Percona XtraDB Cluster Documentation

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CONTENTS

Percona XtraDB Cluster is a database clustering solution for MySQL. It ensures high availability, prevents downtime and data loss, and provides linear scalability for a growing environment.

Features of Percona XtraDB Cluster include:

- **Synchronous replication**

  Data is written to all nodes simultaneously, or not written at all if it fails even on a single node.

- **Multi-master replication**

  Any node can trigger a data update.

- **True parallel replication**

  Multiple threads on slave performing replication on row level.

- **Automatic node provisioning**

  You simply add a node and it automatically syncs.

- **Data consistency**

  No more unsynchronized nodes.

- **PXC Strict Mode**

  Avoids the use of experimental and unsupported features.

- **Configuration script for ProxySQL**

  Percona provides a ProxySQL package with the `proxysql-admin` tool that automatically configures Percona XtraDB Cluster nodes.

- **Automatic configuration of SSL encryption**

  Percona XtraDB Cluster includes the `pxc-encrypt-cluster-traffic` variable that enables automatic configuration of SSL encrytion.

- **Optimized Performance**

  Percona XtraDB Cluster performance is optimized to scale with a growing production workload.

  For more information, see the following blog posts:

  - How We Made Percona XtraDB Cluster Scale
  - Performance improvements in Percona XtraDB Cluster 5.7.17-29.20

Percona XtraDB Cluster is fully compatible with MySQL Server Community Edition, Percona Server, and MariaDB in the following sense:

- **Data compatibility**: You can use data created by any MySQL variant.
- **Application compatibility**: There is no or minimal application changes required.

Part I

Introduction

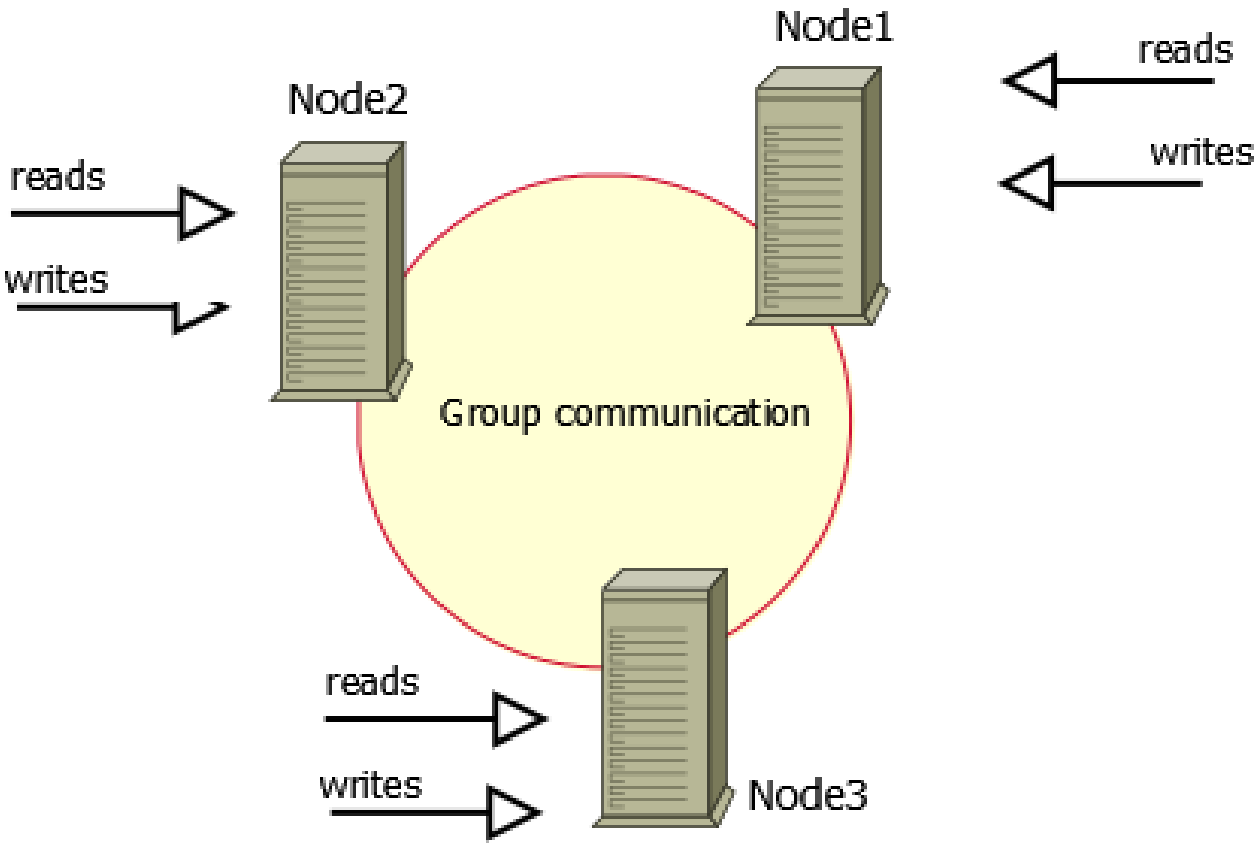
CHAPTER

ONE

ABOUT PERCONA XTRADB CLUSTER

Percona XtraDB Cluster is a fully open-source high-availability solution for MySQL. It integrates Percona Server and Percona XtraBackup with the Galera library to enable synchronous multi-master replication.

A *cluster* consists of *nodes*, where each node contains the same set of data synchronized accross nodes. The recommended configuration is to have at least 3 nodes, but you can have 2 nodes as well. Each node is a regular MySQL Server instance (for example, Percona Server). You can convert an existing MySQL Server instance to a node and run the cluster using this node as a base. You can also detach any node from the cluster and use it as a regular MySQL Server instance.



Benefits:

- When you execute a query, it is executed locally on the node. All data is available locally, no need for remote access.

- No central management. You can loose any node at any point of time, and the cluster will continue to function without any data loss.
- Good solution for scaling a read workload. You can put read queries to any of the nodes.

Drawbacks:

- Overhead of provisioning new node. When you add a new node, it has to copy the full data set from one of existing nodes. If it is 100GB, it copies 100GB.
- This can't be used as an effective write scaling solution. There might be some improvements in write throughput when you run write traffic to 2 nodes versus all traffic to 1 node, but you can't expect a lot. All writes still have to go on all nodes.
- You have several duplicates of the data, for 3 nodes you have 3 duplicates.

Components

Percona XtraDB Cluster is based on Percona Server running with the XtraDB storage engine. It uses the Galera library, which is an implementation of the write set replication (wsrep) API developed by Codership Oy. The default and recommended data transfer method is via Percona XtraBackup.

CHAPTER

TWO

PERCONA XTRADB CLUSTER LIMITATIONS

The following limitations apply to Percona XtraDB Cluster:

- Replication works only with *InnoDB* storage engine. Any writes to tables of other types, including system (`mysql.*`) tables, are not replicated. However, `DDL` statements are replicated in statement level, and changes to `mysql.*` tables will get replicated that way. So you can safely issue `CREATE USER...`, but issuing `INSERT INTO mysql.user...` will not be replicated. You can enable experimental *MyISAM* replication support using the *wsrep_replicate_myisam* variable.
- Unsupported queries:
  - `LOCK TABLES` and `UNLOCK TABLES` is not supported in multi-master setups
  - Lock functions, such as `GET_LOCK()`, `RELEASE_LOCK()`, and so on
- Query log cannot be directed to table. If you enable query logging, you must forward the log to a file:

```
log_output = FILE
```

  Use `general_log` and `general_log_file` to choose query logging and the log file name.
- Maximum allowed transaction size is defined by the *wsrep_max_ws_rows* and *wsrep_max_ws_size* variables. `LOAD DATA INFILE` processing will commit every 10 000 rows. So large transactions due to `LOAD DATA` will be split to series of small transactions.
- Due to cluster-level optimistic concurrency control, transaction issuing `COMMIT` may still be aborted at that stage. There can be two transactions writing to the same rows and committing in separate Percona XtraDB Cluster nodes, and only one of the them can successfully commit. The failing one will be aborted. For cluster-level aborts, Percona XtraDB Cluster gives back deadlock error code:

```
(Error: 1213 SQLSTATE: 40001  (ER_LOCK_DEADLOCK)).
```

- XA transactions are not supported due to possible rollback on commit.
- The write throughput of the whole cluster is limited by the weakest node. If one node becomes slow, the whole cluster slows down. If you have requirements for stable high performance, then it should be supported by corresponding hardware.
- The minimal recommended size of cluster is 3 nodes. The 3rd node can be an arbitrator.
- InnoDB fake changes feature is not supported.
- `enforce_storage_engine=InnoDB` is not compatible with `wsrep_replicate_myisam=OFF` (default).
- The `binlog_rows_query_log_events` variable is not supported.
- When running Percona XtraDB Cluster in cluster mode, avoid `ALTER TABLE ... IMPORT/EXPORT` workloads. It can lead to node inconsistency if not executed in sync on all nodes.

- All tables must have the primary key. This ensures that the same rows appear in the same order on different nodes. The `DELETE` statement is not supported on tables without a primary key.

  See also:

  Galera Documentation: Tables without Primary Keys http://galeracluster.com/documentation-webpages/limitations.html#tables-without-primary-keys

Part II

Getting Started

CHAPTER

THREE

QUICK START GUIDE FOR PERCONA XTRADB CLUSTER

This guide describes the procedure for setting up Percona XtraDB Cluster.

Examples provided in this guide assume there are three Percona XtraDB Cluster nodes, as a common choice for trying out and testing:

Node	Host	IP
Node 1	pxc1	192.168.70.61
Node 2	pxc2	192.168.70.62
Node 3	pxc3	192.168.70.63

Note: Avoid creating a cluster with two or any even number of nodes, because this can lead to *split brain*. For more information, see *Cluster Failover*.

The following procedure provides an overview with links to details for every step:

1. *Install Percona XtraDB Cluster* on all nodes and set up root access for them.

   It is recommended to install from official Percona repositories:

   - On Red Hat and CentOS, *install using YUM*.
   - On Debian and Ubuntu, *install using APT*.

2. *Configure all nodes* with relevant settings required for write-set replication.

   This includes path to the Galera library, location of other nodes, etc.

3. *Bootstrap the first node* to initialize the cluster.

   This must be the node with your main database, which will be used as the data source for the cluster.

4. *Add other nodes* to the cluster.

   Data on new nodes joining the cluster is overwritten in order to synchronize it with the cluster.

5. *Verify replication*.

   Although cluster initialization and node provisioning is performed automatically, it is a good idea to ensure that changes on one node actually replicate to other nodes.

6. *Install ProxySQL*.

   To complete the deployment of the cluster, a high-availability proxy is required. We recommend installing ProxySQL on client nodes for efficient workload management across the cluster without any changes to the applications that generate queries.

Percona Monitoring and Management

Percona Monitoring and Management is the best choice for managing and monitoring Percona XtraDB Cluster performance. It provides visibility for the cluster and enables efficient troubleshooting.

CHAPTER

FOUR

INSTALLING PERCONA XTRADB CLUSTER

Install Percona XtraDB Cluster on all hosts that you are planning to use as cluster nodes and ensure that you have root access to the MySQL server on each one.

It is recommended to install Percona XtraDB Cluster from official Percona software repositories using the corresponding package manager for your system:

- *Debian or Ubuntu*
- *Red Hat or CentOS*

Installation Alternatives

Percona also provides a generic tarball with all required files and binaries for manual installation:

- *Installing Percona XtraDB Cluster from Binary Tarball*

If you want to build Percona XtraDB Cluster from source, see *Compiling and Installing from Source Code*.

If you want to run Percona XtraDB Cluster using Docker, see Running Percona Server in a Docker Container.

Installing Percona XtraDB Cluster on Debian or Ubuntu

Percona provides `.deb` packages for 64-bit versions of the following distributions:

- Debian 7 (“wheezy”)
- Debian 8 (“jessie”)
- Ubuntu 12.04 LTS (Precise Pangolin)
- Ubuntu 14.04 LTS (Trusty Tahr)
- Ubuntu 16.04 LTS (Xenial Xerus)
- Ubuntu 18.04 LTS (Bionic Beaver)
- Ubuntu 18.10 (Cosmic Cuttlefish)

Note: Percona XtraDB Cluster should work on other DEB-based distributions, but it is tested only on platforms listed above.

The packages are available in the official Percona software repository and on the download page. It is recommended to install Percona XtraDB Cluster from the official repository using `apt`.

Prerequisites

You need to have root access on the node where you will be installing Percona XtraDB Cluster (either logged in as a user with root privileges or be able to run commands with `sudo`).

Make sure that the following ports are not blocked by firewall or used by other software. Percona XtraDB Cluster requires them for communication.

- 3306
- 4444
- 4567
- 4568

If *MySQL* Is Installed

If you previously had MySQL installed on the server, there might be an AppArmor profile which will prevent Percona XtraDB Cluster nodes from communicating with each other. The best solution is to remove the `apparmor` package entirely:

```
$ sudo apt-get remove apparmor
```

If you need to have AppArmor enabled due to security policies or for other reasons, it is possible to disable or extend the MySQL profile.

Dependencies on Ubuntu

When installating on a Ubuntu system, make sure that the `universe` repository is enabled to satisfy all essential dependencies.

See also:

Ubuntu Documentation: Repositories https://help.ubuntu.com/community/Repositories/Ubuntu

Installing from Repository

1. Configure Percona repositories as described in Percona Software Repositories Documentation.
2. Install the Percona XtraDB Cluster server package:

   ```
   $ sudo apt-get install percona-xtradb-cluster-57
   ```

   Note: Alternatively, you can install the `percona-xtradb-cluster-full-57` meta package, which contains the following additional packages:

   - `percona-xtradb-cluster-test-5.7`
   - `percona-xtradb-cluster-5.7-dbg`
   - `percona-xtradb-cluster-garbd-3.x`
   - `percona-xtradb-cluster-galera-3.x-dbg`
   - `percona-xtradb-cluster-garbd-3.x-dbg`
   - `libmysqlclient18`

During installation, you will be prompted to provide a password for the `root` user on the database node.

3. Stop the `mysql` service:

```
$ sudo service mysql stop
```

Note: All Debian-based distributions start services as soon as the corresponding package is installed. Before starting a Percona XtraDB Cluster node, it needs to be properly configured. For more information, see *Configuring Nodes for Write-Set Replication*.

Next Steps

After you install Percona XtraDB Cluster and stop the `mysql` service, configure the node according to the procedure described in *Configuring Nodes for Write-Set Replication*.

Installing Percona XtraDB Cluster on Red Hat Enterprise Linux and CentOS

Percona provides `.rpm` packages for 64-bit versions of Red Hat Enterprise Linux 6 (Santiago) and 7 (Maipo), including its derivatives that claim full binary compatibility, for example: CentOS, Oracle Linux, Amazon Linux AMI, and so on.

Note: Percona XtraDB Cluster should work on other RPM-based distributions, but it is tested only on RHEL and CentOS versions 6 and 7.

The packages are available in the official Percona software repository and on the download page. It is recommended to intall Percona XtraDB Cluster from the official repository using `yum`.

Prerequisites

Note: You need to have root access on the node where you will be installing Percona XtraDB Cluster (either logged in as a user with root privileges or be able to run commands with `sudo`).

