic	Introduced	Deprecated
	Yes	2.0	

pc.announce_timeout

Cluster joining announcements are sent every $\frac{1}{2}$ second for this period of time or less if the other nodes are discovered.

```
wsrep_provider_options="pc.announce_timeout=PT3S"
```

Default Value	Dynamic	Introduced	Deprecated
PT3S	No	2.0	

pc.checksum

Checksum replicated messages.

```
wsrep_provider_options="pc.checksum=TRUE"
```

Default Value	Dynamic	Introduced	Deprecated
TRUE	No	1.0	

pc.ignore_sb

Should we allow nodes to process updates even in the case of split brain? This is a dangerous setting in multi-master setup, but should simplify things in master-slave cluster (especially if only 2 nodes are used).

```
wsrep_provider_options="pc.ignore_sb=FALSE"
```

Default Value	Dynamic	Introduced	Deprecated
FALSE	Yes	1.0	

pc.ignore_quorum

Completely ignore quorum calculations. For example if the master splits from several slaves it still remains operational. Use with extreme caution even in master-slave setups, as slaves will not automatically reconnect to master in this case.

```
wsrep_provider_options="pc.ignore_quorum=FALSE"
```

Default Value	Dynamic	Introduced	Deprecated
FALSE	Yes	1.0	

pc.linger

The period for which the PC protocol waits for the EVS termination.

```
wsrep_provider_options="pc.linger=PT2S"
```

Default Value	Dynamic	Introduced	Deprecated
PT2S	No	1.0	

pc.npvo

If set to TRUE, the more recent primary component overrides older ones in the case of conflicting primaries.

```
wsrep_provider_options="pc.npvo=FALSE"
```

Default Value	Dynamic	Introduced	Deprecated
FALSE	No	1.0	

pc.wait_prim

If set to TRUE, the node waits for the *pc.wait_prim_timeout* (page 260) time period. Useful to bring up a non-primary component and make it primary with *pc.bootstrap* (page 258).

```
wsrep_provider_options="pc.wait_prim=FALSE"
```

Default Value	Dynamic	Introduced	Deprecated
FALSE	No	1.0	

pc.wait_prim_timeout

The period of time to wait for a primary component.

```
wsrep_provider_options="pc.wait_prim_timeout=PT30S"
```

Default Value	Dynamic	Introduced	Deprecated
PT30S	No	2.0	

pc.weight

As of version 2.4. Node weight for quorum calculation.

```
wsrep_provider_options="pc.weight=1"
```

Default Value	Dynamic	Introduced	Deprecated
1	Yes	2.4	

pc.version

This status variable is used to check which pc protocol version is used.

This variable is mostly used for troubleshooting purposes and should not be implemented in a production environment.

Default Value	Dynamic	Introduced	Deprecated
	No	1.0	

protonet.backend

Which transport backend to use. Currently only ASIO is supported.

```
wsrep_provider_options="protonet.backend=asio"
```

Default Value	Dynamic	Introduced	Deprecated
asio	No	1.0	

protonet.version

This status variable is used to check which transport backend protocol version is used.

This variable is mostly used for troubleshooting purposes and should not be implemented in a production environment.

Default Value	Dynamic	Introduced	Deprecated
	No	1.0	

repl.commit_order

Whether to allow Out-Of-Order committing (improves parallel applying performance).

```
wsrep_provider_options="repl.commit_order=2"
```

Possible settings:

- 0 or BYPASS All commit order monitoring is switched off (useful for measuring performance penalty).
- 1 or OOOC Allows out of order committing for all transactions.
- 2 or LOCAL_OOOC Allows out of order committing only for local transactions.
- 3 or NO_OOOC No out of order committing is allowed (strict total order committing)

Default Value	Dynamic	Introduced	Deprecated
3	No	1.0	

repl.causal_read_timeout

Sometimes causal reads need to timeout.

```
wsrep_provider_options="repl.causal_read_timeout=PT30S"
```

Default Value	Dynamic	Introduced	Deprecated
PT30S	No	1.0	

repl.key_format

The hash size to use for key formats (in bytes). An A suffix annotates the version.

```
wsrep_provider_options="repl.key_format=FLAT8"
```

Possible settings:

- FLAT8
- FLAT8A
- FLAT16
- FLAT16A

Default Value	Dynamic	Introduced	Deprecated
FLAT8	No	3.0	

repl.max_ws_size

The maximum size of a write-set in bytes. This is limited to 2G.

```
wsrep_provider_options="repl.max_ws_size=2147483647"
```

Default Value	Dynamic	Introduced	Deprecated
2147483647	No	3.0	

repl.proto_max

The maximum protocol version in replication. Changes to this parameter will only take effect after a provider restart.

```
wsrep_provider_options="repl.proto_max=5"
```

Default Value	Dynamic	Introduced	Deprecated
5	No	2.0	

socket.ssl_ca

Defines the path to the SSL Certificate Authority (CA) file.

The node uses the CA file to verify the signature on the certificate. You can use either an absolute path or one relative to the working directory. The file must use PEM format.

```
wsrep_provider_options='socket.ssl_ca=/path/to/ca-cert.pem'
```

Note: **See Also**: For more information on generating SSL certificate files for your cluster, see *SSL Certificates* (page 169).

Default Value	Dynamic	Introduced	Deprecated
	No	1.0	

socket.ssl_cert

Defines the path to the SSL certificate.

The node uses the certificate as a self-signed public key in encrypting replication traffic over SSL. You can use either an absolute path or one relative to the working directory. The file must use PEM format.

```
wsrep_provider_options="socket.ssl_cert=/path/to/server-cert.pem"
```

Note: **See Also**: For more information on generating SSL certificate files for your cluster, see *SSL Certificates* (page 169).

Default Value	Dynamic	Introduced	Deprecated
	No	1.0	

socket.checksum

Checksum to use on socket layer:

- `0` - disable checksum
- `1` - CRC32
- `2` - CRC-32C (optimized and potentially HW-accelerated on Intel CPUs)

```
wsrep_provider_options="socket.checksum=2"
```

Default Value	Dynamic	Introduced	Deprecated
version 1 : `1`	No	2.0	
version 3+: `2`			

socket.ssl_cipher

Symmetric cipher to use. AES128 is used by default it is considerably faster and no less secure than AES256.

```
wsrep_provider_options="socket.ssl_cipher=AES128-SHA"
```

Default Value	Dynamic	Introduced	Deprecated
AES128-SHA	No	1.0	

socket.ssl_compression

Whether to enable compression on SSL connections.

```
wsrep_provider_options="socket.ssl_compression=YES"
```

Default Value	Dynamic	Introduced	Deprecated
YES	No	1.0	

socket.ssl_key

Defines the path to the SSL certificate key.

The node uses the certificate key a self-signed private key in encrypting replication traffic over SSL. You can use either an absolute path or one relative to the working directory. The file must use PEM format.

```
wsrep_provider_options="socket.ssl_key=/path/to/server-key.pem"
```

Note: **See Also**: For more information on generating SSL certificate files for your cluster, see *SSL Certificates* (page 169).

Default Value	Dynamic	Introduced	Deprecated
	No	1.0	

socket.ssl_password_file

Defines a password file for use in SSL connections.

```
wsrep_provider_options="socket.ssl_password_file=/path/to/password-file"
```

In the event that you have your SSL key file encrypted, the node uses the SSL password file to decrypt the key file.

Default Value	Dynamic	Introduced	Deprecated
	No	1.0	

Setting Galera Parameters in MySQL

You can set *Galera Cluster* parameters in the `my.cnf` configuration file as follows:

```
wsrep_provider_options="gcs.fc_limit=256;gcs.fc_factor=0.9"
```

This is useful in master-slave setups.

You can set Galera Cluster parameters through a MySQL client with the following query:

```
SET GLOBAL wsrep_provider_options="evs.send_window=16";
```

This query only changes the *evs.send_window* (page 250) value.

To check which parameters are used in Galera Cluster, enter the following query:

```
SHOW VARIABLES LIKE 'wsrep_provider_options';
```

CHAPTER

FORTYTWO

GALERA STATUS VARIABLES

These variables are *Galera Cluster* 0.8.x status variables. There are two types of wsrep-related status variables:

- Galera Cluster-specific variables exported by Galera Cluster
- Variables exported by MySQL. These variables are for the general wsrep provider.

This distinction is of importance for developers only. For convenience, all status variables are presented as a single list below. Variables exported by MySQL are indicated by an *M* in superscript.