Note: Make sure that the following ports are not blocked by firewall or used by other software. Percona XtraDB Cluster requires them for communication.

- 3306
- 4444
- 4567
- 4568

Note: The SELinux security module can constrain access to data for Percona XtraDB Cluster. The best solution is to change the mode from `enforcing` to `permissive` by running the following command:

```
setenforce 0
```

This only changes the mode at runtime. To run SELinux in permissive mode after a reboot, set `SELINUX=permissive` in the `/etc/selinux/config` configuration file.

Installing from Percona Repository

1. Configure Percona repositories as described in Percona Software Repositories Documentation.
2. Install the Percona XtraDB Cluster packages:

```
$ sudo yum install Percona-XtraDB-Cluster-57
```

Note: Alternatively you can install the `Percona-XtraDB-Cluster-full-57` meta package, which contains the following additional packages:

- `Percona-XtraDB-Cluster-devel-57`
- `Percona-XtraDB-Cluster-test-57`
- `Percona-XtraDB-Cluster-debuginfo-57`
- `Percona-XtraDB-Cluster-galera-3-debuginfo`
- `Percona-XtraDB-Cluster-shared-57`

3. Start the Percona XtraDB Cluster server:

```
$ sudo service mysql start
```

4. Copy the automatically generated temporary password for the superuser account:

```
$ sudo grep 'temporary password' /var/log/mysqld.log
```

5. Use this password to log in as `root`:

```
$ mysql -u root -p
```

6. Change the password for the superuser account and log out. For example:

```
mysql> ALTER USER 'root'@'localhost' IDENTIFIED BY 'rootPass';
Query OK, 0 rows affected (0.00 sec)

mysql> exit
Bye
```

7. Stop the `mysql` service:

```
$ sudo service mysql stop
```

Next Steps

After you install Percona XtraDB Cluster and change the superuser account password, configure the node according to the procedure described in *Configuring Nodes for Write-Set Replication*.

Installing Percona XtraDB Cluster from Binary Tarball

Percona provides generic tarballs with all required files and binaries for manual installation.

You can download the appropriate tarball package from https://www.percona.com/downloads/Percona-XtraDB-Cluster-57

There are multiple tarballs in the **Linux - Generic** section depending on the *OpenSSL* library available in your distribution:

- `ssl100`: for Debian prior to 9 and Ubuntu prior to 14.04 versions
- `ssl101`: for CentOS 6 and CentOS 7
- `ssl102`: for Debian 9 and Ubuntu versions starting from 14.04

For example, you can use `curl` as follows:

```
curl -O https://www.percona.com/downloads/Percona-XtraDB-Cluster-57/Percona-XtraDB-
↪Cluster-5.7.14-26.17/binary/tarball/Percona-XtraDB-Cluster-5.7.14-rel8-26.17.1.
↪Linux.x86_64.ssl101.tar.gz
```

Compiling and Installing from Source Code

If you want to compile Percona XtraDB Cluster, you can find the source code on GitHub. Before you begin, make sure that the following packages are installed:

	apt	yum
Git	`git`	`git`
SCons	`scons`	`scons`
GCC	`gcc`	`gcc`
g++	`g++`	`gcc-c++`
OpenSSL	`openssl`	`openssl`
Check	`check`	`check`
CMake	`cmake`	`cmake`
Bison	`bison`	`bison`
Boost	`libboost-all-dev`	`boost-devel`
Asio	`libasio-dev`	`asio-devel`
Async I/O	`libaio-dev`	`libaio-devel`
ncurses	`libncurses5-dev`	`ncurses-devel`
Readline	`libreadline-dev`	`readline-devel`
PAM	`libpam-dev`	`pam-devel`
socat	`socat`	`socat`
curl	`libcurl-dev`	`libcurl-devel`

You will likely have all or most of the packages already installed. If you are not sure, run one of the following commands to install any missing dependencies:

- For Debian or Ubuntu:

```
$ sudo apt-get install -y git scons gcc g++ openssl check cmake bison \
libboost-all-dev libasio-dev libaio-dev libncurses5-dev libreadline-dev \
libpam-dev socat libcurl-dev
```

- For Red Hat Enterprise Linux or CentOS:

```
$ sudo yum install -y git scons gcc gcc-c++ openssl check cmake bison \
boost-devel asio-devel libaio-devel ncurses-devel readline-devel pam-devel \
socat libcurl-devel
```

To compile Percona XtraDB Cluster from source code:

1. Clone the Percona XtraDB Cluster repository:

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

   Note: You have to clone the latest repository or update it to the latest state. Old codebase may not be compatible with the build script.

2. Check out the `5.7` branch.
3. Initialize the submodule:

   ```
   $ cd percona-xtradb-cluster-galera
   $ git submodule init wsrep/src && git submodule update wsrep/src
   ```

4. Run the build script `./build-ps/build-binary.sh`. By default, it will build into the current directory, but you can specify another target output directory. For example, if you want to build into `./pxc-build`, run the following:

   ```
   $ mkdir ./pxc-build
   $ ./build-ps/build-binary.sh ./pxc-build
   ```

Running Percona XtraDB Cluster in a Docker Container

Docker images of Percona XtraDB Cluster are hosted publicly on Docker Hub at https://hub.docker.com/r/percona/percona-xtradb-cluster/.

For more information about using Docker, see the Docker Docs.

Note: Make sure that you are using the latest version of Docker. The ones provided via `apt` and `yum` may be outdated and cause errors.

Note: By default, Docker will pull the image from Docker Hub if it is not available locally.

The following procedure describes how to set up a simple 3-node cluster for evaluation and testing purposes, with all nodes running Percona XtraDB Cluster 5.7 in separate containers on one host:

1. Create a Docker network:

   ```
   docker network create pxc-network
   ```

2. Bootstrap the cluster (create the first node):

   ```
   docker run -d \
     -e MYSQL_ROOT_PASSWORD=root \
     -e CLUSTER_NAME=cluster1 \
     --name=node1 \
   ```

```
  --net=pxc-network \
  percona/percona-xtradb-cluster:5.7
```

3. Join the second node:

```
docker run -d \
  -e MYSQL_ROOT_PASSWORD=root \
  -e CLUSTER_NAME=cluster1 \
  -e CLUSTER_JOIN=node1 \
  --name=node2 \
  --net=pxc-network \
  percona/percona-xtradb-cluster:5.7
```

4. Join the third node:

```
docker run -d \
  -e MYSQL_ROOT_PASSWORD=root \
  -e CLUSTER_NAME=cluster1 \
  -e CLUSTER_JOIN=node1 \
  --name=node3 \
  --net=pxc-network \
  percona/percona-xtradb-cluster:5.7
```

To ensure that the cluster is running:

1. Access the MySQL client. For example, on the first node:

```
$ sudo docker exec -it node1 /usr/bin/mysql -uroot -proot
mysql: [Warning] Using a password on the command line interface can be insecure.
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 12
Server version: 5.7.19-17-57-log Percona XtraDB Cluster (GPL), Release rel17,␣
↪Revision c10027a, WSREP version 29.22, wsrep_29.22

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affiliates. Other names may be trademarks of their respective
owners.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

mysql@node1>
```

2. View the wsrep status variables:

```
mysql@node1> show status like 'wsrep%';
+----------------------------+--------------------------------------------------+
| Variable_name              | Value                                            |
+----------------------------+--------------------------------------------------+
| wsrep_local_state_uuid     | 625318e2-9e1c-11e7-9d07-aee70d98d8ac             |
...
| wsrep_local_state_comment  | Synced                                           |
...
| wsrep_incoming_addresses   | 172.18.0.2:3306,172.18.0.3:3306,172.18.0.4:3306 |
...
| wsrep_cluster_conf_id      | 3                                                |
```

```
| wsrep_cluster_size           | 3                                                  |
| wsrep_cluster_state_uuid     | 625318e2-9e1c-11e7-9d07-aee70d98d8ac               |
| wsrep_cluster_status         | Primary                                            |
| wsrep_connected              | ON                                                 |
...
| wsrep_ready                  | ON                                                 |
+------------------------------+----------------------------------------------------+
59 rows in set (0.02 sec)
```

CHAPTER

FIVE

CONFIGURING NODES FOR WRITE-SET REPLICATION

After installing Percona XtraDB Cluster on a node, configure it with information about the cluster.

Note: Make sure that the Percona XtraDB Cluster server is not running.

```
$ sudo service mysql stop
```

Configuration examples assume there are three Percona XtraDB Cluster nodes:

Node	Host	IP
Node 1	pxc1	192.168.70.61
Node 2	pxc2	192.168.70.62
Node 3	pxc3	192.168.70.63

If you are running Debian or Ubuntu, add the following configuration variables to `/etc/mysql/my.cnf` on the first node:

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

wsrep_cluster_name=pxc-cluster
wsrep_cluster_address=gcomm://192.168.70.61,192.168.70.62,192.168.70.63

wsrep_node_name=pxc1
wsrep_node_address=192.168.70.61

wsrep_sst_method=xtrabackup-v2
wsrep_sst_auth=sstuser:passw0rd

pxc_strict_mode=ENFORCING

binlog_format=ROW
default_storage_engine=InnoDB
innodb_autoinc_lock_mode=2
```

If you are running Red Hat or CentOS, add the following configuration variables to `/etc/my.cnf` on the first node:

```
wsrep_provider=/usr/lib64/galera3/libgalera_smm.so

wsrep_cluster_name=pxc-cluster
wsrep_cluster_address=gcomm://192.168.70.61,192.168.70.62,192.168.70.63

wsrep_node_name=pxc1
wsrep_node_address=192.168.70.61
```

```
wsrep_sst_method=xtrabackup-v2
wsrep_sst_auth=sstuser:passw0rd

pxc_strict_mode=ENFORCING

binlog_format=ROW
default_storage_engine=InnoDB
innodb_autoinc_lock_mode=2
```

Use the same configuration for the second and third nodes, except the `wsrep_node_name` and `wsrep_node_address` variables:

- For the second node:

```
wsrep_node_name=pxc2
wsrep_node_address=192.168.70.62
```

- For the third node:

```
wsrep_node_name=pxc3
wsrep_node_address=192.168.70.63
```

Configuration Reference

wsrep_provider

Specify the path to the Galera library.

Note: The location depends on the distribution:

- Debian or Ubuntu: `/usr/lib/libgalera_smm.so`
- Red Hat or CentOS: `/usr/lib64/galera3/libgalera_smm.so`

---

wsrep_cluster_name

Specify the logical name for your cluster. It must be the same for all nodes in your cluster.

wsrep_cluster_address

Specify the IP addresses of nodes in your cluster. At least one is required for a node to join the cluster, but it is recommended to list addresses of all nodes. This way if the first node in the list is not available, the joining node can use other addresses.

Note: No addresses are required for the initial node in the cluster. However, it is recommended to specify them and *properly bootstrap the first node*. This will ensure that the node is able to rejoin the cluster if it goes down in the future.

---

wsrep_node_name

Specify the logical name for each individual node. If this variable is not specified, the host name will be used.

wsrep_node_address

Specify the IP address of this particular node.

wsrep_sst_method

By default, Percona XtraDB Cluster uses Percona XtraBackup for *State Snapshot Transfer* (*SST*). Setting `wsrep_sst_method=xtrabackup-v2` is highly recommended. This method requires a user for SST to be set up on the initial node. Provide SST user credentials with the *wsrep_sst_auth* variable.

wsrep_sst_auth

Specify authentication credentials for *SST* as `<sst_user>:<sst_pass>`. You must create this user when *Bootstrapping the First Node* and provide necessary privileges for it:

```
mysql> CREATE USER 'sstuser'@'localhost' IDENTIFIED BY 'passw0rd';
mysql> GRANT RELOAD, LOCK TABLES, PROCESS, REPLICATION CLIENT ON *.* TO
  'sstuser'@'localhost';
mysql> FLUSH PRIVILEGES;
```

For more information, see Privileges for Percona XtraBackup.

pxc_strict_mode

PXC Strict Mode is enabled by default and set to `ENFORCING`, which blocks the use of experimental and unsupported features in Percona XtraDB Cluster.

`binlog_format`

Galera supports only row-level replication, so set `binlog_format=ROW`.

`default_storage_engine`

Galera fully supports only the InnoDB storage engine. It will not work correctly with MyISAM or any other non-transactional storage engines. Set this variable to `default_storage_engine=InnoDB`.

`innodb_autoinc_lock_mode`

Galera supports only interleaved (`2`) lock mode for InnoDB. Setting the traditional (`0`) or consecutive (`1`) lock mode can cause replication to fail due to unresolved deadlocks. Set this variable to `innodb_autoinc_lock_mode=2`.

Next Steps

After you configure all your nodes, initialize Percona XtraDB Cluster by bootstrapping the first node according to the procedure described in *Bootstrapping the First Node*.

CHAPTER

SIX

BOOTSTRAPPING THE FIRST NODE

After you *configure all PXC nodes*, initialize the cluster by bootstrapping the first node. The initial node should be the one that contains all your data, which you want to be replicated to other nodes.

Bootstrapping implies starting the node without any known cluster addresses. If the *wsrep_cluster_address* variable is empty, Percona XtraDB Cluster assumes that this is the first node and initializes the cluster.

Instead of changing the configuration, start the first node using the following command:

```
[root@pxc1 ~]# /etc/init.d/mysql bootstrap-pxc
```

Note: On RHEL or CentOS 7, use the following bootstrap command:

```
[root@pxc1 ~]# systemctl start mysql@bootstrap.service
```

When you start the node using the previous command, it runs in bootstrap mode with `wsrep_cluster_address=gcomm://`. This tells the node to initialize the cluster with *wsrep_cluster_conf_id* set to `1`. After you *add other nodes* to the cluster, you can then restart this node as normal, and it will use standard configuration again.

To make sure that the cluster has been initialized, run the following:

```
mysql@pxc1> show status like 'wsrep%';
+----------------------------+--------------------------------------+
| Variable_name              | Value                                |
+----------------------------+--------------------------------------+
| wsrep_local_state_uuid     | c2883338-834d-11e2-0800-03c9c68e41ec |
| ...                        | ...                                  |
| wsrep_local_state          | 4                                    |
| wsrep_local_state_comment  | Synced                               |
| ...                        | ...                                  |
| wsrep_cluster_size         | 1                                    |
| wsrep_cluster_status       | Primary                              |
| wsrep_connected            | ON                                   |
| ...                        | ...                                  |
| wsrep_ready                | ON                                   |
+----------------------------+--------------------------------------+
40 rows in set (0.01 sec)
```

The previous output shows that the cluster size is 1 node, it is the primary component, the node is in `Synced` state, it is fully connected and ready for write-set replication.

Before *adding other nodes* to your new cluster, create a user for *SST* and provide necessary privileges for it. The credentials must match those specified when *Configuring Nodes for Write-Set Replication*.

```
mysql@pxc1> CREATE USER 'sstuser'@'localhost' IDENTIFIED BY 'passw0rd';
mysql@pxc1> GRANT RELOAD, LOCK TABLES, PROCESS, REPLICATION CLIENT ON *.* TO
  'sstuser'@'localhost';
mysql@pxc1> FLUSH PRIVILEGES;
```

For more information, see Privileges for Percona XtraBackup.

Next Steps

After initializing the cluster, you can *add other nodes*.

CHAPTER

SEVEN

ADDING NODES TO CLUSTER

New nodes that are *properly configured* are provisioned automatically. When you start a node with the address of at least one other running node in the `wsrep_cluster_address` variable, it automatically joins the cluster and synchronizes with it.

Note: Any existing data and configuration will be overwritten to match the data and configuration of the DONOR node. Do not join several nodes at the same time to avoid overhead due to large amounts of traffic when a new node joins.

By default, Percona XtraDB Cluster uses Percona XtraBackup for *State Snapshot Transfer* (*SST*). This requires the following:

- Set the `wsrep_sst_method` variable to `xtrabackup-v2` and provide SST user credentials with the `wsrep_sst_auth` variable.

  For more information, see *Configuring Nodes for Write-Set Replication*.

- Create a user for SST on the initial node.

  For more information, see *Bootstrapping the First Node*.

Starting the Second Node

Start the second node using the following command:

```
[root@pxc2 ~]# /etc/init.d/mysql start
```

After the server starts, it should receive *SST* automatically.

To check the status of the second node, run the following:

```
mysql@pxc2> show status like 'wsrep%';
+----------------------------+--------------------------------------+
| Variable_name              | Value                                |
+----------------------------+--------------------------------------+
| wsrep_local_state_uuid     | c2883338-834d-11e2-0800-03c9c68e41ec |
| ...                        | ...                                  |
| wsrep_local_state          | 4                                    |
| wsrep_local_state_comment  | Synced                               |
| ...                        | ...                                  |
| wsrep_cluster_size         | 2                                    |
| wsrep_cluster_status       | Primary                              |
| wsrep_connected            | ON                                   |
```

```
| ...                          | ...                                      |
| wsrep_ready                  | ON                                       |
+------------------------------+------------------------------------------+
40 rows in set (0.01 sec)
```

Previous output shows that the new node has been successfully added to the cluster. Cluster size is now 2 nodes, it is the primary component, and it is fully connected and ready to receive write-set replication.

If the state of the second node is `Synced` as in the previous example, then the node received full SST, is synchronized with the cluster, and you can proceed to add the next node.

Note: If the state of the node is `Joiner`, it means that SST hasn't finished. Do not add new nodes until all others are in `Synced` state.

Starting the Third Node

To add the third node, start it as usual:

```
[root@pxc3 ~]# /etc/init.d/mysql start
```

To check the status of the third node, run the following:

```
mysql@pxc3> show status like 'wsrep%';
+------------------------------+------------------------------------------+
| Variable_name                | Value                                    |
+------------------------------+------------------------------------------+
| wsrep_local_state_uuid       | c2883338-834d-11e2-0800-03c9c68e41ec     |
| ...                          | ...                                      |
| wsrep_local_state            | 4                                        |
| wsrep_local_state_comment    | Synced                                   |
| ...                          | ...                                      |
| wsrep_cluster_size           | 3                                        |
| wsrep_cluster_status         | Primary                                  |
| wsrep_connected              | ON                                       |
| ...                          | ...                                      |
| wsrep_ready                  | ON                                       |
+------------------------------+------------------------------------------+
40 rows in set (0.01 sec)
```

Previous output shows that the new node has been successfully added to the cluster. Cluster size is now 3 nodes, it is the primary component, and it is fully connected and ready to receive write-set replication.

Next Steps

When you add all nodes to the cluster, you can *verify replication* by running queries and manipulating data on nodes to see if these changes are synchronized accross the cluster.

CHAPTER

EIGHT

VERIFYING REPLICATION

Use the following procedure to verify replication by creating a new database on the second node, creating a table for that database on the third node, and adding some records to the table on the first node.

1. Create a new database on the second node:

```
mysql@pxc2> CREATE DATABASE percona;
Query OK, 1 row affected (0.01 sec)
```

2. Create a table on the third node:

```
mysql@pxc3> USE percona;
Database changed

mysql@pxc3> CREATE TABLE example (node_id INT PRIMARY KEY, node_name VARCHAR(30));
Query OK, 0 rows affected (0.05 sec)
```

3. Insert records on the first node:

```
mysql@pxc1> INSERT INTO percona.example VALUES (1, 'percona1');
Query OK, 1 row affected (0.02 sec)
```

4. Retrieve rows from that table on the second node:

```
mysql@pxc2> SELECT * FROM percona.example;
+---------+-----------+
| node_id | node_name |
+---------+-----------+
|       1 | percona1  |
+---------+-----------+
1 row in set (0.00 sec)
```

Next Steps

- Consider installing ProxySQL on client nodes for efficient workload management across the cluster without any changes to the applications that generate queries. This is the recommended high-availability solution for Percona XtraDB Cluster.

  For more information, see *Load balancing with ProxySQL*.

- Percona Monitoring and Management is the best choice for managing and monitoring Percona XtraDB Cluster performance. It provides visibility for the cluster and enables efficient troubleshooting.

Part III

Features

CHAPTER

NINE

HIGH AVAILABILITY

In a basic setup with 3 nodes, Percona XtraDB Cluster will continue to function if you take any of the nodes down. At any point in time, you can shut down any node to perform maintenance or make configuration changes. Even in unplanned situations (like a node crashing or if it becomes unavailable over the network), the Percona XtraDB Cluster will continue to work and you'll be able to run queries on working nodes.

If there were changes to data while a node was down, there are two options that the node may use when it joins the cluster again:

- **State Snapshot Transfer** (SST) is when all data is copied from one node to another.

  SST is usually used when a new node joins the cluster and receives all data from an existing node. There are three methods of SST available in Percona XtraDB Cluster:

  - **mysqldump**
  - **rsync**
  - **xtrabackup**.

  The downside of `mysqldump` and `rsync` is that your cluster becomes **READ-ONLY** while data is being copied (SST applies the `FLUSH TABLES WITH READ LOCK` command).

  SST using `xtrabackup` does not require the `READ LOCK` command for the entire syncing process, only for syncing *.frm* files (the same as with a regular backup).

- **Incremental State Transfer** (IST) is when only incremental changes are copied from one node to another.

  Even without locking your cluster in read-only state, SST may be intrusive and disrupt normal operation of your services. IST lets you avoid that. If a node goes down for a short period of time, it can fetch only those changes that happened while it was down. IST is implemeted using a caching mechanism on nodes. Each node contains a cache, ring-buffer (the size is configurable) of last N changes, and the node is able to transfer part of this cache. Obviously, IST can be done only if the amount of changes needed to transfer is less than N. If it exceeds N, then the joining node has to perform SST.

You can monitor the current state of a node using the following command:

```
SHOW STATUS LIKE 'wsrep_local_state_comment';
```

When a node is in `Synced (6)` state, it is part of the cluster and ready to handle traffic.

CHAPTER

TEN

MULTI-MASTER REPLICATION

Multi-master replication means that you can write to any node and be sure that the write will be consistent for all nodes in the cluster. This is different from regular MySQL replication, where you have to apply writes to master to ensure that it will be synced.

With multi-master replication any write is either committed on all nodes or not committed at all. The following diagram shows how it works for two nodes, but the same logic is applied with any number of nodes in the cluster:

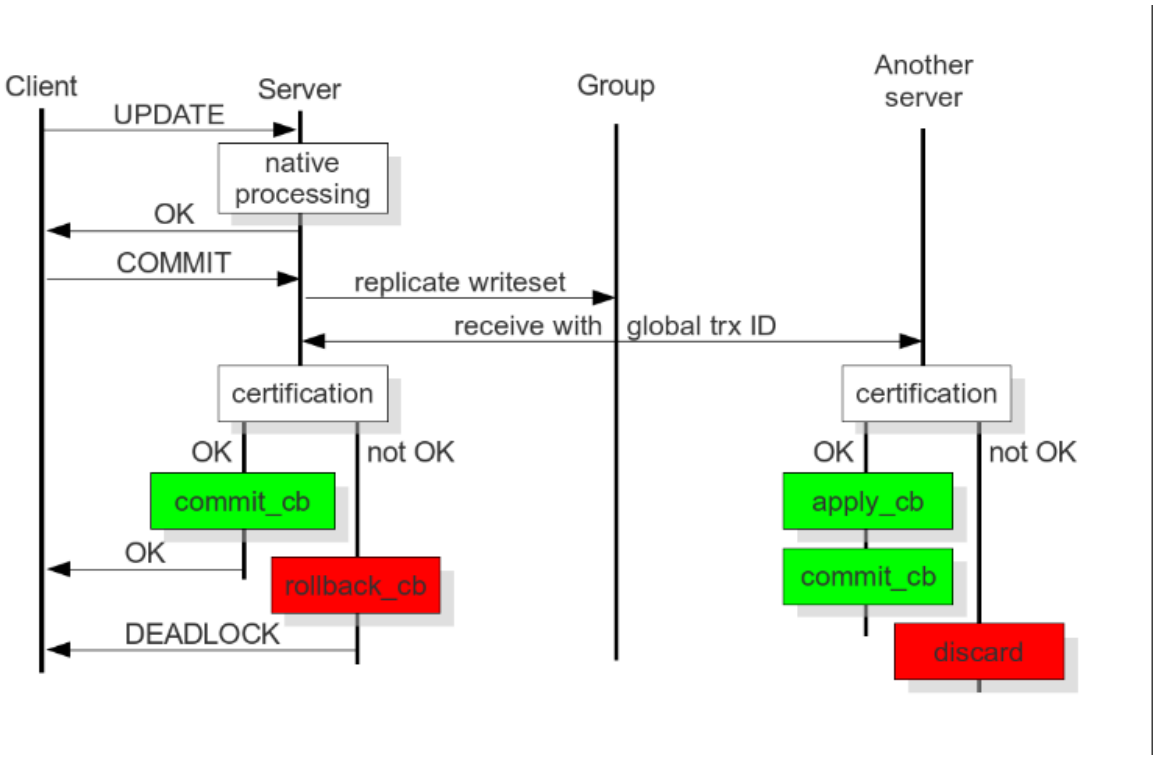


Fig. 10.1: *Image source:* Galera documentation - HOW CERTIFICATION-BASED REPLICATION WORKS

All queries are executed locally on the node, and there is special handling only on `COMMIT`. When the `COMMIT` query is issued, the transaction has to pass certification on all nodes. If it does not pass, you will receive `ERROR` as the response for that query. After that, the transaction is applied on the local node.

Response time of `COMMIT` includes the following:

- Network round-trip time
- Certification time

- Local applying

Note: Applying the transaction on remote nodes does not affect the response time of `COMMIT`, because it happens in the background after the response on certification.

There are two important consequences of this architecture:

- Several appliers can be used in parallel. This enables truely parallel replication. A slave can have many parallel threads configured using the *wsrep_slave_threads* variable.
- There might be a small period of time when a slave is out of sync. This happens because the master may apply events faster than the slave. And if you do read from the slave, you may read the data that has not changed yet. You can see that from the diagram.

  However, this behavior can be changed by setting the `wsrep_causal_reads=ON` variable. In this case, the read on the slave will wait until the event is applied (this will obviously increase the response time of the read). The gap between the slave and the master is the reason why this replication is called *virtually synchronous replication*, and not *real synchronous replication*.

The described behavior of `COMMIT` also has another serious implication. If you run write transactions to two different nodes, the cluster will use an optimistic locking model. This means a transaction will not check on possible locking conflicts during the individual queries, but rather on the `COMMIT` stage, and you may get `ERROR` response on `COMMIT`.

This is mentioned because it is one of the incompatibilities with regular *InnoDB* that you might experience. With InnoDB, `DEADLOCK` and `LOCK TIMEOUT` errors usually happen in response to a particular query, but not on `COMMIT`. It is good practice to check the error codes after a `COMMIT` query, but there are still many applications that do not do that.

If you plan to use multi-master replication and run write transactions on several nodes, you may need to make sure you handle the responses on `COMMIT` queries.

CHAPTER

ELEVEN

PXC STRICT MODE

PXC Strict Mode is designed to avoid the use of experimental and unsupported features in Percona XtraDB Cluster. It performs a number of validations at startup and during runtime.

Depending on the actual mode you select, upon encountering a failed validation, the server will either throw an error (halting startup or denying the operation), or log a warning and continue running as normal. The following modes are available:

- `DISABLED`: Do not perform strict mode validations and run as normal.
- `PERMISSIVE`: If a vaidation fails, log a warning and continue running as normal.
- `ENFORCING`: If a validation fails during startup, halt the server and throw an error. If a validation fails during runtime, deny the operation and throw an error.
- `MASTER`: The same as `ENFORCING` except that the validation of *explicit table locking* is not performed. This mode can be used with clusters in which write operations are isolated to a single node.

By default, PXC Strict Mode is set to `ENFORCING`, except if the node is acting as a standalone server or the node is bootstrapping, then PXC Strict Mode defaults to `DISABLED`.

It is recommended to keep PXC Strict Mode set to `ENFORCING`, because in this case whenever Percona XtraDB Cluster encounters an experimental feature or an unsupported operation, the server will deny it. This will force you to re-evaluate your Percona XtraDB Cluster configuration without risking the consistency of your data.

If you are planning to set PXC Strict Mode to anything else than `ENFORCING`, you should be aware of the limitations and effects that this may have on data integrity. For more information, see *Validations*.

To set the mode, use the *`pxc_strict_mode`* variable in the configuration file or the `--pxc-strict-mode` option during `mysqld` startup.

Note: It is better to start the server with the necessary mode (the default `ENFORCING` is highly recommended). However, you can dynamically change it during runtime. For example, to set PXC Strict Mode to `PERMISSIVE`, run the following command:

```
mysql> SET GLOBAL pxc_strict_mode=PERMISSIVE;
```

Note: To further ensure data consistency, it is important to have all nodes in the cluster running with the same configuration, including the value of `pxc_strict_mode` variable.

Validations

PXC Strict Mode validations are designed to ensure optimal operation for common cluster setups that do not require experimental features and do not rely on operations not supported by Percona XtraDB Cluster.

Warning: If an unsupported operation is performed on a node with `pxc_strict_mode` set to `DISABLED` or `PERMISSIVE`, it will not be validated on nodes where it is replicated to, even if the destination node has `pxc_strict_mode` set to `ENFORCING`.

This section describes the purpose and consequences of each validation.

Storage engine

Percona XtraDB Cluster currently supports replication only for tables that use a transactional storage engine (XtraDB or InnoDB). To ensure data consistency, the following statements should not be allowed for tables that use a non-transactional storage engine (MyISAM, MEMORY, CSV, etc.):

- Data manipulation statements that perform writing to table (for example, `INSERT`, `UPDATE`, `DELETE`, etc.)
- The following administrative statements: `CHECK`, `OPTIMIZE`, `REPAIR`, and `ANALYZE`
- `TRUNCATE TABLE` and `ALTER TABLE`

Depending on the selected mode, the following happens:

`DISABLED`

At startup, no validation is performed.

At runtime, all operations are permitted.

`PERMISSIVE`

At startup, no validation is perfromed.

At runtime, all operations are permitted, but a warning is logged when an undesirable operation is performed on an unsupported table.

`ENFORCING` or `MASTER`

At startup, no validation is performed.

At runtime, any undesirable operation performed on an unsupported table is denied and an error is logged.

Note: Unsupported tables can be converted to use a supported storage engine.

MyISAM replication

Percona XtraDB Cluster provides experimental support for replication of tables that use the MyISAM storage engine. Due to the non-transactional nature of MyISAM, it is not likely to ever be fully supported in Percona XtraDB Cluster.

MyISAM replication is controlled using the *wsrep_replicate_myisam* variable, which is set to `OFF` by default. Due to its unreliability, MyISAM replication should not be enabled if you want to ensure data consistency.

Depending on the selected mode, the following happens:

`DISABLED`

At startup, no validation is performed.

At runtime, you can set *wsrep_replicate_myisam* to any value.

`PERMISSIVE`

At startup, if *wsrep_replicate_myisam* is set to `ON`, a warning is logged and startup continues.

At runtime, it is permitted to change *wsrep_replicate_myisam* to any value, but if you set it to `ON`, a warning is logged.

`ENFORCING` or `MASTER`

At startup, if *wsrep_replicate_myisam* is set to `ON`, an error is logged and startup is aborted.

At runtime, any attempt to change *wsrep_replicate_myisam* to `ON` fails and an error is logged.

Note: The *wsrep_replicate_myisam* variable controls *replication* for MyISAM tables, and this validation only checks whether it is allowed. Undesirable operations for MyISAM tables are restricted using the *Storage engine* validation.

Binary log format

Percona XtraDB Cluster supports only the default row-based binary logging format. Setting the `binlog_format`[1] variable to anything but `ROW` at startup is not allowed, because this changes the global scope, which must be set to ROW. Validation is performed only at runtime and against session scope.

Depending on the selected mode, the following happens:

`DISABLED`

At runtime, you can set `binlog_format` to any value.

`PERMISSIVE`

At runtime, it is permitted to change `binlog_format` to any value, but if you set it to anything other than `ROW`, a warning is logged.

`ENFORCING` or `MASTER`

[1] http://dev.mysql.com/doc/refman/5.7/en/replication-options-binary-log.html#sysvar_binlog_format

At runtime, any attempt to change `binlog_format` to anything other than `ROW` fails and an error is logged.

Tables without primary keys

Percona XtraDB Cluster cannot properly propagate certain write operations to tables that do not have primary keys defined. Undesirable operations include data manipulation statements that perform writing to table (especially `DELETE`).

Depending on the selected mode, the following happens:

`DISABLED`

At startup, no validation is performed.

At runtime, all operations are permitted.

`PERMISSIVE`

At startup, no validation is perfromed.

At runtime, all operations are permitted, but a warning is logged when an undesirable operation is performed on a table without an explicit primary key defined.

`ENFORCING` or `MASTER`

At startup, no validation is performed.

At runtime, any undesirable operation performed on a table without an explicit primary key is denied and an error is logged.

Log output

Percona XtraDB Cluster does not support tables in the MySQL database as the destination for log output. By default, log entries are written to file. This validation checks the value of the `log_output`[2] variable.

Depending on the selected mode, the following happens:

`DISABLED`

At startup, no validation is performed.

At runtime, you can set `log_output` to any value.

`PERMISSIVE`

At startup, if `log_output` is set only to `TABLE`, a warning is logged and startup continues.

At runtime, it is permitted to change `log_output` to any value, but if you set it only to `TABLE`, a warning is logged.

`ENFORCING` or `MASTER`

At startup, if `log_output` is set only to `TABLE`, an error is logged and startup is aborted.

At runtime, any attempt to change `log_output` only to `TABLE` fails and an error is logged.

[2] http://dev.mysql.com/doc/refman/5.7/en/server-system-variables.html#sysvar_log_output

Explicit table locking

Percona XtraDB Cluster has only experimental support for explicit table locking operations, The following undesirable operations lead to explicit table locking and are covered by this validation:

- `LOCK TABLES`
- `GET_LOCK()` and `RELEASE_LOCK()`
- `FLUSH TABLES <tables> WITH READ LOCK`
- Setting the `SERIALIZABLE` transaction level

Depending on the selected mode, the following happens:

`DISABLED` or `MASTER`

At startup, no validation is performed.

At runtime, all operations are permitted.

`PERMISSIVE`

At startup, no validation is performed.

At runtime, all operations are permitted, but a warning is logged when an undesirable operation is performed.

`ENFORCING`

At startup, no validation is performed.

At runtime, any undesirable operation is denied and an error is logged.

Auto-increment lock mode

The lock mode for generating auto-increment values must be *interleaved* to ensure that each node generates a unique (but non-sequential) identifier.

This validation checks the value of the `innodb_autoinc_lock_mode`[3] variable. By default, the variable is set to `1` (*consecutive* lock mode), but it should be set to `2` (*interleaved* lock mode).

Depending on the strict mode selected, the following happens:

`DISABLED`

At startup, no validation is performed.

`PERMISSIVE`

At startup, if `innodb_autoinc_lock_mode` is not set to `2`, a warning is logged and startup continues.

`ENFORCING` or `MASTER`

At startup, if `innodb_autoinc_lock_mode` is not set to `2`, an error is logged and startup is aborted.

Note: This validation is not performed during runtime, because the `innodb_autoinc_lock_mode` variable cannot be set dynamically.

---

[3] http://dev.mysql.com/doc/refman/5.7/en/innodb-parameters.html#sysvar_innodb_autoinc_lock_mode

Combining schema and data changes in a single statement

Percona XtraDB Cluster does not support `CREATE TABLE ... AS SELECT` (CTAS) statements, because they combine both schema and data changes.

Depending on the strict mode selected, the following happens:

`DISABLED`

At startup, no validation is performed.

At runtime, all operations are permitted.

`PERMISSIVE`

At startup, no validation is perfromed.

At runtime, all operations are permitted, but a warning is logged when a CTAS operation is performed.

`ENFORCING`

At startup, no validation is performed.

At runtime, any CTAS operation is denied and an error is logged.

Note: CTAS operations for temporary tables are permitted even in strict mode.

Discarding and Importing Tablespaces

`DISCARD TABLESPACE` and `IMPORT TABLESPACE` are not replicated using TOI. This can lead to data inconsistency if executed on only one node.

Depending on the strict mode selected, the following happens:

`DISABLED`

At startup, no validation is performed.

At runtime, all operations are permitted.

`PERMISSIVE`

At startup, no validation is perfromed.

At runtime, all operations are permitted, but a warning is logged when you discard or import a tablespace.

`ENFORCING`

At startup, no validation is performed.

At runtime, discarding or importing a tablespace is denied and an error is logged.

References

Part IV

PXC Security

CHAPTER

TWELVE

SECURITY BASICS

By default, Percona XtraDB Cluster does not provide any protection for stored data. There are several considerations to take into account for securing Percona XtraDB Cluster:

- *Securing the Network*

  Anyone with access to your network can connect to any Percona XtraDB Cluster node either as a client or as another node joining the cluster. You should consider restricting access using VPN and filter traffic on ports used by Percona XtraDB Cluster.

- *Encrypting PXC Traffic*

  Unencrypted traffic can potentially be viewed by anyone monitoring your network. You should enable encryption for all nodes in the cluster to prevent this.

- Data-at-rest encryption

  Percona XtraDB Cluster supports tablespace encryption to provide at-rest encryption for physical tablespace data files.

  For more information, see the following blog post:

  - MySQL Data at Rest Encryption

Security Modules

Most modern disributions include special security modules that control access to resources for users and applications. By default, these modules will most likely constrain communication between Percona XtraDB Cluster nodes.

The easiest solution is to disable or remove such programs, however, this is not recommended for production environments. You should instead create necessary security policies for Percona XtraDB Cluster.

SELinux

SELinux is usually enabled by default in Red Hat Enterprise Linux and derivatives (including CentOS). During installation and configuration, you can set the mode to `permissive` by running the following command:

```
setenforce 0
```

Note: This only changes the mode at runtime. To run SELinux in permissive mode after a reboot, set `SELINUX=permissive` in the `/etc/selinux/config` configuration file.

To use SELinux with Percona XtraDB Cluster, you need to create an access policy. For more information, see SELinux and MySQL.

AppArmor

AppArmor is included in Debian and Ubuntu. During installation and configuration, you can disable AppArmor for `mysqld`:

1. Create the following symbolic link:

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

2. Restart AppArmor:

```
$ sudo service apparmor restart
```

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

```
$ sudo systemctl restart apparmor
```

To use AppArmor with Percona XtraDB Cluster, you need to create or extend the MySQL profile. For more information, see AppArmor and MySQL.

CHAPTER

THIRTEEN

SECURING THE NETWORK

By default, anyone with access to your network can connect to any Percona XtraDB Cluster node either as a client or as another node joining the cluster. This could potentially let them query your data or get a complete copy of it.

In general, it is a good idea to disable all remote connections to Percona XtraDB Cluster nodes. If you require clients or nodes from outside of your network to connect, you can set up a VPN (virtual private network) for this purpose.

Firewall Configuration

A firewall can let you filter Percona XtraDB Cluster traffic based on the clients and nodes that you trust.

By default, Percona XtraDB Cluster nodes use the following ports:

- 3306 is used for MySQL client connections and *SST* (State Snapshot Transfer) via `mysqldump`.
- 4444 is used for *SST* via `rsync` and *Percona XtraBackup*.
- 4567 is used for write-set replication traffic (over TCP) and multicast replication (over TCP and UDP).
- 4568 is used for *IST* (Incremental State Transfer).

Ideally you want to make sure that these ports on each node are accessed only from trusted IP addresses. You can implement packet filtering using `iptables`, `firewalld`, `pf`, or any other firewall of your choice.

Using iptables

To restrict access to Percona XtraDB Cluster ports using `iptables`, you need to append new rules to the `INPUT` chain on the filter table. In the following example, the trusted range of IP addresses is 192.168.0.1/24. It is assumed that only Percona XtraDB Cluster nodes and clients will connect from these IPs. To enable packet filtering, run the commands as root on each Percona XtraDB 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 4444 \
   --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 udp --match udp --dport 4567 \
   --source 192.168.0.1/24 --jump ACCEPT
```

Note: The last one opens port 4567 for multicast replication over UDP.

If the trusted IPs are not in sequence, you will need to run these commands for each address on each node. In this case, you can consider to open all ports between trusted hosts. This is a little bit less secure, but reduces the amount of commands. For example, if you have three Percona XtraDB Cluster nodes, you can run the following commands on each one:

```
# 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
```

Running the previous commands will allow TCP connections from the IP addresses of the other Percona XtraDB Cluster nodes.

Note: The changes that you make in `iptables` are not persistent unless you save the packet filtering state:

```
# service save iptables
```

For distributions that use `systemd`, you need to save the current packet filtering rules to the path where `iptables` reads from when it starts. This path can vary by distribution, but it is usually in the `/etc` directory. For example:

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

Use `iptables-save` to update the file:

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

CHAPTER

FOURTEEN

ENCRYPTING PXC TRAFFIC

There are two kinds of traffic in Percona XtraDB Cluster:

1. Client-Server traffic (the one between client applications and cluster nodes),
2. Replication traffic, that includes *SST*, *IST*, write-set replication, and various service messages.

Percona XtraDB Cluster supports encryption for all types of traffic. Replication traffic encryption can be configured either in automatic or in manual mode.

Encrypting Client-Server Communication

Percona XtraDB Cluster uses the underlying MySQL encryption mechanism to secure communication between client applications and cluster nodes.

Specify the following settings in the `my.cnf` configuration file for each node:

```
[mysqld]
ssl-ca=/etc/mysql/certs/ca.pem
ssl-cert=/etc/mysql/certs/server-cert.pem
ssl-key=/etc/mysql/certs/server-key.pem

[client]
ssl-ca=/etc/mysql/certs/ca.pem
ssl-cert=/etc/mysql/certs/client-cert.pem
ssl-key=/etc/mysql/certs/client-key.pem
```

After restart the node will use these files to encrypt communication with clients. MySQL clients require only the second part of the configuration to communicate with cluster nodes.

Starting from the version 5.7, *MySQL* generates default key and certificate files and places them in data directory. You can either use them or generate new certificates. For generation of new certificate please refer to *Generating Keys and Certificates Manually* section.

Encrypting Replication Traffic

Replication traffic refers to the inter-node traffic which includes *SST* traffic, *IST* traffic, and replication traffic.

Traffic of each type is transferred via different channel, and so it is important to configure secure channels for all 3 variants to completely secure the replication traffic.

Starting from 5.7, PXC supports a single configuration option which helps to secure complete replication traffic, and is often referred as Automatic Configuration. User can also ignore this and configure security of each channel by specifying independent parameters.

Section below will help, covering this aspect.

SSL Automatic Configuration

Enabling `pxc-encrypt-cluster-traffic`

Percona XtraDB Cluster includes the `pxc-encrypt-cluster-traffic` variable that enables automatic configuration of SSL encryption there-by encrypting *SST*, *IST*, and replication traffic.

This variable is not dynamic and so cannot be changed on runtime. To enable automatic configuration of SSL encryption, set `pxc-encrypt-cluster-traffic=ON` in the the `[mysqld]` section of the `my.cnf` file, and restart the cluster (by default it is disabled there-by using non-secured channel for replication).

Note: Setting `pxc-encrypt-cluster-traffic=ON` has effect of applying the following settings in `my.cnf` configuration file:

```
[mysqld]
wsrep_provider_options="socket.ssl_key=server-key.pem;socket.ssl_cert=server-cert.pem;
↪socket.ssl_ca=ca.pem"

[sst]
encrypt=4
ssl-key=server-key.pem
ssl-ca=ca.pem
ssl-cert=server-cert.pem
```

For *wsrep_provider_options*, only the mentioned options are affected (`socket.ssl_key`, `socket.ssl_cert`, and `socket.ssl_ca`), the rest is not modified.

Automatic configuration of the SSL encryption needs key and certificate files. Starting from the version 5.7, *MySQL* generates default key and certificate files and places them in data directory. These auto-generated files are suitable for automatic SSL configuration, but you should use the same key and certificate files on all nodes. Also you can override auto-generated files with manually created ones, as covered by the *Generating Keys and Certificates Manually* section.

Necessary key and certificate files are first searched at the `ssl-ca`, `ssl-cert`, and `ssl-key` options under `[mysqld]`. If these options are not set, it then looks in the data directory for `ca.pem`, `server-cert.pem`, and `server-key.pem` files.

Note: The `[sst]` section is not searched.

If all three files are found, they are used to configure encryption. If any of the files is missing, a fatal error is generated.

SSL Manual Configuration

If user wants to enable encryption for specific channel only or use different certificates or other mix-match, then user can opt for manual configuration. This helps to provide more flexibility to end-users.

To enable encryption manually, the location of the required key and certificate files shoud be specified in the Percona XtraDB Cluster configuration. If you do not have the necessary files, see *Generating Keys and Certificates Manually*.

Note: Encryption settings are not dynamic. To enable it on a running cluster, you need to restart the entire cluster.

There are three aspects of Percona XtraDB Cluster operation, where you can enable encryption:

- *Encrypting SST Traffic*

  This refers to *SST* traffic during full data copy from one cluster node (donor) to the joining node (joiner).

- *Encrypting Replication Traffic*

- *Encrypting IST Traffic*

  This refers to all internal Percona XtraDB Cluster communication, such as, write-set replication, *IST*, and various service messages.

Encrypting SST Traffic

This refers to full data transfer that usually occurs when a new node (JOINER) joins the cluster and receives data from an existing node (DONOR).