Status Variable	Example	Support
wsrep_apply_oooe (page 266)	`0.671120`	1+
wsrep_apply_oool (page 266)	`0.195248`	1+
wsrep_apply_window (page 267)	`5.163966`	1+
wsrep_cert_deps_distance (page 267)	`23.88889`	1+
wsrep_cert_index_size (page 267)	`30936`	1+
wsrep_cert_interval (page 268)		1+
wsrep_cluster_conf_id (page 268) ^{M}	`34`	1+
wsrep_cluster_size (page 268) ^{M}	`3`	1+
wsrep_cluster_state_uuid (page 269) ^{M}		1+
wsrep_cluster_status (page 269) ^{M}	`Primary`	1+
wsrep_commit_oooe (page 269)	`0.000000`	1+
wsrep_commit_oool (page 269)	`0.000000`	1+
wsrep_commit_window (page 270)	`0.000000`	1+
wsrep_connected (page 270)	`ON`	1+
wsrep_evs_delayed (page 270)		3.8+
wsrep_evs_evict_list (page 271)		3.8+
wsrep_evs_repl_latency (page 271)		3.0+
wsrep_evs_state (page 271)		3.8+
wsrep_desync_count (page 271)	`0`	3+
wsrep_flow_control_paused (page 272)	`0.184353`	1+
wsrep_flow_control_paused_ns (page 272)	`20222491180`	1+
wsrep_flow_control_recv (page 272)	`11`	1+
wsrep_flow_control_sent (page 273)	`7`	1+
wsrep_gcomm_uuid (page 273)		1+
wsrep_incoming_addresses (page 273)		1+
wsrep_last_committed (page 274)	`409745`	1+
wsrep_local_bf_aborts (page 274)	`960`	1+
wsrep_local_cached_downto (page 274)		1+
wsrep_local_cert_failures (page 274)	`333`	1+
wsrep_local_commits (page 275)	`14981`	1+

Continued on next page

Table 42.1 – continued from previous page

Status Variable	Example	Support
wsrep_local_index (page 275)	1	1+
wsrep_local_recv_queue (page 275)	0	1+
wsrep_local_recv_queue_avg (page 276)	3.348452	1+
wsrep_local_recv_queue_max (page 276)	10	1+
wsrep_local_recv_queue_min (page 276)	0	1+
wsrep_local_replays (page 276)	0	1+
wsrep_local_send_queue (page 277)	1	1+
wsrep_local_send_queue_avg (page 277)	0.145000	1+
wsrep_local_send_queue_max (page 277)	10	1+
wsrep_local_send_queue_min (page 278)	0	1+
wsrep_local_state (page 278)	4	1+
wsrep_local_state_comment (page 278)	Synced	1+
wsrep_local_state_uuid (page 279)		1+
wsrep_protocol_version (page 279)	4	1+
wsrep_provider_name (page 279) M	Galera	1+
wsrep_provider_vendor (page 279) M		1+
wsrep_provider_version (page 280) M		1+
wsrep_ready (page 280) M	ON	1+
wsrep_received (page 280)	17831	1+
wsrep_received_bytes (page 281)	6637093	1+
wsrep_repl_data_bytes (page 281)	265035226	1+
wsrep_repl_keys (page 281)	797399	1+
wsrep_repl_keys_bytes (page 282)	11203721	1+
wsrep_repl_other_bytes (page 282)	0	1+
wsrep_replicated (page 282)	16109	1+
wsrep_replicated_bytes (page 282)	6526788	1+

wsrep_apply_oooe

How often applier started write-set applying out-of-order (parallelization efficiency).

```
SHOW STATUS LIKE 'wsrep_apply_oooe';

+------------------+----------+
| Variable_name    | Value    |
+------------------+----------+
| wsrep_apply_oooe | 0.671120 |
+------------------+----------+
```

Example Value	Location	Introduced	Deprecated
0.671120	Galera		

wsrep_apply_oool

How often write-set was so slow to apply that write-set with higher seqno's were applied earlier. Values closer to 0 refer to a greater gap between slow and fast write-sets.

```
SHOW STATUS LIKE 'wsrep_apply_oool';

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

```
| Variable_name     | Value    |
+-------------------+----------+
| wsrep_apply_oool  | 0.195248 |
+-------------------+----------+
```

Example Value	Location	Introduced	Deprecated
0.195248	Galera		

wsrep_apply_window

Average distance between highest and lowest concurrently applied seqno.

```
SHOW STATUS LIKE 'wsrep_apply_window';

+--------------------+----------+
| Variable_name      | Value    |
+--------------------+----------+
| wsrep_apply_window | 5.163966 |
+--------------------+----------+
```

Example Value	Location	Introduced	Deprecated
5.163966	Galera		

wsrep_cert_deps_distance

Average distance between highest and lowest seqno value that can be possibly applied in parallel (potential degree of parallelization).

```
SHOW STATUS LIKE 'wsrep_cert_deps_distance';

+--------------------------+----------+
| Variable_name            | Value    |
+--------------------------+----------+
| wsrep_cert_deps_distance | 23.88889 |
+--------------------------+----------+
```

Example Value	Location	Introduced	Deprecated
23.888889	Galera		

wsrep_cert_index_size

The number of entries in the certification index.

```
SHOW STATUS LIKE 'wsrep_certs_index_size';

+------------------------+-------+
| Variable_name          | Value |
+------------------------+-------+
| wsrep_certs_index_size | 30936 |
+------------------------+-------+
```

Example Value	Location	Introduced	Deprecated
30936	Galera		

wsrep_cert_interval

Average number of transactions received while a transaction replicates.

```
SHOW STATUS LIKE 'wsrep_cert_interval';

+---------------------+-------+
| Variable_name       | Value |
+---------------------+-------+
| wsrep_cert_interval | 1.0   |
+---------------------+-------+
```

When a node replicates a write-set to the cluster, it can take some time before all the nodes in the cluster receive it. By the time a given node receives, orders and commits a write-set, it may receive and potentially commit others, changing the state of the database from when the write-set was sent and rendering the transaction inapplicable.

To prevent this, Galera Cluster checks write-sets against all write-sets within its certification interval for potential conflicts. Using the *wsrep_cert_interval* (page 268) status variable, you can see the average number of transactions with the certification interval.

This shows you the number of write-sets concurrently replicating to the cluster. In a fully synchronous cluster, with one write-set replicating at a time, *wsrep_cert_interval* (page 268) returns a value of `1.0`.

Example Value	Location	Introduced	Deprecated
`1.0`	Galera		

wsrep_cluster_conf_id

Total number of cluster membership changes happened.

```
SHOW STATUS LIKE 'wsrep_cluster_conf_id';

+-----------------------+-------+
| Variable_name         | Value |
+-----------------------+-------+
| wsrep_cluster_conf_id | 34    |
+-----------------------+-------+
```

Example Value	Location	Introduced	Deprecated
`34`	MySQL		

wsrep_cluster_size

Current number of members in the cluster.

```
SHOW STATUS LIKE 'wsrep_cluster_size';

+--------------------+-------+
| Variable_name      | Value |
+--------------------+-------+
| wsrep_cluster_size | 15    |
+--------------------+-------+
```

Example Value	Location	Introduced	Deprecated
`3`	MySQL		

wsrep_cluster_state_uuid

Provides the current State UUID. This is a unique identifier for the current state of the cluster and the sequence of changes it undergoes.

```
SHOW STATUS LIKE 'wsrep_cluster_state_uuid';

+--------------------------+--------------------------------------+
| Variable_name            | Value                                |
+--------------------------+--------------------------------------+
| wsrep_cluster_state_uuid | e2c9a15e-5485-11e0-0800-6bbb637e7211 |
+--------------------------+--------------------------------------+
```

Note: See Also: For more information on the state UUID, see *wsrep API* (page 47).

Example Value	Location	Introduced	Deprecated
e2c9a15e-5485-11e0 0900-6bbb637e7211	MySQL		

wsrep_cluster_status

Status of this cluster component. That is, whether the node is part of a PRIMARY or NON_PRIMARY component.

```
SHOW STATUS LIKE 'wsrep_cluster_status';

+----------------------+---------+
| Variable_name        | Value   |
+----------------------+---------+
| wsrep_cluster_status | Primary |
+----------------------+---------+
```

Example Value	Location	Introduced	Deprecated
Primary	MySQL		

wsrep_commit_oooe

How often a transaction was committed out of order.

```
SHOW STATUS LIKE 'wsrep_commit_oooe';

+-------------------+----------+
| Variable_name     | Value    |
+-------------------+----------+
| wsrep_commit_oooe | 0.000000 |
+-------------------+----------+
```

Example Value	Location	Introduced	Deprecated
0.000000	Galera		

wsrep_commit_oool

No meaning.

```
SHOW STATUS LIKE 'wsrep_commit_oool';

+-------------------+----------+
| Variable_name     | Value    |
+-------------------+----------+
| wsrep_commit_oool | 0.000000 |
+-------------------+----------+
```

Example Value	Location	Introduced	Deprecated
0.000000	Galera		

wsrep_commit_window

Average distance between highest and lowest concurrently committed seqno.