For more information, see *State Snapshot Transfer*.

Note: If `keyring_file` plugin is used, then SST encryption is mandatory: when copying encrypted data via SST, the keyring must be sent over with the files for decryption. In this case following options are to be set in `my.cnf` on all nodes:

```
early-plugin-load=keyring_file.so
keyring-file-data=/path/to/keyring/file
```

The cluster will not work if keyring configuration across nodes is different.

The following SST methods are available: `xtrabackup`, `rsync`, and `mysqldump`.

xtrabackup

This is the default SST method (the *`wsrep_sst_method`* is set to `xtrabackup-v2`), which uses Percona XtraBackup to perform non-blocking transfer of files. For more information, see *Percona XtraBackup SST Configuration*.

Encryption mode for this method is selected using the *`encrypt`* option:

- `encrypt=0` is the default value, meaning that encryption is disabled.
- `encrypt=1`, `encrypt=2`, and `encrypt=3` have been deprecated.
- `encrypt=4` enables encryption based on key and certificate files generated with OpenSSL. For more information, see *Generating Keys and Certificates Manually*.

To enable encryption for SST using XtraBackup, specify the location of the keys and certificate files in the each node's configuration under `[sst]`:

```
[sst]
encrypt=4
ssl-ca=/etc/mysql/certs/ca.pem
ssl-cert=/etc/mysql/certs/server-cert.pem
ssl-key=/etc/mysql/certs/server-key.pem
```

Note: SSL clients require DH parameters to be at least 1024 bits, due to the logjam vulnerability. However, versions of `socat` earlier than 1.7.3 use 512-bit parameters. If a `dhparams.pem` file of required length is not found during SST in the data directory, it is generated with 2048 bits, which can take several minutes. To avoid this delay, create the `dhparams.pem` file manually and place it in the data directory before joining the node to the cluster:

```
openssl dhparam -out /path/to/datadir/dhparams.pem 2048
```

For more information, see this blog post.

rsync

This SST method does not support encryption. Avoid using this method if you need to secure traffic between DONOR and JOINER nodes. If you using keyring plugin then keyring file needs to be send over from DONOR to JOINER. Avoid using this method in such cases too.

mysqldump

This SST method dumps data from DONOR and imports it to JOINER. Encryption in this case is performed using the same certificates configured for *Encrypting Client-Server Communication*, because `mysqldump` connects through the database client.

Here is how to enable encryption for SST using `mysqldump` in a running cluster:

1. Create a user for SST on one of the nodes:

```
mysql> CREATE USER 'sst_user'$'%' IDENTIFIED BY PASSWORD 'sst_password';
```

Note: This user must have the same name and password on all nodes where you want to use `mysqldump` for SST.

2. Grant usage privileges to this user and require SSL:

```
mysql> GRANT USAGE ON *.* TO 'sst_user' REQUIRE SSL;
```

3. To make sure that the SST user replicated across the cluster, run the following query on another node:

```
mysql> SELECT User, Host, ssl_type FROM mysql.user WHERE User='sst_user';

+----------+------+----------+
| User     | Host | ssl_type |
+----------+------+----------+
| sst_user | %    | Any      |
+----------+------+----------+
```

Note: If the *wsrep_OSU_method* is set to ROI, you need to manually create the SST user on each node in the cluster.

4. Specify corresponding certificate files in both `[mysqld]` and `[client]` sections of the configuration file on each node:

```
[mysqld]
ssl-ca=/etc/mysql/certs/ca.pem
ssl-cert=/etc/mysql/certs/server-cert.pem
ssl-key=/etc/mysql/certs/server-key.pem

[client]
ssl-ca=/etc/mysql/certs/ca.pem
ssl-cert=/etc/mysql/certs/client-cert.pem
ssl-key=/etc/mysql/certs/client-key.pem
```

   For more information, see *Encrypting Client-Server Communication*.

5. Also specify the SST user credentials in the *wsrep_sst_auth* variable on each node:

```
[mysqld]
wsrep_sst_auth = sst_user:sst_password
```

6. Restart the cluster with the new configuration.

If you do everything correctly, `mysqldump` will connect to DONOR with the SST user, generate a dump file, and import it to JOINER node.

Encrypting Replication/IST Traffic

Replication traffic refers to the following:

- Write-set replication which is the main workload of Percona XtraDB Cluster (replicating transactions that execute on one node to all other nodes).
- Incremental State Transfer (*IST*) which is copying only missing transactions from DONOR to JOINER node.
- Service messages which ensure that all nodes are synchronized.

All this traffic is transferred via the same underlying communication channel (`gcomm`). Securing this channel will ensure that *IST* traffic, write-set replication, and service messages are encrypted. (For IST, a separate channel is configured using the same configuration parameters, so 2 sections are described together).

To enable encryption for all these processes, define the paths to the key, certificate and certificate authority files using the following *wsrep provider options*:

- *socket.ssl_ca*
- *socket.ssl_cert*
- *socket.ssl_key*

To set these options, use the *wsrep_provider_options* variable in the configuration file:

```
wsrep_provider_options="socket.ssl=yes;socket.ssl_ca=/etc/mysql/certs/ca.pem;socket.
↪ssl_cert=/etc/mysql/certs/server-cert.pem;socket.ssl_key=/etc/mysql/certs/server-
↪key.pem"
```

Note: You must use the same key and certificate files on all nodes, preferably those used for *Encrypting Client-Server Communication*.

Check :upgrade-certificate: section on how to upgrade existing certificates.

Generating Keys and Certificates Manually

As mentioned above, *MySQL* generates default key and certificate files and places them in data directory. If user wants to override these certificates, the following new sets of files can be generated:

- *Certificate Authority (CA) key and certificate* to sign the server and client certificates.
- *Server key and certificate* to secure database server activity and write-set replication traffic.
- *Client key and certificate* to secure client communication traffic.

These files should be generated using OpenSSL.

Note: The `Common Name` value used for the server and client keys and certificates must differ from that value used for the CA certificate.

Generating CA Key and Certificate

The Certificate Authority is used to verify the signature on certificates.

1. Generate the CA key file:

```
$ openssl genrsa 2048 > ca-key.pem
```

2. Generate the CA certificate file:

```
$ openssl req -new -x509 -nodes -days 3600
    -key ca-key.pem -out ca.pem
```

Generating Server Key and Certificate

1. Generate the server key file:

```
$ openssl req -newkey rsa:2048 -days 3600 \
    -nodes -keyout server-key.pem -out server-req.pem
```

2. Remove the passphrase:

```
$ openssl rsa -in server-key.pem -out server-key.pem
```

3. Generate the server certificate file:

```
$ openssl x509 -req -in server-req.pem -days 3600 \
    -CA ca.pem -CAkey ca-key.pem -set_serial 01 \
    -out server-cert.pem
```

Generating Client Key and Certificate

1. Generate the client key file:

```
$ openssl req -newkey rsa:2048 -days 3600 \
    -nodes -keyout client-key.pem -out client-req.pem
```

2. Remove the passphrase:

```
$ openssl rsa -in client-key.pem -out client-key.pem
```

3. Generate the client certificate file:

```
$ openssl x509 -req -in client-req.pem -days 3600 \
    -CA ca.pem -CAkey ca-key.pem -set_serial 01 \
    -out client-cert.pem
```

Verifying Certificates

To verify that the server and client certificates are correctly signed by the CA certificate, run the following command:

```
$ openssl verify -CAfile ca.pem server-cert.pem client-cert.pem
```

If the verification is successful, you should see the following output:

```
server-cert.pem: OK
client-cert.pem: OK
```

Deploying Keys and Certificates

Use a secure method (for example, `scp` or `sftp`) to send the key and certificate files to each node. Place them under the `/etc/mysql/certs/` directory or similar location where you can find them later.

Note: Make sure that this directory is protected with proper permissions. Most likely, you only want to give read permissions to the user running `mysqld`.

The following files are required:

- Certificate Authority certificate file (`ca.pem`)

  This file is used to verify signatures.

- Server key and certificate files (`server-key.pem` and `server-cert.pem`)

  These files are used to secure database server activity and write-set replication traffic.

- Client key and certificate files (`client-key.pem` and `client-cert.pem`)

  These files are required only if the node should act as a MySQL client. For example, if you are planning to perform SST using `mysqldump`.

Note: *Upgrading Certificates* subsection covers the details on upgrading certificates, if necessary.

Upgrading Certificates

The following procedure shows how to upgrade certificates used for securing replication traffic when there are two nodes in the cluster.

1. Restart the first node with the *socket.ssl_ca* option set to a combination of the the old and new certificates in a single file.

   For example, you can merge contents of `old-ca.pem` and `new-ca.pem` into `upgrade-ca.pem` as follows:

   ```
   cat old-ca.pem > upgrade-ca.pem && \
   cat new-ca.pem >> upgrade-ca.pem
   ```

   Set the *wsrep_provider_options* variable as follows:

   ```
   wsrep_provider_options="socket.ssl=yes;socket.ssl_ca=/etc/mysql/certs/upgrade-ca.
   ↪pem;socket.ssl_cert=/etc/mysql/certs/old-cert.pem;socket.ssl_key=/etc/mysql/
   ↪certs/old-key.pem"
   ```

2. Restart the second node with the *socket.ssl_ca*, *socket.ssl_cert*, and *socket.ssl_key* options set to the corresponding new certificate files.

   ```
   wsrep_provider_options="socket.ssl=yes;socket.ssl_ca=/etc/mysql/certs/new-ca.pem;
   ↪socket.ssl_cert=/etc/mysql/certs/new-cert.pem;socket.ssl_key=/etc/mysql/certs/
   ↪new-key.pem"
   ```

3. Restart the first node with the new certificate files, as in the previous step.

4. You can remove the old certificate files.

Part V

User's Manual

CHAPTER

FIFTEEN

STATE SNAPSHOT TRANSFER

State Snapshot Transfer (SST) is a full data copy from one node (donor) to the joining node (joiner). It's used when a new node joins the cluster. In order to be synchronized with the cluster, the new node has to receive data from a node that is already part of the cluster.

There are three methods of SST available in Percona XtraDB Cluster:

- **mysqldump**
- **rsync**
- **xtrabackup**

The downside of `mysqldump` and `rsync` is that the donor node becomes **READ-ONLY** while data is being copied. Xtrabackup SST, on the other hand, uses backup locks, which means the Galera provider is not paused at all as with FTWRL (Flush Tables with Read Lock) earlier. The SST method can be configured using the *`wsrep_sst_method`* variable.

Note: If the *`gcs.sync_donor`* variable is set to `Yes` (default is `No`), the whole cluster will get blocked if the donor is blocked by SST.

Choosing the SST Donor

If there are no nodes available that can safely perform incremental state transfer (*IST*), the cluster defaults to *SST*.

If there are nodes available that can perform *IST*, the cluster prefers a local node over remote nodes to serve as the donor.

If there are no local nodes available that can perform *IST*, the cluster chooses a remote node to serve as the donor.

If there are several local and remote nodes that can perform *IST*, the cluster chooses the node with the highest `seqno` to serve as the donor.

Using Percona Xtrabackup

The default SST method is `xtrabackup-v2` which uses *Percona XtraBackup*. This is the least blocking method that leverages backup locks. XtraBackup is run locally on the donor node, so it's important that the correct user credentials are set up on the donor node. In order for Percona XtraDB Cluster to perform SST using XtraBackup, credentials for connecting to the donor node need to be set up in the *`wsrep_sst_auth`* variable. Besides the credentials, the *datadir* needs to be specified in the server configuration file `my.cnf`, otherwise the transfer process will fail.

For more information about the required credentials, see the XtraBackup manual.

To test if the credentials will work, run **innobackupex** on the donor node with the username and password specified in the *wsrep_sst_auth* variable. For example, if the value of *wsrep_sst_auth* is `root:Passw0rd`, the **innobackupex** command should look like this:

```
innobackupex --user=root --password=Passw0rd /tmp/
```

Detailed information on this method is provided in *Percona XtraBackup SST Configuration* documentation.

Using mysqldump

This method uses the standard **mysqldump** utility to dump all the databases from the donor node and import them to the joining node. For this method to work, the *wsrep_sst_auth* variable needs to be set up with the root credentials. This method is the slowest and it performs a global lock during *SST*, which blocks writes to the donor node.

The script used for this method is `/usr/bin/wsrep_sst_mysqldump` and it is included in the Percona XtraDB Cluster binary packages.

Using `rsync`

This method uses **rsync** to copy files from donor to the joining node. In some cases, this can be faster than using XtraBackup, but it requires a global data lock, which will block writes to the donor node. This method doesn't require root credentials to be set up in the *wsrep_sst_auth* variable.

The script used for this method is `/usr/bin/wsrep_sst_rsync` and it is included in the Percona XtraDB Cluster binary packages.

SST for tables with tablespaces that are not in the data directory

For example:

```
CREATE TABLE t1 (c1 INT PRIMARY KEY) DATA DIRECTORY = '/alternative/directory';
```

The result depends on the SST method:

- SST using `rsync`

  SST will report success, however the table's data will not be copied over, since `rsync` just copies the files. You will not be able to access the table on the joiner node:

  ```
  mysql> select * from t1;
  ERROR 1812 (HY000): Tablespace is missing for table `sbtest`.`t1`.
  ```

- SST using `mysqldump`

  Works as expected. If the file does not exist, it will be created. Otherwise it will attempt to use the file (if the file doesn't have the expected format, an error is returned).

- SST using Percona XtraBackup

  XtraBackup will restore the table to the same location on the joiner node. If the target directory does not exist, it will be created. If the target file already exists, an error will be returned, because XtraBackup cannot clear tablespaces not in the data directory.

Other Reading

- SST Methods for MySQL
- *Xtrabackup SST configuration*

CHAPTER

SIXTEEN

PERCONA XTRABACKUP SST CONFIGURATION

Percona XtraBackup SST works in two stages:

- First it identifies the type of data transfer based on the presence of `xtrabackup_ist` file on the joiner node.
- Then it starts data transfer:
  - In case of *SST*, it empties the data directory except for some files (`galera.cache`, `sst_in_progress`, `grastate.dat`) and then proceeds with SST
  - In case of *IST*, it proceeds as before.

Note: As of Percona XtraDB Cluster 5.7, `xtrabackup-v2` is the only XtraBackup SST method.

SST Options

The following options specific to *SST* can be used in `my.cnf` under `[sst]`.

Note:

- Non-integer options which have no default value are disabled if not set.
- `:Match: Yes` implies that option should match on donor and joiner nodes.
- SST script reads `my.cnf` when it runs on either donor or joiner node, not during `mysqld` startup.
- SST options must be specified in the main `my.cnf` file.

option `streamfmt`

Values xbstream, tar

Default xbstream

Match Yes

Used to specify the Percona XtraBackup streaming format. The recommended value is `streamfmt=xbstream`. Certain features are not available with `tar`, for instance: encryption, compression, parallel streaming, streaming incremental backups. For more information about the `xbstream` format, see The xbstream Binary.

option `transferfmt`

Values `socat`, `nc`

Default `socat`

Match Yes

Used to specify the data transfer format. The recommended value is the default `transferfmt=socat` because it allows for socket options, such as transfer buffer sizes. For more information, see socat(1).

Note: Using `transferfmt=nc` does not support any of the SSL-based encryption modes (values `2`, `3`, and `4` for the *`encrypt`* option). Only `encrypt=1` is supported.

---

option `tca`

Example tca=/etc/ssl/certs/mycert.crt

Used to specify the full path to the certificate authority (CA) file for `socat` encryption based on OpenSSL.

option `tcert`

Example tcert=/etc/ssl/certs/mycert.pem

Used to specify the full path to the certificate file in PEM format for `socat` encryption based on OpenSSL.

Note: For more information about `tca` and `tcert`, see http://www.dest-unreach.org/socat/doc/socat-openssltunnel.html. The `tca` is essentially the self-signed certificate in that example, and `tcert` is the PEM file generated after concatenation of the key and the certificate generated earlier. The names of options were chosen to be compatible with `socat` parameter names as well as with MySQL's SSL authentication. For testing you can also download certificates from launchpad.

Note: Irrespective of what is shown in the example, you can use the same .crt and .pem files on all nodes and it will work, since there is no server-client paradigm here, but rather a cluster with homogeneous nodes.

---

option `tkey`

Example tkey=/etc/ssl/keys/key.pem

Used to specify the full path to the private key in PEM format for socat encryption based on OpenSSL.

option `encrypt`

Values 0, 1, 2, 3

Default 0

Match Yes

Used to enable and specify SST encryption mode:

- Set `encrypt=0` to disable SST encryption. This is the default value.
- Set `encrypt=1` to perform symmetric SST encryption based on XtraBackup.
- Set `encrypt=2` to perform SST encryption based on OpenSSL with `socat`. Ensure that `socat` is built with OpenSSL: `socat -V | grep OPENSSL`. This is recommended if your nodes are over WAN and security constraints are higher.
- Set `encrypt=3` to perform SST encryption based on SSL for just the key and certificate files as implemented in Galeracluster

  It does not provide certificate validation. In order to work correctly, paths to the key and certificate files need to be specified as well, for example:

```
[sst]
encrypt=3
tkey=/etc/mysql/key.pem
tcert=/etc/mysql/cert.pem
```

- Set `encrypt=4` for SST encryption with SSL files generated by MySQL. This is the recommended mode.

  Considering that you have all three necessary files:

```
[sst]
encrypt=4
ssl-ca=ca.pem
ssl-cert=server-cert.pem
ssl-key=server-key.pem
```

Note: All encryption modes can only be used when *wsrep_sst_method* is set to `xtrabackup-v2` (which is the default).

For more information, see *Encrypting PXC Traffic*.

option `encrypt-algo`

Values AES128, AES192, AES256

Used to specify the SST encryption algorithm. It uses the same values as the `--encryption` option for XtraBackup (see this document). The `encrypt-algo` option is considered only if *encrypt* is set to `1`.

option `sockopt`

Used to specify key/value pairs of socket options, separated by commas, for example:

```
[sst]
sockopt="retry=2,interval=3"
```

The previous example causes socat to try to connect three times (initial attempt and two retries with a 3-second interval between attempts).

Note: For versions of Percona XtraDB Cluster before 5.7.17-29.20, the value must begin with a comma, for example:

```
[sst]
sockopt=",cipher=AES128"
```

This option only applies when socat is used (`transferfmt=socat`). For more information about socket options, see socat (1).

Note: You can also enable SSL based compression with *sockopt*. This can be used instead of the Percona XtraBackup `compress` option.

option `ncsockopt`

Used to specify socket options for the `netcat` transfer format (`transferfmt=nc`).

option `progress`

Values 1, path/to/file

Used to specify where to write SST progress. If set to `1`, it writes to MySQL `stderr`. Alternatively, you can specify the full path to a file. If this is a FIFO, it needs to exist and be open on reader end before itself, otherwise `wsrep_sst_xtrabackup` will block indefinitely.

Note: Value of 0 is not valid.

---

option `rebuild`

Values 0, 1

Default 0

Used to enable rebuilding of index on joiner node. This is independent of compaction, though compaction enables it. Rebuild of indexes may be used as an optimization.

Note: #1192834 affects this option.

---

option `time`

Values 0, 1

Default 0

Enabling this option instruments key stages of backup and restore in SST.

option `rlimit`

Example rlimit=128k

Used to set a a ratelimit in bytes. Add a suffix (k, m, g, t) to specify units. For example, `128k` is 128 kilobytes. For more information, see pv(1).

Note: Rate is limited on donor node. The rationale behind this is to not allow SST to saturate the donor's regular cluster operations or to limit the rate for other purposes.

---

option `use_extra`

Values 0, 1

Default 0

Used to force SST to use the thread pool's extra_port. Make sure that thread pool is enabled and the `extra_port` option is set in `my.cnf` before you enable this option.

option `cpat`

Default
```
'.*\.pem$\|.*init\.ok$\|.*galera\.cache$\|.
   *sst_in_progress$\|.*\.sst$\|.*gvwstate\.dat$\|.*grastate\.
   dat$\|.*\.err$\|.*\.log$\|.*RPM_UPGRADE_MARKER$\|.
   *RPM_UPGRADE_HISTORY$'
```

Used to define the files that need to be retained in the *datadir* before running SST, so that the state of the other node can be restored cleanly. For example:

```
[sst]
cpat='.*galera\.cache$\|.*sst_in_progress$\|.*grastate\.dat$\|.*\.err$\|.*\.log$\|.
↪*RPM_UPGRADE_MARKER$\|.*RPM_UPGRADE_HISTORY$\|.*\.xyz$'
```

Note: This option can only be used when *wsrep_sst_method* is set to `xtrabackup-v2` (which is the default value).

option `compressor`

Default not set (disabled)

Example compressor='gzip'

option `decompressor`

Default not set (disabled)

Example decompressor='gzip -dc'

Two previous options enable stream-based compression/decompression. When these options are set, compression/decompression is performed on stream, in contrast to performing decompression after streaming to disk, involving additional I/O. This saves a lot of I/O (up to twice less I/O on joiner node).

You can use any compression utility which works on stream: `gzip`, `pigz` (which is recommended because it is multi-threaded), etc. Compressor has to be set on donor node and decompressor on joiner node (although you can set them vice-versa for configuration homogeneity, it won't affect that particular SST). To use XtraBackup based compression as before, set `compress` under `[xtrabackup]`. Having both enabled won't cause any failure (although you will be wasting CPU cycles).

option `inno-backup-opts`

option `inno-apply-opts`

option `inno-move-opts`

Default Empty

Type Quoted String

This group of options is used to pass XtraBackup options for backup, apply, and move stages. The SST script doesn't alter, tweak, or optimize these options.

Note: Although these options are related to XtraBackup SST, they cannot be specified in `my.cnf`, because they are for passing innobackupex options.

option `sst-initial-timeout`

Default 100

Unit seconds

This option is used to configure initial timeout (in seconds) to receive the first packet via SST. This has been implemented, so that if the donor node fails somewhere in the process, the joiner node will not hang up and wait forever.

By default, the joiner node will not wait for more than 100 seconds to get a donor node. The default should be sufficient, however, it is configurable, so you can set it appropriately for your cluster. To disable initial SST timeout, set `sst-initial-timeout=0`.

Note: If you are using *wsrep_sst_donor*, and you want the joiner node to strictly wait for donors listed in the variable and not fall back (that is, without a terminating comma at the end), **and** there is a possibility of **all** nodes in that variable to be unavailable, disable initial SST timeout or set it to a higher value (maximum threshold that you want the joiner node to wait). You can also disable this option (or set it to a higher value) if you believe all other nodes in

the cluster can potentially become unavailable at any point in time (mostly in small clusters) or there is a high network latency or network disturbance (which can cause donor selection to take longer than 100 seconds).

---

option `tmpdir`

Version Introduced in 5.7.17-29.20

Default Empty

Example /path/to/tmp/dir

This option specifies the location for storing the temporary file on a donor node where the transaction log is stored before streaming or copying it to a remote host.

Note: Starting from Percona XtraDB Cluster *5.7.20-29.24* this option can be used on joiner node also, to specify non-default location to receive temporary SST files. This location must be large enough to hold the contents of the entire database. If tmpdir is empty then default location datadir/.sst will be used.

The `tmpdir` option can be set in the following `my.cnf` groups:

- `[sst]` is the primary location (others are ignored)
- `[xtrabackup]` is the secondary location (if not specified under `[sst]`)
- `[mysqld]` is used if it is not specified in either of the above

`wsrep_debug`

Specifies whether additional debugging output for the database server error log should be enabled. Disabled by default.

This option can be set in the following `my.cnf` groups:

- Under `[mysqld]` it enables debug logging for `mysqld` and the SST script
- Under `[sst]` it enables debug logging for the SST script only

option `encrypt_threads`

Version Introduced in 5.7.19-29.22

Default `4`

Specifies the number of threads that XtraBackup should use for encrypting data (when `encrypt=1`). The value is passed using the `--encrypt-threads` option in XtraBackup.

This option affects only SST with XtraBackup and should be specified under the `[sst]` group.

option `backup_threads`

Version Introduced in 5.7.19-29.22

Default `4`

Specifies the number of threads that XtraBackup should use to create backups. See the `--parallel` option in XtraBackup.

This option affects only SST with XtraBackup and should be specified under the `[sst]` group.

XtraBackup SST Dependencies

Although any current version of Percona XtraBackup *may* be compatible with any current version of Percona XtraDB Cluster, there are certain differences that may break compatibility. As a result, starting from Percona XtraDB Cluster 5.6 every version is tested against a specific Percona XtraBackup version only:

- Percona XtraDB Cluster 5.6 requires Percona XtraBackup 2.3
- Percona XtraDB Cluster 5.7 requires Percona XtraBackup 2.4

Other combinations are not guaranteed to work.

The following are optional dependencies of Percona XtraDB Cluster introduced by `wsrep_sst_xtrabackup-v2` (except for obvious and direct dependencies):

- `qpress` for decompression. It is an optional dependency of *Percona XtraBackup* 2.1.4 and it is available in our software repositories.
- `my_print_defaults` to extract values from `my.cnf`. Provided by the server package.
- `openbsd-netcat` or `socat` for transfer. `socat` is a direct dependency of Percona XtraDB Cluster and it is the default.
- `xbstream` or `tar` for streaming. `xbstream` is the default.
- `pv` is required for *`progress`* and *`rlimit`*.
- `mkfifo` is required for *`progress`*. Provided by `coreutils`.
- `mktemp` is required. Provided by `coreutils`.
- `which` is required.

XtraBackup-based Encryption

This is enabled when *`encrypt`* is set to `1` under `[sst]` in `my.cnf`. However, due to bug #1190335, it will also be enabled when you specify any of the following options under `[xtrabackup]` in `my.cnf`:

- `encrypt`
- `encrypt-key`
- `encrypt-key-file`

There is no way to disable encryption from innobackupex if any of the above are in `my.cnf` under `[xtrabackup]`. For that reason, consider the following scenarios:

1. If you want to use XtraBackup-based encryption for SST but not otherwise, use `encrypt=1` under `[sst]` and provide the above XtraBackup encryption options under `[sst]`. Details of those options can be found here.
2. If you want to use XtraBackup-based encryption always, use `encrypt=1` under `[sst]` and have the above XtraBackup encryption options either under `[sst]` or `[xtrabackup]`.
3. If you don't want to use XtraBackup-based encryption for SST, but want it otherwise, use `encrypt=0` or `encrypt=2` and do **NOT** provide any XtraBackup encryption options under `[xtrabackup]`. You can still have them under `[sst]` though. You will need to provide those options on innobackupex command line then.
4. If you don't want to use XtraBackup-based encryption at all (or only the OpenSSL-based for SST with `encrypt=2`), don't provide any XtraBackup encryption options in `my.cnf`.

Note: The *encrypt* option under [sst] is different from the one under [xtrabackup]. The former is for disabling/changing encryption mode, while the latter is to provide an encryption algorithm. To disambiguate, if you need to provide the latter under [sst] (for example, in cases 1 and 2 above), it should be specified as *encrypt-algo*.

Warning: An implication of the above is that if you specify any of the XtraBackup encryption options, and encrypt=0 under [sst], it will still be encrypted and SST will fail. Look at case 3 above for resolution.

Warning: It is insecure to use the encrypt-key option when performing an SST with xtrabackup-v2 and encrypt=1 (using wsrep_sst_method='xtrabackup-v2' under [mysqld] and encrypt=1 under [sst]) since the key will appear on the command line, and will be visible via ps. Therefore it is strongly recommended to place the key into a file and use the encrypt-key-file option.

Memory Allocation

The amount of memory for XtraBackup is defined by the --use-memory option. You can pass it using the *inno-apply-opts* option under [sst] as follows:

```
[sst]
inno-apply-opts="--use-memory=500M"
```

If it is not specified, the use-memory option under [xtrabackup] will be used:

```
[xtrabackup]
use-memory=32M
```

If neither of the above are specified, the size of the InnoDB memory buffer will be used:

```
[mysqld]
innodb_buffer_pool_size=24M
```

CHAPTER

SEVENTEEN

RESTARTING THE CLUSTER NODES

To restart a cluster node, shut down MySQL and restarting it. The node should leave the cluster (and the total vote count for *quorum* should decrement).

When it rejoins, the node should synchronize using *IST*. If the set of changes needed for IST are not found in the `gcache` file on any other node in the entire cluster, then *SST* will be performed instead. Therefore, restarting cluster nodes for rolling configuration changes or software upgrades is rather simple from the cluster's perspective.

Note: If you restart a node with an invalid configuration change that prevents MySQL from loading, Galera will drop the node's state and force an SST for that node.

Note: If MySQL fails for any reason, it will not remove its PID file (which is by design deleted only on clean shutdown). Obviously server will not restart if existing PID file is present. So in case of encountered MySQL failure for any reason with the relevant records in log, PID file should be removed manually.

CHAPTER

EIGHTEEN

CLUSTER FAILOVER

Cluster membership is determined simply by which nodes are connected to the rest of the cluster; there is no configuration setting explicitly defining the list of all possible cluster nodes. Therefore, every time a node joins the cluster, the total size of the cluster is increased and when a node leaves (gracefully) the size is decreased.

The size of the cluster is used to determine the required votes to achieve *quorum*. A quorum vote is done when a node or nodes are suspected to no longer be part of the cluster (they do not respond). This no response timeout is the `evs.suspect_timeout` setting in the `wsrep_provider_options` (default 5 sec), and when a node goes down ungracefully, write operations will be blocked on the cluster for slightly longer than that timeout.

Once a node (or nodes) is determined to be disconnected, then the remaining nodes cast a quorum vote, and if the majority of nodes from before the disconnect are still still connected, then that partition remains up. In the case of a network partition, some nodes will be alive and active on each side of the network disconnect. In this case, only the quorum will continue. The partition(s) without quorum will change to non-primary state.

As a consequence, it's not possible to have safe automatic failover in a 2 node cluster, because failure of one node will cause the remaining node to become non-primary. Moreover, any cluster with an even number of nodes (say two nodes in two different switches) have some possibility of a *split brain* situation, when neither partition is able to retain quorum if connection between them is lost, and so they both become non-primary.