```
SHOW STATUS LIKE 'wsrep_commit_window';

+---------------------+----------+
| Variable_name       | Value    |
+---------------------+----------+
| wsrep_commit_window | 0.000000 |
+---------------------+----------+
```

Example Value	Location	Introduced	Deprecated
0.000000	Galera		

wsrep_connected

If the value is OFF, the node has not yet connected to any of the cluster components. This may be due to misconfiguration. Check the error log for proper diagnostics.

```
SHOW STATUS LIKE 'wsrep_connected';

+-----------------+-------+
| Variable_name   | Value |
+-----------------+-------+
| wsrep_connected | ON    |
+-----------------+-------+
```

Example Value	Location	Introduced	Deprecated
ON	Galera		

wsrep_evs_delayed

Provides a comma separated list of all the nodes this node has registered on its delayed list.

The node listing format is

```
uuid:address:count
```

This refers to the UUID and IP address of the delayed node, with a count of the number of entries it has on the delayed list.

Example Value	Location	Introduced	Deprecated
	Galera	3.8	

wsrep_evs_evict_list

Lists the UUID's of all nodes evicted from the cluster. Evicted nodes cannot rejoin the cluster until you restart their `mysqld` processes.

Example Value	Location	Introduced	Deprecated
	Galera	3.8	

wsrep_evs_repl_latency

This status variable provides figures for the replication latency on group communication. It measures latency from the time point when a message is sent out to the time point when a message is received. As replication is a group operation, this essentially gives you the slowest ACK and longest RTT in the cluster.

For example,

```
SHOW STATUS LIKE 'wsrep_evs_repl_latency';

+------------------------+------------------------------------------+
| Variable_name          | Value                                    |
+------------------------+------------------------------------------+
| wsrep_evs_repl_latency | 0.00243433/0.144022/0.591963/0.215824/13 |
+------------------------+------------------------------------------+
```

The units are in seconds. The format of the return value is:

```
Minimum / Average / Maximum / Standard Deviation / Sample Size
```

This variable periodically resets. You can control the reset interval using the *evs.stats_report_period* (page 251) parameter. The default value is 1 minute.

Example Value	Location	Introduced	Deprecated
`0.00243433/0.144033/ 0.581963/0.215724/13`	Galera	3.0	

wsrep_evs_state

Shows the internal state of the EVS Protocol.

Example Value	Location	Introduced	Deprecated
	Galera	3.8	

wsrep_desync_count

Returns the number of operations in progress that require the node to temporarily desync from the cluster.

```
SHOW STATUS LIKE 'wsrep_desync_count';

+--------------------+-------+
| Variable_name      | Value |
+--------------------+-------+
```

```
| wsrep_desync_count | 1      |
+--------------------+-------+
```

Certain operations, such as DDL statements issued when *wsrep_OSU_method* (page 228) is set to Rolling Schema Upgrade or when you enable *wsrep_desync* (page 220) cause the node to desync from the cluster. The counter on this status variable shows how many of these operations are currently running on the node. When all of these operations complete, the counter returns to its default value `0` and the node can sync back to the cluster.

Example Value	Location	Introduced	Deprecated
0	Galera	3.8	

wsrep_flow_control_paused

The fraction of time since the last `FLUSH STATUS` command that replication was paused due to flow control.

In other words, how much the slave lag is slowing down the cluster.

```
SHOW STATUS LIKE 'wsrep_flow_control_paused';

+---------------------------+----------+
| Variable_name             | Value    |
+---------------------------+----------+
| wsrep_flow_control_paused | 0.184353 |
+---------------------------+----------+
```

Example Value	Location	Introduced	Deprecated
0.174353	Galera		

wsrep_flow_control_paused_ns

The total time spent in a paused state measured in nanoseconds.

```
SHOW STATUS LIKE 'wsrep_flow_control_paused_ns';

+------------------------------+-------------+
| Variable_name                | Value       |
+------------------------------+-------------+
| wsrep_flow_control_paused_ns | 20222491180 |
+------------------------------+-------------+
```

Example Value	Location	Introduced	Deprecated
20222491180	Galera		

wsrep_flow_control_recv

Returns the number of `FC_PAUSE` events the node has received, including those the node has sent. Unlike most status variables, the counter for this one does not reset every time you run the query.

```
SHOW STATUS LIKE 'wsrep_flow_control_recv';

+-------------------------+-------+
| Variable_name           | Value |
+-------------------------+-------+
```

```
| wsrep_flow_control_recv | 11     |
+-------------------------+-------+
```

Example Value	Location	Introduced	Deprecated
11	Galera		

wsrep_flow_control_sent

Returns the number of FC_PAUSE events the node has sent. Unlike most status variables, the counter for this one does not reset every time you run the query.

```
SHOW STATUS LIKE 'wsrep_flow_control_sent';

+-------------------------+-------+
| Variable_name           | Value |
+-------------------------+-------+
| wsrep_flow_control_sent | 7     |
+-------------------------+-------+
```

Example Value	Location	Introduced	Deprecated
7	Galera		

wsrep_gcomm_uuid

Displays the group communications UUID.

```
SHOW STATUS LIKE 'wsrep_gcomm_uuid';

+------------------+--------------------------------------+
| Variable_name    | Value                                |
+------------------+--------------------------------------+
| wsrep_gcomm_uuid | 7e729708-605f-11e5-8ddd-8319a704b8c4 |
+------------------+--------------------------------------+
```

Example Value	Location	Introduced	Deprecated
7e729708-605f-11e5-8ddd-8319a704b8c4	Galera	1	

wsrep_incoming_addresses

Comma-separated list of incoming server addresses in the cluster component.

```
SHOW STATUS LIKE 'wsrep_incoming_addresses';

+--------------------------+--------------------------------------+
| Variable_name            | Value                                |
+--------------------------+--------------------------------------+
| wsrep_incoming_addresses | 10.0.0.1:3306,10.0.02:3306,undefined |
+--------------------------+--------------------------------------+
```

Example Value	Location	Introduced	Deprecated
10.0.0.1:3306, 10.0.0.2:3306, undefined	Galera		

wsrep_last_committed

The sequence number, or seqno, of the last committed transaction. See *wsrep API* (page 47).

```
SHOW STATUS LIKE 'wsrep_last_committed';

+----------------------+--------+
| Variable_name        | Value  |
+----------------------+--------+
| wsrep_last_committed | 409745 |
+----------------------+--------+
```

Note: **See Also**: For more information, see *wsrep API* (page 47).

Example Value	Location	Introduced	Deprecated
409745	Galera		

wsrep_local_bf_aborts

Total number of local transactions that were aborted by slave transactions while in execution.

```
SHOW STATUS LIKE 'wsrep_local_bf_aborts';

+-----------------------+-------+
| Variable_name         | Value |
+-----------------------+-------+
| wsrep_local_bf_aborts | 960   |
+-----------------------+-------+
```

Example Value	Location	Introduced	Deprecated
960	Galera		

wsrep_local_cached_downto

The lowest sequence number, or seqno, in the write-set cache (GCache).

```
SHOW STATUS LIKE 'wsrep_local_cached_downto';

+---------------------------+----------------------+
| Variable_name             | Value                |
+---------------------------+----------------------+
| wsrep_local_cached_downto | 18446744073709551615 |
+---------------------------+----------------------+
```

Example Value	Location	Introduced	Deprecated
18446744073709551615	Galera		

wsrep_local_cert_failures

Total number of local transactions that failed certification test.

```
SHOW STATUS LIKE 'wsrep_local_cert_failures';

+---------------------------+-------+
| Variable_name             | Value |
+---------------------------+-------+
| wsrep_local_cert_failures | 333   |
+---------------------------+-------+
```

Example Value	Location	Introduced	Deprecated
333	Galera		

wsrep_local_commits

Total number of local transactions committed.

```
SHOW STATUS LIKE 'wsrep_local_commits';

+---------------------+-------+
| Variable_name       | Value |
+---------------------+-------+
| wsrep_local_commits | 14981 |
+---------------------+-------+
```

Example Value	Location	Introduced	Deprecated
14981	Galera		

wsrep_local_index

This node index in the cluster (base 0).

```
SHOW STATUS LIKE 'wsrep_local_index';

+-------------------+-------+
| Variable_name     | Value |
+-------------------+-------+
| wsrep_local_index | 1     |
+-------------------+-------+
```

Example Value	Location	Introduced	Deprecated
1	MySQL		

wsrep_local_recv_queue

Current (instantaneous) length of the recv queue.

```
SHOW STATUS LIKE 'wsrep_local_recv_queue';

+------------------------+-------+
| Variable_name          | Value |
+------------------------+-------+
| wsrep_local_recv_queue | 0     |
+------------------------+-------+
```

Example Value	Location	Introduced	Deprecated
0	Galera		

wsrep_local_recv_queue_avg

Recv queue length averaged over interval since the last FLUSH STATUS command. Values considerably larger than 0.0 mean that the node cannot apply write-sets as fast as they are received and will generate a lot of replication throttling.

```
SHOW STATUS LIKE 'wsrep_local_recv_queue_avg';

+----------------------------+----------+
| Variable_name              | Value    |
+----------------------------+----------+
| wsrep_local_recv_queue_avg | 3.348452 |
+----------------------------+----------+
```

Example Value	Location	Introduced	Deprecated
3.348452	Galera		

wsrep_local_recv_queue_max

The maximum length of the recv queue since the last FLUSH STATUS command.

```
SHOW STATUS LIKE 'wsrep_local_recv_queue_max';

+----------------------------+-------+
| Variable_name              | Value |
+----------------------------+-------+
| wsrep_local_recv_queue_max | 10    |
+----------------------------+-------+
```

Example Value	Location	Introduced	Deprecated
10	Galera		

wsrep_local_recv_queue_min

The minimum length of the recv queue since the last FLUSH STATUS command.

```
SHOW STATUS LIKE 'wsrep_local_recv_queue_min';

+-----------------------------+-------+
| Variable_name               | Value |
+-----------------------------+-------+
| wsrep_local_recev_queue_min | 0     |
+-----------------------------+-------+
```

Example Value	Location	Introduced	Deprecated
0	Galera		

wsrep_local_replays

Total number of transaction replays due to *asymmetric lock granularity*.

```
SHOW STATUS LIKE 'wsrep_local_replays';

+---------------------+-------+
| Variable_name       | Value |
+---------------------+-------+
| wsrep_lcoal_replays | 0     |
+---------------------+-------+
```

Example Value	Location	Introduced	Deprecated
0	Galera		

wsrep_local_send_queue

Current (instantaneous) length of the send queue.

```
SHOW STATUS LIKE 'wsrep_local_send_queue';

+------------------------+-------+
| Variable_name          | Value |
+------------------------+-------+
| wsrep_local_send_queue | 1     |
+------------------------+-------+
```

Example Value	Location	Introduced	Deprecated
1	Galera		

wsrep_local_send_queue_avg

Send queue length averaged over time since the last `FLUSH STATUS` command. Values considerably larger than 0.0 indicate replication throttling or network throughput issue.

```
SHOW STATUS LIKE 'wsrep_local_send_queue_avg';

+----------------------------+----------+
| Variable_name              | Value    |
+----------------------------+----------+
| wsrep_local_send_queue_avg | 0.145000 |
+----------------------------+----------+
```

Example Value	Location	Introduced	Deprecated
0.145000	Galera		

wsrep_local_send_queue_max

The maximum length of the send queue since the last `FLUSH STATUS` command.

```
SHOW STATUS LIKE 'wsrep_local_send_queue_max';

+----------------------------+-------+
| Variable_name              | Value |
+----------------------------+-------+
| wsrep_local_send_queue_max | 10    |
+----------------------------+-------+
```

Example Value	Location	Introduced	Deprecated
10	Galera		

wsrep_local_send_queue_min

The minimum length of the send queue since the last `FLUSH STATUS` command.

```
SHOW STATUS LIKE 'wsrep_local_send_queue_min';

+----------------------------+-------+
| Variable_name              | Value |
+----------------------------+-------+
| wsrep_local_send_queue_min | 0     |
+----------------------------+-------+
```

Example Value	Location	Introduced	Deprecated
0	Galera		

wsrep_local_state

Internal Galera Cluster FSM state number.

```
SHOW STATUS LIKE 'wsrep_local_state';

+-------------------+-------+
| Variable_name     | Value |
+-------------------+-------+
| wsrep_local_state | 4     |
+-------------------+-------+
```

Note: **See Also**: For more information on the possible node states, see *Node State Changes* (page 58).

Example Value	Location	Introduced	Deprecated
4	Galera		

wsrep_local_state_comment

Human-readable explanation of the state.

```
SHOW STATUS LIKE 'wsrep_local_state_comment';

+---------------------------+--------+
| Variable_name             | Value  |
+---------------------------+--------+
| wsrep_local_state_comment | Synced |
+---------------------------+--------+
```

Example Value	Location	Introduced	Deprecated
Synced	Galera		

wsrep_local_state_uuid

The UUID of the state stored on this node.

```
SHOW STATUS LIKE 'wsrep_local_state_uuid';

+------------------------+--------------------------------------+
| Variable_name          | Value                                |
+------------------------+--------------------------------------+
| wsrep_local_state_uuid | e2c9a15e-5485-11e0-0800-6bbb637e7211 |
+------------------------+--------------------------------------+
```

Note: See Also: For more information on the state UUID, see *wsrep API* (page 47).

Example Value	Location	Introduced	Deprecated
e2c9a15e-5385-11e0- 0800-6bbb637e7211	Galera		

wsrep_protocol_version

The version of the wsrep Protocol used.

```
SHOW STATUS LIKE 'wsrep_protocol_version';

+------------------------+-------+
| Variable_name          | Value |
+------------------------+-------+
| wsrep_protocol_version | 4     |
+------------------------+-------+
```

Example Value	Location	Introduced	Deprecated
4	Galera		

wsrep_provider_name

The name of the wsrep Provider.

```
SHOW STATUS LIKE 'wsrep_provider_name';

+---------------------+--------+
| Variable_name       | Value  |
+---------------------+--------+
| wsrep_provider_name | Galera |
+---------------------+--------+
```

Example Value	Location	Introduced	Deprecated
Galera	MySQL		

wsrep_provider_vendor

The name of the wsrep Provider vendor.

```
SHOW STATUS LIKE 'wsrep_provider_vendor';

+-----------------------+-----------------------------------+
| Variable_name         | Value                             |
+-----------------------+-----------------------------------+
| wsrep_provider_vendor | Codership Oy <info@codership.com> |
+-----------------------+-----------------------------------+
```

Example Value	Location	Introduced	Deprecated
Codership Oy <info@codership.com>	MySQL		

wsrep_provider_version

The name of the wsrep Provider version string.

```
SHOW STATUS LIKE 'wsrep_provider_version';

+------------------------+----------------------+
| Variable_name          | Value                |
+------------------------+----------------------+
| wsrep_provider_version | 25.3.5-wheezy(rXXXX) |
+------------------------+----------------------+
```

Example Value	Location	Introduced	Deprecated
25.3.5-wheezy(rXXXX)	MySQL		

wsrep_ready

Whether the server is ready to accept queries. If this status is `OFF`, almost all of the queries will fail with:

```
ERROR 1047 (08S01) Unknown Command
```

unless the `wsrep_on` session variable is set to `0`.

```
SHOW STATUS LIKE 'wsrep_ready';

+---------------+-------+
| Variable_name | Value |
+---------------+-------+
| wsrep_ready   | ON    |
+---------------+-------+
```

Example Value	Location	Introduced	Deprecated
ON	MySQL		

wsrep_received

Total number of write-sets received from other nodes.

```
SHOW STATUS LIKE 'wsrep_received';

+----------------+-------+
| Variable_name  | Value |
```

```
+----------------+--------+
| wsrep_received | 17831  |
+----------------+--------+
```

Example Value	Location	Introduced	Deprecated
17831	Galera		

wsrep_received_bytes

Total size of write-sets received from other nodes.

```
SHOW STATUS LIKE 'wsrep_received_bytes';

+----------------------+---------+
| Variable_name        | Value   |
+----------------------+---------+
| wsrep_received_bytes | 6637093 |
+----------------------+---------+
```

Example Value	Location	Introduced	Deprecated
6637093	Galera		

wsrep_repl_data_bytes

Total size of data replicated.

```
SHOW STATUS LIKE 'wsrep_repl_data_bytes';

+-----------------------+---------+
| Variable_name         | Value   |
+-----------------------+---------+
| wsrep_repl_data_bytes | 6526788 |
+-----------------------+---------+
```

Example Value	Location	Introduced	Deprecated
6526788	Galera		

wsrep_repl_keys

Total number of keys replicated.

```
SHOW STATUS LIKE 'wsrep_repl_keys';

+-----------------+--------+
| Variable_name   | Value  |
+-----------------+--------+
| wsrep_repl_keys | 797399 |
+-----------------+--------+
```

Example Value	Location	Introduced	Deprecated
797399	Galera		

wsrep_repl_keys_bytes

Total size of keys replicated.

```
SHOW STATUS LIKE 'wsrep_repl_keys_bytes';

+-----------------------+----------+
| Variable_name         | Value    |
+-----------------------+----------+
| wsrep_repl_keys_bytes | 11203721 |
+-----------------------+----------+
```

Example Value	Location	Introduced	Deprecated
11203721	Galera		

wsrep_repl_other_bytes

Total size of other bits replicated.

```
SHOW STATUS LIKE 'wsrep_repl_other_bytes';

+------------------------+-------+
| Variable_name          | Value |
+------------------------+-------+
| wsrep_repl_other_bytes | 0     |
+------------------------+-------+
```

Example Value	Location	Introduced	Deprecated
0	Galera		

wsrep_replicated

Total number of write-sets replicated (sent to other nodes).