Therefore, for automatic failover, the *rule of 3s* is recommended. It applies at various levels of your infrastructure, depending on how far the cluster is spread out to avoid single points of failure. For example:

- A cluster on a single switch should have 3 nodes
- A cluster spanning switches should be spread evenly across at least 3 switches
- A cluster spanning networks should span at least 3 networks
- A cluster spanning data centers should span at least 3 data centers

These rules will prevent split brain situations and ensure automatic failover works correctly.

Using an arbitrator

If it is too expensive to add a third node, switch, network, or datacenter, you should use an arbitrator. An arbitrator is a voting member of the cluster that can receive and relay replication, but it does not persist any data, and runs its own daemon instead of `mysqld`. Placing even a single arbitrator in a 3rd location can add split brain protection to a cluster that is spread across only two nodes/locations.

Recovering a Non-Primary cluster

It is important to note that the *rule of 3s* applies only to automatic failover. In the event of a 2-node cluster (or in the event of some other outage that leaves a minority of nodes active), the failure of one node will cause the other to become non-primary and refuse operations. However, you can recover the node from non-primary state using the following command:

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

This will tell the node (and all nodes still connected to its partition) that it can become a primary cluster. However, this is only safe to do when you are sure there is no other partition operating in primary as well, or else Percona XtraDB Cluster will allow those two partitions to diverge (and you will end up with two databases that are impossible to re-merge automatically).

For example, assume there are two data centers, where one is primary and one is for disaster recovery, with an even number of nodes in each. When an extra arbitrator node is run only in the primary data center, the following high availability features will be available:

- Auto-failover of any single node or nodes within the primary or secondary data center
- Failure of the secondary data center would not cause the primary to go down (because of the arbitrator)
- Failure of the primary data center would leave the secondary in a non-primary state.
- If a disaster-recovery failover has been executed, you can tell the secondary data center to bootstrap itself with a single command, but disaster-recovery failover remains in your control.

Other Reading

- PXC - Failure Scenarios with only 2 nodes

CHAPTER

NINETEEN

MONITORING THE CLUSTER

Each node can have a different view of the cluster. There is no centralized node to monitor. To track down the source of issues, you have to monitor each node independently.

Values of many variables depend on the node from which you are querying. For example, replication sent from a node and writes received by all other nodes.

Having data from all nodes can help you understand where flow messages are coming from, which node sends excessively large transactions, and so on.

Manual Monitoring

Manual cluster monitoring can be performed using myq-tools.

Alerting

Besides standard MySQL alerting, you should use at least the following triggers specific to Percona XtraDB Cluster:

- Cluster state of each node
  - *wsrep_cluster_status* != Primary
- Node state
  - *wsrep_connected* != `ON`
  - *wsrep_ready* != `ON`

For additional alerting, consider the following:

- Excessive replication conflicts can be identtified using the *wsrep_local_cert_failures* and *wsrep_local_bf_aborts* variables
- Excessive flow control messages can be identified using the *wsrep_flow_control_sent* and *wsrep_flow_control_recv* variables
- Large replication queues can be identified using the *wsrep_local_recv_queue*.

Metrics

Cluster metrics collection for long-term graphing should be done at least for the following:

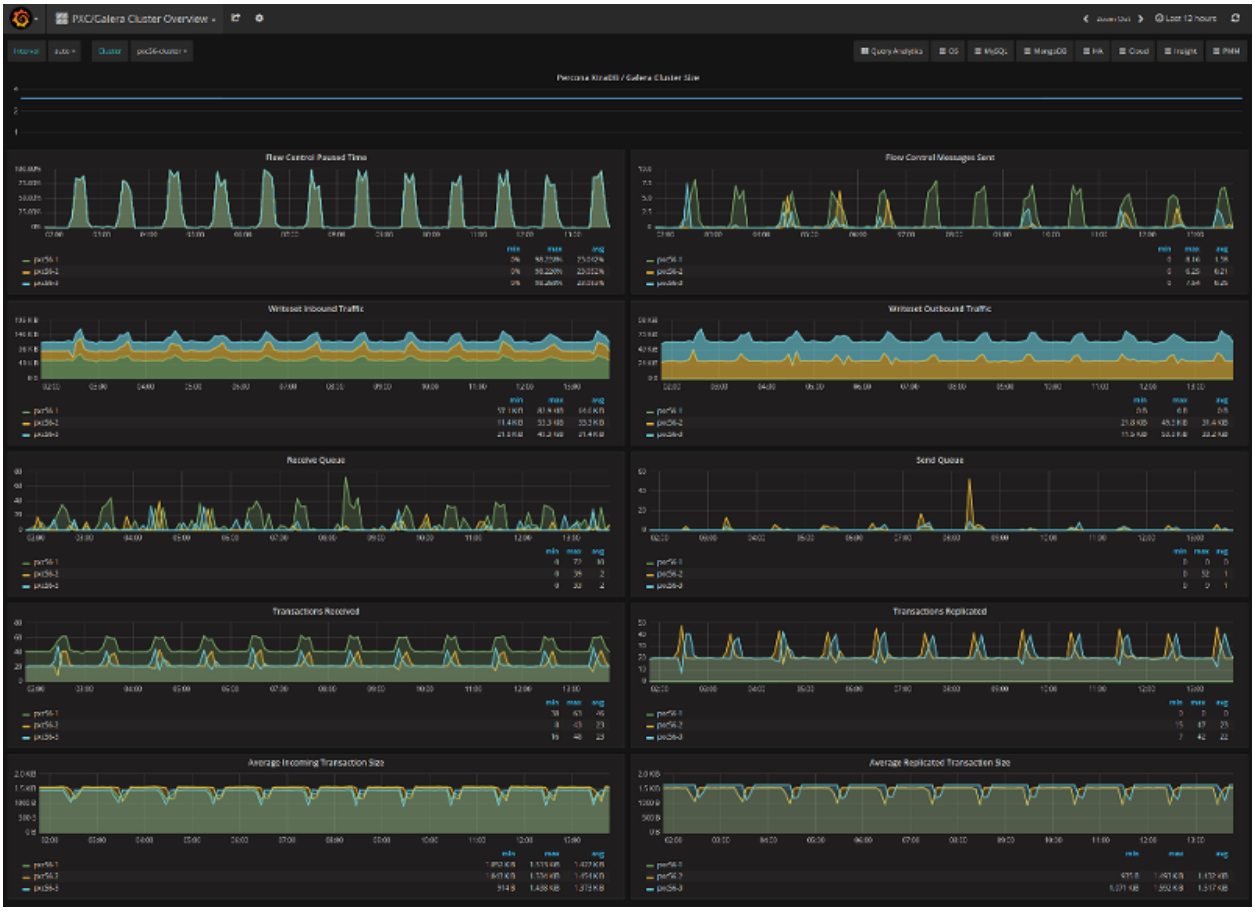
- Queue sizes: *wsrep_local_recv_queue* and *wsrep_local_send_queue*

- Flow control: *wsrep_flow_control_sent* and *wsrep_flow_control_recv*
- Number of transactions for a node: *wsrep_replicated* and *wsrep_received*
- Number of transactions in bytes: *wsrep_replicated_bytes* and *wsrep_received_bytes*
- Replication conflicts: *wsrep_local_cert_failures* and *wsrep_local_bf_aborts*

Using Percona Monitoring and Management

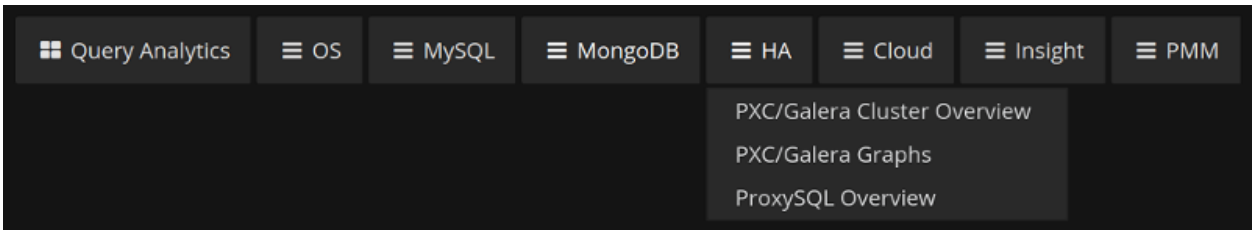
Percona Monitoring and Management includes two dashboards to monitor PXC:

1. PXC/Galera Cluster Overview:



2. PXC/Galera Graphs:

These dashboards are available from the menu:



Please refer to the official documentation for details on Percona Monitoring and Management installation and setup.

Other Reading

- Realtime stats to pay attention to in PXC and Galera

CHAPTER

TWENTY

CERTIFICATION IN PERCONA XTRADB CLUSTER

Percona XtraDB Cluster replicates actions executed on one node to all other nodes in the cluster, and makes it fast enough to appear as if it is synchronous (*virtually synchronous*).

The following types of actions exist:

- DDL actions are executed using *Total Order Isolation* (TOI). We can ignore *Rolling Schema Upgrades* (ROI).
- DML actions are executed using normal Galera replication protocol.

Note: This manual page assumes the reader is aware of TOI and MySQL replication protocol.

DML (`INSERT`, `UPDATE`, and `DELETE`) operations effectively change the state of the database, and all such operations are recorded in *XtraDB* by registering a unique object identifier (key) for each change (an update or a new addition).

- A transaction can change an arbitrary number of different data objects. Each such object change is recorded in *XtraDB* using an `append_key` operation. An `append_key` operation registers the key of the data object that has undergone change by the transaction. The key for rows can be represented in three parts as `db_name`, `table_name`, and `pk_columns_for_table` (if `pk` is absent, a hash of the complete row is calculated).

  This ensures that there is quick and short meta information about the rows that this transaction has touched or modified. This information is passed on as part of the write-set for certification to all the nodes in the cluster while the transaction is in the commit phase.
- For a transaction to commit, it has to pass XtraDB/Galera certification, ensuring that transactions don't conflict with any other changes posted on the cluster group/channel. Certification will add the keys modified by a given transaction to its own central certification vector (CCV), represented by `cert_index_ng`. If the said key is already part of the vector, then conflict resolution checks are triggered.
- Conflict resolution traces the reference transaction (that last modified this item in the cluster group). If this reference transaction is from some other node, that suggests the same data was modified by the other node, and changes of that node have been certified by the local node that is executing the check. In such cases, the transaction that arrived later fails to certify.

Changes made to database objects are bin-logged. This is similar to how *MySQL* does it for replication with its Master-Slave ecosystem, except that a packet of changes from a given transaction is created and named as a write-set.

Once the client/user issues a `COMMIT`, Percona XtraDB Cluster will run a commit hook. Commit hooks ensure the following:

- Flush the binary logs.
- Check if the transaction needs replication (not needed for read-only transactions like `SELECT`).

- If a transaction needs replication, then it invokes a pre-commit hook in the Galera ecosystem. During this pre-commit hook, a write-set is written in the group channel by a *replicate* operation. All nodes (including the one that executed the transaction) subscribe to this group-channel and read the write-set.
- `gcs_recv_thread` is the first to receive the packet, which is then processed through different action handlers.
- Each packet read from the group-channel is assigned an `id`, which is a locally maintained counter by each node in sync with the group. When any new node joins the group/cluster, a seed-id for it is initialized to the current active id from group/cluster.

  There is an inherent assumption/protocol enforcement that all nodes read the packet from a channel in the same order, and that way even though each packet doesn't carry `id` information, it is inherently established using the locally maintained `id` value.

Common Situation

The following example shows what happens in a common situation. `act_id` is incremented and assigned only for totally ordered actions, and only in primary state (skip messages while in state exchange).

```
rcvd->id = ++group->act_id_;
```

Note: This is an amazing way to solve the problem of the id coordination in multi-master systems. Otherwise a node will have to first get an id from central system or through a separate agreed protocol, and then use it for the packet, thereby doubling the round-trip time.

Conflicts

The following happens if two nodes get ready with their packet at same time:

- Both nodes will be allowed to put the packet on the channel. That means the channel will see packets from different nodes queued one behind another.
- The following example shows what happens if two nodes modify same set of rows. Nodes are in sync until this point:

  ```
  create -> insert (1,2,3,4)
  ```

  - Node 1: `update i = i + 10;`
  - Node 2: `update i = i + 100;`

  Let's associate transaction ID (`trx-id`) for an update transaction that is executed on Node 1 and Node 2 in parallel. Although the real algorithm is more involved (with `uuid` + `seqno`), it is conceptually the same, so we are using `trx_id`.

  - Node 1: `update action:  trx-id=n1x`
  - Node 2: `update action:  trx-id=n2x`

  Both node packets are added to the channel, but the transactions are conflicting. The protocol says: FIRST WRITE WINS.

  So in this case, whoever is first to write to the channel will get certified. Let's say Node 2 is first to write the packet, and then Node 1 makes changes immediately after it.

Note: Each node subscribes to all packages, including its own package.

- Node 2 will see its own packet and will process it. Then it will see the packet from Node 1, try to certify it, and fail.
- Node 1 will see the packet from Node 2 and will process it.

  Note: InnoDB allows isolation, so Node 1 can process packets from Node 2 independent of Node 1 transaction changes

  Then Node 1 will see its own packet, try to certify it, and fail.

  Note: Even though the packet originated from Node 1, it will undergo certification to catch cases like these.

Resolving Certification Conflicts

The certification protocol can be described using the previous example. The central certification vector (CCV) is updated to reflect reference transaction.

- Node 2 sees its own packet for certification, adds it to its local CCV and performs certification checks. Once these checks pass, it updates the reference transaction by setting it to `n2x`.

  Node 2 then gets the packet from Node 1 for certification. The packet key is already present in CCV, with the reference transaction set it to `n2x`, whereas write-set proposes setting it to `n1x`. This causes a conflict, which in turn causes the transaction from Node 1 to fail the certification test.

- Node 1 sees the packet from Node 2 for certification, which is then processed, the local CCV is updated, and the reference transaction is set to `n2x`.

  Using the same case as explained above, Node 1 certification also rejects the packet from Node 1.

This suggests that the node doesn't need to wait for certification to complete, but just needs to ensure that the packet is written to the channel. The applier transaction will always win and the local conflicting transaction will be rolled back.

The following example shows what happens if one of the nodes has local changes that are not synced with the group:

```
create (id primary key) -> insert (1), (2), (3), (4);
node-1: wsrep_on=0; insert (5); wsrep_on=1
node-2: insert(5).
```

The `insert(5)` statement will generate a write-set that will then be replicated to Node 1. Node 1 will try to apply it but will fail with `duplicate-key-error`, because 5 already exist.

XtraDB will flag this as an error, which would eventually cause Node 1 to shutdown.

Incrementing GTID

GTID is incremented only when the transaction passes certification, and is ready for commit. That way errant packets don't cause GTID to increment.

Also, group packet `id` is not confused with GTID. Without errant packets, it may seem that these two counters are the same, but they are not related.

CHAPTER

TWENTYONE

PERCONA XTRADB CLUSTER THREADING MODEL

Percona XtraDB Cluster creates a set of threads to service its operations, which are not related to existing *MySQL* threads. There are three main groups of threads:

Contents

Applier threads

Applier threads apply write-sets that the node receives from other nodes. Write messages are directed through `gcv_recv_thread`.

The number of applier threads is controlled using the *`wsrep_slave_threads`* variable. The default value is `1`, which means at least one wsrep applier thread exists to process the request.