```
SHOW STATUS LIKE 'wsrep_replicated';

+------------------+-------+
| Variable_name    | Value |
+------------------+-------+
| wsrep_replicated | 16109 |
+------------------+-------+
```

Example Value	Location	Introduced	Deprecated
16109	Galera		

wsrep_replicated_bytes

Total size of write-sets replicated.

```
SHOW STATUS LIKE 'wsrep_replicated_bytes';

+------------------------+---------+
| Variable_name          | Value   |
```

```
+------------------------+---------+
| wsrep_replicated_bytes | 6526788 |
+------------------------+---------+
```

Example Value	Location	Introduced	Deprecated
6526788	Galera		

CHAPTER

FORTYTHREE

XTRABACKUP PARAMETERS

When using `xtrabackup-v2` as your *State Snapshot Transfer* method, you can fine tune how the script operates using the `[sst]` unit in the `my.cnf` configuration file.

```
[mysqld]
wsrep_sst_method=xtrabackup-v2

[sst]
compressor="gzip"
decompressor="gzip -dc"
rebuild=ON
compact=ON
encrypt=3
tkey="/path/to/key.pem"
tcert="/path/to/cert.pem"
tca="/path/to/ca.pem"
```

Bear in mind, some XtraBackup parameters require that you match the configuration on donor and joiner nodes, (as designated in the table below).

Option	Default	Match
compressor (page 285)		
cpat (page 286)	`0`	
decompressor (page 286)		
encrypt (page 287)	`0`	Yes
encrypt-algo (page 287)		
progress (page 287)		
rebuild (page 288)	`0`	
rlimit (page 288)		
sst_initial_timeout (page 288)	`100`	
sst_special_dirs (page 289)	`1`	
sockopt (page 289)		
streamfmt (page 289)	`xbstream`	Yes
tca (page 290)		
tcert (page 290)		
time (page 290)	`0`	
transferfmt (page 291)	`socat`	Yes

`compressor`

Defines the compression utility the donor node uses to compress the state transfer.

System Variable	*Name:*	`compressor`
	Match:	Yes
Permitted Values	*Type:*	String
	Default Value:	

This parameter defines whether the donor node performs compression on the state transfer stream. It also defines what compression utility it uses to perform the operation. You can use any compression utility which works on a stream, such as `gzip` or `pigz`. Given that the joiner node must decompress the state transfer before attempting to read it, you must match this parameter with the *decompressor* (page 286) parameter, using the appropriate flags for each.

```
compression="gzip"
```

`compact`

Defines whether the joiner node performs compaction when rebuilding indexes after applying a *State Snapshot Transfer*.

System Variable	*Name:*	`compact`
	Match:	No
Permitted Values	*Type:*	Boolean
	Default Value:	`OFF`

This parameter operates on the joiner node with the *rebuild* (page 288) parameter. When enabled, the node performs compaction when rebuilding indexes after applying a state transfer.

```
rebuild=ON
compact=ON
```

`cpat`

Defines what files to clean up from the datadir during state transfers.

System Variable	*Name:*	`cpat`
	Match:	No
Permitted Values	*Type:*	String
	Default Value:	

When the donor node begins a *State Snapshot Transfer*, it cleans up various files from the datadir. This ensures that the joiner node can cleanly apply the state transfer. With this parameter, you can define what files you want the node to delete before the state transfer.

```
cpat=".*glaera\.cache$\|.*sst_in_progress$\|.*grastate\.dat$\|.*\.err"
```

`decompressor`

Defines the decompression utility the joiner node uses to decompress the state transfer.

System Variable	*Name:*	`decompressor`
	Match:	No
Permitted Values	*Type:*	String
	Default Value:	

This parameter defines whether the joiner node performs decompression on the state transfer stream. It also defines what decompression utility it uses to perform the operation. You can use any compression utility which works on a stream, such as gzip or pigz. Given that the donor node must compress the state transfer before sending it, you must match this parameter with the *compressor* (page 285) parameter, using the appropriate flags for each.

```
decompressor="gzip -dc"
```

encrypt

Defines whether the node uses SSL encryption for XtraBackup and what kind of encryption it uses.

System Variable	*Name:*	encrypt
	Match:	Yes
Permitted Values	*Type:*	Integer
	Default Value:	0

This parameter determines the type of SSL encryption the node uses when sending state transfers through xtrabackup. The recommended type is 2 when using the cluster over WAN.

Value	Description
0	No encryption.
1	The node encrypts State Snapshot Transfers through XtraBackup.
2	The node encrypts State Snapshot Transfers through OpenSSL, using Socat.
3	The node encrypts State Snapshot Transfers through the key and certificate files implemented for Galera Cluster.

```
encrypt=3
tkey="/path/to/key.pem"
tcert="/path/to/cert.pem"
tca="/path/to/ca.pem"
```

encrypt-algo

Defines the SSL encryption type the node uses for XtraBackup state transfers.

System Variable	*Name:*	encrypt-algo
	Match:	No
Permitted Values	*Type:*	Integer
	Default Value:	0

When using the *encrypt* (page 287) parameter in both the [xtrabackup] and [sst] units, there is a potential issue in it having different meanings according to the unit under which it occurs. That is, in [xtrabackup], it turns encryption on while in [sst] it both turns it on as specifies the algorithm.

In the event that you need to clarify the meaning, this parameter allows you to define the encryption algorithm separately from turning encryption on. It is only read in the event that *encrypt* (page 287) is set to 1

```
encrypt=1
encrypt-algo=3
```

progress

Defines whether where the node reports *State Snapshot Transfer* progress.

System Variable	*Name:*	`progress`
	Match:	No
Permitted Values	*Type:*	String
	Default Value:	
	Valid Values:	`1`
		/path/to/file

When you set this parameter, the node reports progress on XtraBackup progress in state transfers. If you set the value to `1`, the node makes these reports to the database server stderr. If you set the value to a file path, it writes the progress to that file.

Note: Bear in mind, that a `0` value is invalid. If you want to disable this parameter, delete or comment it out.

```
progress="/var/log/mysql/xtrabackup-progress.log"
```

`rebuild`

Defines whether the joiner node rebuilds indexes during a *State Snapshot Transfer*.

System Variable	*Name:*	`rebuild`
	Match:	No
Permitted Values	*Type:*	Boolean
	Default Value:	`OFF`

This parameter operates on the joiner node. When enabled, the node rebuilds indexes when applying the state transfer. Bear in mind, this operation is separate from compaction. Due to Bug #1192834, it is recommended that you use this parameter with *compact* (page 286).

```
rebuild=ON
compact=ON
```

`rlimit`

Defines the rate limit for the donor node.

System Variable	*Name:*	`rlimit`
	Match:	No
Permitted Values	*Type:*	Integer
	Default Value:	

This parameter allows you to definite the rate-limit the donor node. This allows you to keep state transfers from blocking regular cluster operations.

```
rlimit=300M
```

`sst_initial_timeout`

Defines the initial timeout to receive the first state transfer packet.

System Variable	*Name:*	`sst_initial_timeout`
	Match:	No
Permitted Values	*Type:*	Integer
	Default Value:	`100`

This parameter determines the initial timeout in seconds for the joiner to receive the first packet in a *State Snapshot Transfer*. This keeps the joiner node from hanging in the event that the donor node crashes while starting the operation.

```
sst_initial_timeout=130
```

sst_special_dirs

Defines whether the node uses special InnoDB home and log directories.

System Variable	*Name:*	`sst_special_dirs`
	Match:	No
Permitted Values	*Type:*	Boolean
	Default Value:	`OFF`

This parameter enables support for `innodb_data_home_dir` and `innodb_log_home_dir` parameters for XtraBackup. It requires that you define `innodb_data_home_dir` and `innodb_log_group_home_dir` in the `[mysqld]` unit.

```
[mysqld]
innodb_data_home_dir="/var/mysqld/innodb"
innodb_log_group_home_dir="/var/log/innodb"
wsrep_sst_method="xtrabackup-v2"

[sst]
sst_special_dirs=TRUE
```

sockopt

Defines socket options.

System Variable	*Name:*	`sockopt`
	Match:	No
Permitted Values	*Type:*	String
	Default Value:	

This parameter allows you to define one or more socket options for XtraBackup using the Socat transfer format.

streamfmt

Defines the stream formatting utility.

System Variable	*Name:*	`streamfmt`
	Match:	Yes
Permitted Values	*Type:*	String
	Default Value:	`xbstream`
	Valid Values:	`tar`
		`xbstream`

This parameter defines the utility the node uses to archive the node state before the transfer is sent and how to unarchive the state transfers that is receives. There are two methods available: `tar` and `xbstream`. Given that the receiving node needs to know how to read the stream, it is necessary that both nodes use the same values for this parameter.

The default and recommended utility is `xbstream` given that it supports encryption, compression, parallel streaming, incremental backups and compaction. `tar` does not support these features.

```
streamfmt='xbstream'
```

`tca`

Defines the Certificate Authority (CA) to use in SSL encryption.

System Variable	*Name:*	`tca`
	Match:	No
Permitted Values	*Type:*	path
	Default Value:	

This parameter defines the Certificate Authority (CA) file that the node uses with XtraBackup state transfers. In order to use SSL encryption with XtraBackup, you must configure the *transferfmt* (page 291) parameter to use `socat`.

Note: For more information on using Socat with encryption, see Securing Traffic between Two Socat Instances using SSL.

```
transferfmt="socat"
tca="/path/to/ca.pem"
```

`tcert`

Defines the certificate to use in SSL encryption.

System Variable	*Name:*	`tcert`
	Match:	No
Permitted Values	*Type:*	String
	Default Value:	

This parameter defines the SSL certificate file that the node uses with SSL encryption on XtraBackup state transfers. In order to use SSL encryption with XtraBackup, you must configure the *transferfmt* (page 291) parameter to use Socat.

Note: For more information on using Socat with encryption, see Securing Traffic between Two Socat Instances using SSL.

```
transferfmt="socat"
tcert="/path/to/cert.pem"
```

`time`

Defines whether XtraBackup instruments key stages in the backup and restore process for state transfers.

System Variable	*Name:*	`time`
	Match:	No
Permitted Values	*Type:*	Boolean
	Default Value:	`OFF`

This parameter instruments key stages of the backup and restore process for state transfers.

```
time=ON
```

`transferfmt`

Defines the transfer stream utility.

System Variable	*Name:*	`transferfmt`
	Match:	Yes
Permitted Values	*Type:*	String
	Default Value:	`socat`
	Valid Values:	`socat`
		`nc`

This parameter defines the utility that the node uses to format transfers sent from donor to joiner nodes. There are two methods supported: Socat and `nc`. Given that the receiving node needs to know how to interpret the transfer, it is necessary that both nodes use the same values for this parameter.

The default and recommended utility is Socat, given that it allows for socket options, such as transfer buffer size. For more information, see the socat Documentation.

```
transferfmt="socat"
```

CHAPTER

FORTYFOUR

GALERA LOAD BALANCER PARAMETERS

Galera Load Balancer provides simple TCP connection balancing developed with scalability and performance in mind. It draws on Pen for inspiration, but its functionality is limited to only balancing TCP connections.

It can be run either through the `service` command or the command-line interface of `glbd`. Configuration for Galera Load Balancer depends on which you use to run it.

Configuration Parameters

When Galera Load Balancer starts as a system service, it reads the `glbd.cfg` configuration file for default parameters you want to use. Only the *LISTEN_ADDR* (page 294) parameter is mandatory.

Parameter	Default Configuration
CONTROL_ADDR (page 293)	`127.0.0.1:8011`
CONTROL_FIFO (page 293)	`/var/run/glbd.fifo`
DEFAULT_TARGETS (page 294)	`127.0.0.1:80 10.0.1:80 10.0.0.2:80`
LISTEN_ADDR (page 294)	`8010`
MAX_CONN (page 294)	
OTHER_OPTIONS (page 294)	
THREADS (page 295)	`2`

CONTROL_ADDR

Defines the IP address and port for controlling connections.

Command-line Argument	*–control* (page 296)
Default Configuration	`127.0.0.1:8011`
Mandatory Parameter	No

This is an optional parameter. Use it to define the server used in controlling client connections. When using this parameter you must define the port. In the event that you do not define this parameter, Galera Load Balancer does not open the relevant socket.

```
CONTROL_ADDR="127.0.0.1:8011"
```

CONTROL_FIFO

Defines the path to the FIFO control file.

Command-line Argument	*–fifo* (page 297)
Default Configuration	`/var/run/glbd.fifo`
Mandatory Parameter	No

This is an optional parameter. It defines the path to the FIFO control file as is always opened. In the event that there is already a file at this path, Galera Load Balancer fails to start.

```
CONTROL_FIFO="/var/run/glbd.fifo"
```

DEFAULT_TARGETS

Defines the IP addresses and ports of the destination servers.

Default Configuration	`127.0.0.1:80 10.0.0.1:80 10.0.0.2:80:2`
Mandatory Parameter	No

This parameter defines that IP addresses that Galera Load Balancer uses as destination servers. Specifically, in this case the Galera Cluster nodes that it routes application traffic onto.

```
DEFAULT_TARGETS="192.168.1.1 192.168.1.2 192.168.1.3"
```

LISTEN_ADDR

Defines the IP address and port used for client connections.

Default Configuration	`8010`
Mandatory Parameter	Yes

This parameter defines the IP address and port that Galera Load Balancer listens on for incoming client connections. The IP address is optional, the port mandatory. In the event that you define a port without an IP address, Galera Load Balancer listens on that port for all available network interfaces.

```
LISTEN_ADDR="8010"
```

MAX_CONN

Defines the maximum allowed client connections.

Command-line Argument	*–max_conn* (page 298)
Mandatory Parameter	No

This parameter defines the maximum number of client connections that you want to allow to Galera Load Balancer. It modifies the system open files limit to accommodate at least this many connections, provided sufficient privileges. It is recommend that you define this parameter if you expect the number of client connections to exceed five hundred.

```
MAX_CONN="135"
```

This option defines the maximum number of client connections that you want allow to Galera Load Balancer. Bear in mind, that it can be operating system dependent.

OTHER_OPTIONS

Defines additional options that you want to pass to Galera Load Balancer.

Mandatory Parameter	No

This parameter defines various additional options that you would like to pass to Galera Load Balancer, such as a destination selection policy or Watchdog configurations. Use the same syntax as you would for the command-line arguments. For more information on the available options, see *Configuration Options* (page 295).

```
OTHER_OPTIONS="--random --watchdog exec:'mysql -utest -ptestpass' --discover"
```

THREADS

Defines the number of threads you want to use.

Command-line Argument	*–threads* (page 300)
Mandatory Parameter	No

This parameter allows you to define the number of threads (that is, connection pools), which you want to allow Galera Load Balancer to use. It is advisable that you have at least a few per CPU core.

```
THREADS="6"
```

Configuration Options

When Galera Load Balancer starts as a daemon process, through the `/sbin/glbd` command, it allows you to pass a number of command-line arguments to configure how it operates. It uses the following syntax:

```
/usr/local/sbin/glbd [OPTIONS] LISTEN_ADDRESS [DESTINATION_LIST]
```

In the event that you would like to set any of these options when you run Galera Load Balancer as a service, you can define them through the *OTHER_OPTIONS* (page 294) parameter.

Long Argument	Short	Type	Parameter
–control (page 296)	`-c`	IP address	*CONTROL_ADDR* (page 293)
–daemon (page 296)	`-d`	Boolean	
–defer-accept (page 296)	`-a`	Boolean	
–discover (page 296)	`-D`	Boolean	
–extra (page 297)	`-x`	Decimal	
–fifo (page 297)	`-f`	File Path	*CONTROL_FIFO* (page 293)
–interval (page 297)	`-i`	Decimal	
–keepalive (page 297)	`-K`	Boolean	
–latency (page 298)	`-L`	Integer	
–linger (page 298)	`-l`	Boolean	
–max_conn (page 298)	`-m`	Integer	*MAX_CONN* (page 294)
–nodelay (page 299)	`-n`	Boolean	
–random (page 299)	`-r`	Boolean	
–round (page 299)	`-b`	Boolean	
–single (page 299)	`-S`	Boolean	
–source (page 300)	`-s`	Boolean	
–threads (page 300)	`-t`	Integer	*THREADS* (page 295)
–top (page 300)	`-T`	Boolean	
–verbose (page 301)	`-v`	Boolean	
–watchdog (page 301)	`-w`	String	

--control

Defines the IP address and port for control connections.

Short Argument	`-c`
Syntax	`--control [IP|Hostname:]port`
Type	IP Address
Configuration Parameter	*CONTROL_ADDR* (page 293)

For more information on defining the controlling connections, see the *CONTROL_ADDR* (page 293) parameter.

```
# glbd --control 192.168.1.1:80 3306 \
      192.168.1.1 192.168.1.2 192.168.1.3
```

--daemon

Defines whether you want Galera Load Balancer to run as a daemon process.

Short Argument	`-d`
Syntax	`--daemon`
Type	Boolean

This option defines whether you want to start `glbd` as a daemon process. That is, if you want it to run in the background, instead of claiming the current terminal session.

```
# glbd --daemon 3306 \
      192.168.1.1 192.168.1.2 192.168.1.3
```

--defer-accept

Enables TCP deferred acceptance on the listening socket.

Short Argument	`-a`
Syntax	`--defer-accept`
Type	Boolean

Enabling `TCP_DEFER_ACCEPT` allows Galera Load Balancer to awaken only when data arrives on the listening socket. It is disabled by default.

```
# glbd --defer-accept 3306 \
      192.168.1.1 192.168.1.2 192.168.1.3
```

--discover

Defines whether you want to use watchdog results to discover and set new destinations.

Short Argument	`-D`
Syntax	`--discover`
Type	Boolean

When you define the *–watchdog* (page 301) option, this option defines whether Galera Load Balancer uses the return value in discovering and setting new addresses for destination servers. For instance, after querying for the *wsrep_cluster_address* (page 217) parameter.

```
# glbd --discover -w exec:"mysql.sh -utest -ptestpass" 3306 \
     192.168.1.1 192.168.1.2 192.168.1.3
```

--extra

Defines whether you want to perform an extra destination poll on connection attempts.

Short Argument	`-x`
Syntax	`--extra D.DDD`
Type	Decimal

This option defines whether and when you want Galera Load Balancer to perform an additional destination poll on connection attempts. The given value indicates how many seconds after the previous poll that you want it to run the extra poll. By default, the extra polling feature is disabled.

```
# glbd --extra 1.35 3306 \
     192.168.1.1 192.168.1.2 192.168.1.3
```

--fifo

Defines the path to the FIFO control file.

Short Argument	`-f`
Syntax	`--fifo /path/to/glbd.fifo`
Type	File Path
Configuration Parameter	*CONTROL_FIFO* (page 293)

For more information on using FIFO control files, see the *CONTROL_FIFO* (page 293) parameter.

```
# glbd --fifo /var/run/glbd.fifo 3306 \
     192.168.1.1 192.168.1.2 192.168.1.3
```

--interval

Defines how often to probe destinations for liveliness.

Short Argument	`-i`
Syntax	`--interval D.DDD`
Type	Decimal

This option defines how often Galera Load Balancer checks destination servers for liveliness. It uses values given in seconds. By default, it checks every second.

```
# glbd --interval 2.013 3306 \
     192.168.1.1 192.168.1.2 192.168.1.3
```

--keepalive

Defines whether you want to disable the `SO_KEEPALIVE` socket option on server-side sockets.

Short Argument	`-K`
Syntax	`--keepalive`
Type	Boolean

Linux systems feature the socket option `SO_KEEPALIVE`, which causes the server to send packets to a remote system in order to main the client connection with the destination server. This option allows you to disable `SO_KEEPALIVE` on server-side sockets. It allows `SO_KEEPALIVE` by default.

```
# glbd --keepalive 3306 \
     192.168.1.1 192.168.1.2 192.168.1.3
```

--latency

Defines the number of samples to take in calculating latency for watchdog.

Short Argument	`-L`
Syntax	`--latency N`
Type	Integer

When the Watchdog module tests a destination server to calculate latency, it sends a number of packets through to measure its responsiveness. This option configures how many packets it sends in sampling latency.

```
# glbd --latency 25 3306 \
     192.168.1.1 192.168.1.2 192.168.1.3
```

--linger

Defines whether Galera Load Balancer disables sockets lingering after they are closed.

Short Argument	`-l`
Syntax	`--linger`
Type	Boolean

When Galera Load Balancer sends the `close()` command, occasionally sockets linger in a `TIME_WAIT` state. This options defines whether or not you want Galera Load Balancer to disable lingering sockets.

```
# glbd --linger 3306 \
     192.168.1.1 192.168.1.2 192.168.1.3
```

--max_conn

Defines the maximum allowed client connections.

Short Argument	`-m`
Syntax	`--max_conn N`
Type	Integer

For more information on defining the maximum client connections, see the *MAX_CONN* (page 294) parameter.

```
# glbd --max_conn 125 3306 \
     192.168.1.1 192.168.1.2 192.168.1.3
```

`--nodelay`

Defines whether it disables the TCP no-delay socket option.

Short Argument	`-n`
Syntax	`--nodelay`
Type	Boolean

Under normal operation, TCP connections automatically concatenate small packets into larger frames through the Nagle algorithm. In the event that you want Galera Load Balancer to disable this feature, this option causes it to open TCP connections with the `TCP_NODELAY` feature.

```
# glbd --nodelay 3306 \
      192.168.1.1 192.168.1.2 192.168.1.3
```

`--random`

Defines the destination selection policy as Random.

Short Argument	`-r`
Syntax	`--random`
Type	Boolean

The destination selection policy determines how Galera Load Balancer determines which servers to route traffic to. When you set the policy to Random, it randomly chooses a destination from the pool of available servers. You can enable this feature by default through the *OTHER_OPTIONS* (page 294) parameter.

For more information on other policies, see *Destination Selection Policies* (page 134).

```
# glbd --random 3306 \
      192.168.1.1 192.168.1.2 192.168.1.3
```

`--round`

Defines the destination selection policy as Round Robin.

Short Argument	`-b`
Syntax	`--round`
Type	Boolean

The destination selection policy determines how Galera Load Balancer determines which servers to route traffic to. When you set the policy to Round Robin, it directs new connections to the next server in a circular order list. You can enable this feature by default through the *OTHER_OPTIONS* (page 294) parameter.

For more information on other policies, see *Destination Selection Policies* (page 134).

```
# glbd --round 3306 \
      192.168.1.1 192.168.1.2 192.168.1.3
```

`--single`

Defines the destination selection policy as Single.

Short Argument	`-S`
Syntax	`--single`
Type	Boolean

The destination selection policy determines how Galera Load Balancer determines which servers to route traffic to.

When you set the policy to Single, all connections route to the server with the highest weight value. You can enable this by default through the *OTHER_OPTIONS* (page 294) parameter.

```
# glbd --single 3306 \
     192.168.1.1 192.168.1.2 192.168.1.3
```

--source

Defines the destination selection policy as Source Tracking.

Short Argument	`-s`
Syntax	`--source`
Type	Boolean

The destination selection policy determines how Galera Load Balancer determines which servers to route traffic to. When you set the policy to Source Tracking, connections that originate from one address are routed to the same destination. That is, you can ensure that certain IP addresses always route to the same destination server. You can enable this by default through the *OTHER_OPTIONS* (page 294) parameter.

Bear in mind, there are some limitations to this selection policy. When the destination list changes, the destination choice for new connections changes as well, while established connections remain in place. Additionally, when a destination is marked as unavailable, all connections that would route to it fail over to another, randomly chosen destination. When the original target becomes available again, routing to it for new connections resumes. In other words, Source Tracking works best with short-lived connections.

For more information on other policies, see *Destination Selection Policies* (page 134).

```
# glbd --source 3306 \
     192.168.1.1 192.168.1.2 192.168.1.3
```

--threads

Defines the number of threads that you want to use.

Short Argument	`-t`
Syntax	`--threads N`
Type	Integer

For more information on threading in Galera Load Balancer, see *THREADS* (page 295).

```
# glbd --threads 6 3306 \
     192.168.1.1 192.168.1.2 192.168.1.3
```

--top

Enables balancing to top weights only.

Short Argument	-T
Syntax	--top
Type	Boolean

This option restricts all balancing policies to a subset of destination servers with the top weight. For instance, if you have servers with weights 1, 2 and 3, balancing occurs only on servers with weight 3, while they remain available.

```
# glbd --top 3306 \
      192.168.1.1 192.168.1.2 192.168.1.3
```

--verbose

Defines whether you want Galera Load Balancer to run as verbose.

Short Argument	-v
Syntax	--verbose
Type	Boolean

This option enables verbose output for Galera Load Balancer, which you may find useful for debugging purposes.

```
# glbd --verbose 3306 \
      192.168.1.1 192.168.1.2 192.168.1.3
```

--watchdog

Defines specifications for watchdog operations.

Short Argument	-w
Syntax	--watchdog SPEC_STR
Type	String

Under normal operation, Galera Load Balancer checks destination availability by attempting to establish a TCP connection to the server. For most use cases, this is insufficient. If you want to establish a connection with web server, you need to know if it is able to serve web pages. If you want to establish a connection with a database server, you need to know if it is able to execute queries. TCP connections don't provide that kind of information.

The Watchdog module implements asynchronous monitoring of destination servers through back-ends designed to service availability. This option allows you to enable it by defining the back-end ID string, optionally followed by a colon and the configuration options.

```
# glbd -w exec:"mysql.sh -utest -ptestpass" 3306 \
      192.168.1.1 192.168.1.2 192.168.1.3
```

This initializes the exec back-end to execute external programs. It runs the mysql.sh script on each destination server in order to determine it's availability. You can find the mysql.sh in the Galera Load Balancer build directory, under files/.

Note: The Watchdog module remains a work in progress. Neither its functionality nor terminology is final.

CHAPTER

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VERSIONING INFORMATION

Galera Cluster for MySQL is available in binary software packages for several different Linux distributions, as well as in source code for other distributions and other Unix-like operating systems, such as FreeBSD and Solaris.

For Linux distributions, binary packages in 32-bit and 64-bit for both the MySQL database server with the wsrep API patch and the *Galera Replication Plugin* are available from the Codership Repository. These include support for:

- Red Hat Enterprise Linux
- Fedora
- CentOS
- SUSE Linux Enterprise Server
- openSUSE
- Debian
- Ubuntu

By installing and configuring the Codership Repository on any of these systems, you can install and update Galera Cluster for MySQL through your package manager. In the event that you use a distribution of Linux that is not supported, or if you use another Unix-like operating system, source files are available on GitHub, at:

- MySQL Server with the wsrep API patch.
- Galera Replication Plugin.
- glb, the Galera Load Balancer.

For users of FreeBSD and similar operating systems, the Galera Replication Plugin is also available in ports, at `/usr/ports/databases/galera`, which corrects for certain compatibility issues with Linux dependencies.

Note: For more information on the installation process, see *Installation* (page 9).

Release Numbering Schemes

Software packages for Galera Cluster have their own release numbering schemas. There are two schemas to consider in version numbering:

- **Galera wsrep Provider** Also, referred to as the *Galera Replication Plugin*. The wsrep Provider uses the following versioning schema: `<wsrep API main version>.<Galera version>`. For example, release 24.2.4 indicates wsrep API version 24.x.x with Galera wsrep Provider version 2.4.

- **MySQL Server with wsrep API patch** The second versioning schema relates to the database server. Here, the MySQL server uses the following versioning schema `<MySQL server version>-<wsrep API version>`. For example, release 5.5.29-23.7.3 indicates a MySQL database server in 5.5.29 with wsrep API version 23.7.3.

For instances of Galera Cluster that use the MariaDB or Percona XtraDB database servers, consult their respective documentation for version and release information.

Third-party Implementations of Galera Cluster

In addition to the Galera Cluster for MySQL, the reference implementation from Codership Oy, there are two third party implementations of Galera Cluster. These are,

- Percona XtraDB Cluster is a high-availability and high-scalability solution for MySQL users. Percona XtraDB CLuster integrates Percona XtraDB Server with the Galera library of high-availability solutions in a single product package.
- MariaDB Galera Cluster uses the Galera library for the replication implementation. To interface with the Galera Replication Plugin, MariaDB is enhanced to support the replication API definition in the wsrep API project. Additionally, releases of MariaDB Server from version 10.1 on are packaged with Galera Cluster.

  For more information, see What is MariaDB Galera Cluster.

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GLOSSARY

Galera Arbitrator External process that functions as an additional node in certain cluster operations, such as quorum calculations and generating consistent application state snapshots.

Consider a situation where you cluster becomes partitioned due to a loss of network connectivity that results in two components of equal size. Each component initiates quorum calculations to determine which should remain the *Primary Component* and which should become a nonoperational component. If the components are of equal size, it risks a split-brain condition. Galera Arbitrator provides an addition vote in the quorum calculation, so that one component registers as larger than the other. The larger component then remains the Primary Component.

Unlike the main `mysqld` process, `garbd` does not generate replication events of its own and does not store replication data, but it does acknowledge all replication events. Furthermore, you can route replication through Galera Arbitrator, such as when generating a consistent application state snapshot for backups.

> **Note:** **See Also**: For more information, see *Galera Arbitrator* (page 115) and *Backing Up Cluster Data* (page 119).

Galera Replication Plugin Galera Replication Plugin is a general purpose replication plugin for any transactional system. It can be used to create a synchronous multi-master replication solution to achieve high availability and scale-out.

> **Note:** **See Also**: For more information, see *Galera Replication Plugin* (page 48) for more details.

GCache See *Write-set Cache*.

Global Transaction ID To keep the state identical on all nodes, the *wsrep API* uses global transaction IDs (GTID), which are used to both:

- Identify the state change
- Identify the state itself by the ID of the last state change

The GTID consists of:

- A state UUID, which uniquely identifies the state and the sequence of changes it undergoes
- An ordinal sequence number (seqno, a 64-bit signed integer) to denote the position of the change in the sequence

> **Note:** **See Also**: For more information on Global Transaction ID's, see *wsrep API* (page 47).

Incremental State Transfer In an Incremental State Transfer (IST) a node only receives the missing write-sets and catch up with the group by replaying them. See also the definition for State Snapshot Transfer (SST).

Note: See Also: For more information on IST's, see *Incremental State Transfer (IST)* (page 54).

IST See *Incremental State Transfer*.

Logical State Transfer Method Type of back-end state transfer method that operates through the database server. For example: `mysqldump`.

Note: See Also: For more information see, *Logical State Snapshot* (page 77).

NBO See *Non-Blocking Operation*.

Non-Blocking Operation The non-blocking operation schema upgrade is a DDL processing method, where the cluster replicates a limited subset of DDL statements without blocking reads or writes on the nodes during the process.

When the DDL statement starts, the relevant table is locked using metadata locks. The DDL statement is then replicated to all nodes in the cluster. The node apply the changes, then simultaneously release the locks.

DDL statements that support Non-Blocking Operation:

- `ALTER TABLE table_name LOCK = {SHARED|EXCLUSIVE}, alter_specification`
- `ALTER TABLE table_name LOCK = {SHARED|EXCLUSIVE} PARTITION`
- `ANALYZE TABLE`
- `OPTIMIZE TABLE`

Note: For partition management, no comma is used after `LOCK = {SHARED|EXCLUSIVE}`

DDL statements that do not support Non-Blocking Operation:

- `ALTER TABLE LOCK = {DEFAULT|NONE}`, including `ALTER` statements without the `LOCK` clause, as these default to the `DEFAULT` lock.
- `CREATE`, `RENAME`, `DROP` and `REPAIR`.

Issuing unsupported operations while using the Non-Blocking Operation method results in an error code.

Given its *limitations* (page 101), the recommended method for using this online schema upgrade method is to enable it as a session variable, update the schema, then reset *wsrep_OSU_method* (page 228) back to either `RSU` or `TOI`.

Physical State Transfer Method Type of back-end state transfer method that operates on the physical media in the datadir. For example: `rsync` and `xtrabackup`.

Note: See Also: For more information see, *Physical State Snapshot* (page 79).

Primary Component In addition to single node failures, the cluster may be split into several components due to network failure. In such a situation, only one of the components can continue to modify the database state to avoid history divergence. This component is called the Primary Component (PC).

Note: See Also: For more information on the Primary Component, see *Weighted Quorum* (page 63) for more details.

Rolling Schema Upgrade The rolling schema upgrade is a DDL processing method, where the DDL will only be processed locally at the node. The node is desynchronized from the cluster for the duration of the DDL processing in a way that it does not block the rest of the nodes. When the DDL processing is complete, the node applies the delayed replication events and synchronizes back with the cluster.

> **Note:** **See Also**: For more information, see *Rolling Schema Upgrade* (page 100).

RSU See *Rolling Schema Upgrade*.

seqno See *Sequence Number*.

sequence number 64-bit signed integer that the node uses to denote the position of a given transaction in the sequence. The seqno is second component to the *Global Transaction ID*.

SST See *State Snapshot Transfer*.

State Snapshot Transfer State Snapshot Transfer refers to a full data copy from one cluster node (donor) to the joining node (joiner). See also the definition for Incremental State Transfer (IST).

> **Note:** **See Also**: For more information, see *State Snapshot Transfer (SST)* (page 53).

State UUID Unique identifier for the state of a node and the sequence of changes it undergoes. It is the first component of the *Global Transaction ID*.

Streaming Replication Provides an alternative replication method for handling large or long-running write transactions. This is a new feature in version 4.0 of Galera Cluster. In older versions the feature is unsupported.

Under normal operation, the node performs all replication and certification operations when the transaction commits, which with large transactions can result in conflicts if smaller transactions are committed first. With Streaming Replication, the node breaks the transaction into fragments, then certifies and replicates them to all nodes while the transaction is still in progress. Once certified, a fragment can no longer be aborted by a conflicting transaction.

> **Note:** For more information see *Streaming Replication* (page 69) and *Using Streaming Replication* (page 103).

TOI See *Total Order Isolation*.

Total Order Isolation By default, DDL statements are processed by using the Total Order Isolation (TOI) method. In TOI, the query is replicated to the nodes in a statement form before executing on master. The query waits for all preceding transactions to commit and then gets executed in isolation on all nodes simultaneously.

> **Note:** **See Also**: For more information, see *Total Order Isolation* (page 99).

write-set Transaction commits the node sends to and receives from the cluster.

Write-set Cache Galera stores write-sets in a special cache called Write-set Cache (GCache). In short, GCache is a memory allocator for write-sets and its primary purpose is to minimize the write set footprint on the RAM.

> **Note:** **See Also**: For more information, see *Write-set Cache (GCache)* (page 54).

wsrep API The wsrep API is a generic replication plugin interface for databases. The API defines a set of application callbacks and replication plugin calls.

Note: **See Also**: For more information, see *wsrep API* (page 47).

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