Applier threads wait for an event, and once it gets the event, it applies it using normal slave apply routine path, and relays the log info apply path with wsrep-customization. These threads are similar to slave worker threads (but not exactly the same).

Coordination is achieved using *Apply and Commit Monitor*. A transaction passes through two important states: `APPLY` and `COMMIT`. Every transaction registers itself with an apply monitor, where its apply order is defined. So all transactions with apply order sequence number (`seqno`) of less than this transaction's sequence number, are applied before applying this transaction. The same is done for commit as well (`last_left >= trx_.depends_seqno()`).

Rollback thread

There is only one rollback thread to perform rollbacks in case of conflicts.

- Transactions executed in parallel can conflict and may need to roll back.
- Applier transactions always take priority over local transactions. This is natural, as applier transactions have been accepted by the cluster, and some of the nodes may have already applied them. Local conflicting transactions still have a window to rollback.

All the transactions that need to be rolled back are added to the rollback queue, and the rollback thread is notified. The rollback thread then iterates over the queue and performs rollback operations.

If a transaction is active on a node, and a node receives a transaction write-set from the cluster group that conflicts with the local active transaction, then such local transactions are always treated as a victim transaction to roll back.

Transactions can be in a commit state or an execution stage when the conflict arises. Local transactions in the execution stage are forcibly killed so that the waiting applier transaction is allowed to proceed. Local transactions in the commit stage fail with a certification error.

Other threads

Service thread

This thread is created during boot-up and used to perform auxiliary services. It has two main functions:

- It releases the GCache buffer after the cached write-set is purged up to the said level.
- It notifies the cluster group that the respective node has committed a transaction up to this level. Each node maintains some basic status info about other nodes in the cluster. On receiving the message, the information is updated in this local metadata.

Receiving thread

The `gcs_recv_thread` thread is the first one to see all the messages received in a group.

It will try to assign actions against each message it receives. It adds these messages to a central FIFO queue, which are then processed by the Applier threads. Messages can include different operations like state change, configuration update, flow-control, and so on.

One important action is processing a write-set, which actually is applying transactions to database objects.

Gcomm connection thread

The gcomm connection thread `GCommConn::run_fn` is used to co-ordinate the low-level group communication activity. Think of it as a black box meant for communication.

Action-based threads

Besides the above, some threads are created on a needed basis. SST creates threads for donor and joiner (which eventually forks out a child process to host the needed SST script), IST creates receiver and async sender threads, PageStore creates a background thread for removing the files that were created.

If the checksum is enabled and the replicated write-set is big enough, the checksum is done as part of a separate thread.

CHAPTER

TWENTYTWO

UNDERSTANDING GCACHE AND RECORD-SET CACHE

In Percona XtraDB Cluster, there is a concept of GCache and Record-Set cache (which can also be called transaction write-set cache). The use of these two caches is often confusing if you are running long transactions, because both of them result in the creation of disk-level files. This manual describes what their main differences are.

Record-Set Cache

When you run a long-running transaction on any particular node, it will try to append a key for each row that it tries to modify (the key is a unique identifier for the row `{db,table,pk.columns}`). This information is cached in out-write-set, which is then sent to the group for certification.

Keys are cached in HeapStore (which has `page-size=64K` and `total-size=4MB`). If the transaction data-size outgrows this limit, then the storage is switched from Heap to Page (which has `page-size=64MB` and `total-limit=free-space-on-disk`).

All these limits are non-configurable, but having a memory-page size greater than 4MB per transaction can cause things to stall due to memory pressure, so this limit is reasonable. This is another limitation to address when Galera supports large transaction.

The same long-running transaction will also generate binlog data that also appends to out-write-set on commit (`HeapStore->FileStore`). This data can be significant, as it is a binlog image of rows inserted/updated/deleted by the transaction. The *wsrep_max_ws_size* variable controls the size of this part of the write-set. The threshold doesn't consider size allocated for caching-keys and the header.

If `FileStore` is used, it creates a file on the disk (with names like `xxxx_keys` and `xxxx_data`) to store the cache data. These files are kept until a transaction is committed, so the lifetime of the transaction is linked.

When the node is done with the transaction and is about to commit, it will generate the final-write-set using the two files (if the data size grew enough to use `FileStore`) plus `HEADER`, and will publish it for certification to cluster.

The native node executing the transaction will also act as subscription node, and will receive its own write-set through the cluster publish mechanism. This time, the native node will try to cache write-set into its GCache. How much data GCache retains is controlled by the GCache configuration.

GCache

GCache holds the write-set published on the cluster for replication. The lifetime of write-set in GCache is not transaction-linked.

When a `JOINER` node needs an IST, it will be serviced through this GCache (if possible).

GCache will also create the files to disk. You can read more about it here.

At any given point in time, the native node has two copies of the write-set: one in GCache and another in Record-Set Cache.

For example, lets say you `INSERT/UPDATE` 2 million rows in a table with the following schema.

```
(int, char(100), char(100) with pk (int, char(100))
```

It will create write-set key/data files in the background similar to the following:

```
-rw------- 1 xxx xxx 67108864 Apr 11 12:26 0x00000707_data.000000
-rw------- 1 xxx xxx 67108864 Apr 11 12:26 0x00000707_data.000001
-rw------- 1 xxx xxx 67108864 Apr 11 12:26 0x00000707_data.000002
-rw------- 1 xxx xxx 67108864 Apr 11 12:26 0x00000707_keys.000000
```

CHAPTER

TWENTYTHREE

PERFOMANCE SCHEMA INSTRUMENTATION

To improve monitoring *Percona XtraDB Cluster* has implemented an infrastructure to expose Galera instruments (mutexes, cond-variables, files, threads) as a part of `PERFOMANCE_SCHEMA`.

Although mutexes and condition variables from `wsrep` were already part of `PERFORMANCE_SCHEMA` threads weren't.

Mutexes, condition variables, threads, and files from Galera library also were not part of the `PERFORMANCE_SCHEMA`.

You can see the complete list of available instruments by running:

```
mysql> SELECT * FROM performance_schema.setup_instruments WHERE name LIKE '%galera%'␣
↪OR name LIKE '%wsrep%';

+-----------------------------------------------------------+---------+--------+
| NAME                                                      | ENABLED | TIMED  |
+-----------------------------------------------------------+---------+--------+
| wait/synch/mutex/sql/LOCK_wsrep_ready                     | NO      | NO     |
| wait/synch/mutex/sql/LOCK_wsrep_sst                       | NO      | NO     |
| wait/synch/mutex/sql/LOCK_wsrep_sst_init                  | NO      | NO     |
...
| stage/wsrep/wsrep: in rollback thread                     | NO      | NO     |
| stage/wsrep/wsrep: aborter idle                           | NO      | NO     |
| stage/wsrep/wsrep: aborter active                         | NO      | NO     |
+-----------------------------------------------------------+---------+--------+
73 rows in set (0.00 sec)
```

Some of the most important are:

- Two main actions that Galera does are `REPLICATION` and `ROLLBACK`. Mutexes, condition variables, and threads related to this are part of `PERFORMANCE_SCHEMA`.
- Galera internally uses monitor mechanism to enforce ordering of events. These monitor control events apply and are mainly responsible for the wait between different action. All such monitor mutexes and condition variables are covered as part of this implementation.
- There are lot of other miscellaneous action related to receiving of package and servicing messages. Mutexes and condition variables needed for them are now visible too. Threads that manage receiving and servicing are also being instrumented.

This feature has exposed all the important mutexes, condition variables that lead to lock/threads/files as part of this process.

Besides exposing file it also tracks write/read bytes like stats for file. These stats are not exposed for Galera files as Galera uses `mmap`.

Also, there are some threads that are short-lived and created only when needed especially for SST/IST purpose. They are also tracked but come into PERFORMANCE_SCHEMA tables only if/when they are created.

Stage Info from Galera specific function which server updates to track state of running thread is also visible in PERFORMANCE_SCHEMA.

What is not exposed ?

Galera uses customer data-structure in some cases (like STL structures). Mutexes used for protecting these structures which are not part of mainline Galera logic or doesn't fall in big-picture are not tracked. Same goes with threads that are gcomm library specific.

Galera maintains a process vector inside each monitor for its internal graph creation. This process vector is 65K in size and there are two such vectors per monitor. That is 128K * 3 = 384K condition variables. These are not tracked to avoid hogging PERFORMANCE_SCHEMA limits and sidelining of the main crucial information.

CHAPTER

TWENTYFOUR

DATA AT REST ENCRYPTION

This feature is considered **BETA** quality.

Introduction

"Data-at-rest" term refers to all the data stored on disk by some server within system tablespace, general tablespace, redo-logs, undo-logs, etc. As an opposite, "data-in-transit" means data transmitted to other node or client. Data-in-transit can be encrypted using SSL connection (details are available in the encrypt traffic documentation) and therefore supposed to be safe. Below sections are about securing the data-at-rest only.

Currently data-at-rest encryption is supported in Percona XtraDB Cluster for general tablespace, file-per-tablespace, and temporary tables.

InnoDB tablespace encryption

MySQL supports tablespace encryption, but only for file-per-table tablespace. User should create a table that has its own dedicated tablespace, making this tablespace encrypted by specifying the appropriate option.

Percona Server starting from `5.7.21-20` is extending support for encrypting other tablespaces too.

Percona XtraDB Cluster already supported data-at-rest encryption starting from `5.7`. File-per-tablespace and General tablespace encryption are table/tablespace specific features and are enabled on object level through DDL:

```
CREATE TABLE t1 (c1 INT, PRIMARY KEY pk(c1)) ENCRYPTION='Y';
CREATE TABLESPACE foo ADD DATAFILE 'foo.ibd' ENCRYPTION='Y';
```

DDL statements are replicated in PXC cluster, thus creating encrypted table or tablespace on all the nodes of the cluster.

This feature requires a keyring plugin to be loaded before it can be used. Currently Percona Server (and in turn Percona XtraDB Cluster) supports 2 types of keyring plugin: `keyring_file` and `keyring_vault`.

Configuring PXC to use keyring_file plugin

keyring_file

Support for the keyring file was added back when Percona XtraDB Cluster 5.7 got General Availability (GA) status. Following subsection covers some of the important semantics of `keyring_file` plugin needed to use it in scope of data-at-rest encryption.

`keyring_file` stores encryption key to a physical file. Location of this file is specified by `keyring_file_data` parameter configured during startup.

Configuration

Percona XtraDB Cluster inherits upstream (Percona Server) behavior to configure `keyring_file` plugin. Following options are to be set in the configuration file:

```
[mysqld]
early-plugin-load=keyring_file.so
keyring_file_data=<PATH>/keyring
```

A `SHOW PLUGINS` statement can be used further to check if plugin has been successfully loaded.

Note: PXC recommends same configuration on all the nodes of the cluster, and that also means all the nodes of the cluster should have keyring configured. Mismatch in keyring configuration will not allow JOINER node to join the cluster.

If user has bootstrapped node with keyring enabled, then upcoming nodes of the cluster will inherit the keyring (encrypted key) from the DONOR node (in Percona XtraDB Cluster prior to 5.7.22) or generate it (starting from Percona XtraDB Cluster 5.7.22).

Usage

Prior to Percona XtraDB Cluster *5.7.22-29.26* DONOR node had to send keyring to JOINER, because **xtrabackup** backs up encrypted tablespaces in encrypted fashion and in order for JOINER to read these encrypted tablespaces it needs the same encryption key that was used for its encryption on DONOR. This restriction has been relaxed in Percona XtraDB Cluster 5.7.22 and now **xtrabackup** re-encrypts the data using transition-key and JOINER re-encrypts it using a new generated master-key.

Keyring is sent from DONOR to JOINER as part of SST process (prior to Percona XtraDB Cluster 5.7.22) or generated on JOINER. SST can be done using xtrabackup (the recommended way), rsync, or mysqldump. In *xtrabackup* case, keyring is sent over explicitly before the real data backup/streaming starts. Other two SST variants behave differently: mysqldump uses logical backup so it doesn't need to send keyring, while rsync will sync the keys when it syncs data directories.

Warning: rsync doesn't provide a secure channel. This means keyring sent using rsync SST could be vulnerable to attack. As an opposite, following the recommended SST way with xtrabackup user can configure secure channel and so keyring is fully secured (in fact, xtrabackup will not allow user to send the keyring if the SST channel is not secured).

Percona XtraDB Cluster doesn't allow to combine nodes with encryption and nodes without encryption. This is not allowed in order to maintain data consistency. For example, user creates node-1 with encryption (keyring) enabled and node-2 with encryption (keyring) disabled. Now if user tries to create a table with encryption on node-1, it will fail on node-2 causing data inconsistency. With Percona XtraDB Cluster *5.7.22-29.26*, node will fail to start if it fails to load keyring plugin.

Note: If user hasn't specifiy keyring parameters there is no way for node to know that it needs to load keyring. JOINER node may start but eventually shutdown when DML level inconsistency with encrypted tablespace will be detected.

If a node doesn't have encrypted tablespace, keyring is not generated and the keyring file is empty. Actual keyring is generated only when node starts using encrypted tablespace.

User can rotate the key as and when needed. `ALTER INSTANCE ROTATE INNODB MASTER KEY` statement is not replicated on cluster, so it is local operation for the said node.

Starting from Percona XtraDB Cluster 5.7.22 JOINER generates its own keyring. In Percona XtraDB Cluster prior to 5.7.22 when JOINER joined the cluster its keyring was the same as DONOR's one. User could rotate the key if different keys for each of the node where demanded by the user's requirements (internal rules). But using different keys for each node is not necessary from the technical side, as all nodes of the cluster can continue operating with same MASTER-key.

Compatibility

Keyring (or, more generally, the Percona XtraDB Cluster SST process) is backward compatible, as in higher version JOINER can join from lower version DONOR, but not vice-versa. More details are covered below, in *Upgrade and compatibility issues* section.

Note: Since Percona XtraDB Cluster 5.6 didn't have encrypted tablespace, no major upgrade scenario for data-at-rest encryption is possible from it.

Configuring PXC to use keyring_vault plugin

keyring_vault

The `keyring_vault` plugin is supported starting from PXC 5.7.22. This plugin allows storing the master-key in vault-server (vs. local file as in case of `keyring_file`).

Warning: rsync doesn't support `keyring_vault`, and SST on JOINER is aborted if rsync is used on the node with `keyring_vault` configured.

Configuration

Configuration options are same as upstream. The `my.cnf` configuration file should contain following options:

```
[mysqld]
early-plugin-load="keyring_vault=keyring_vault.so"
keyring_vault_config="<PATH>/keyring_vault_n1.conf"
```

Also `keyring_vault_n1.conf` file contents should be :

```
vault_url = http://127.0.0.1:8200
secret_mount_point = secret1
token = e0345eb4-35dd-3ddd-3b1e-e42bb9f2525d
vault_ca = /data/keyring_vault_confs/vault_ca.crt
```

Detailed description of these options can be found in the upstream documentation.

Vault-server is an external server so make sure PXC node is able to reach to the said server.

Note: Percona XtraDB Cluster recommends to use same keyring_plugin on all the nodes of the cluster. Mix-match is recommended to use it only while transitioning from `keyring_file` -> `keyring_vault` or vice-versa.

It is not necessary that all the nodes refer to same vault server. Whatever vault server is used, it should be accessible from the respective node. Also there is no restriction for all nodes to use the same mount point.

If the node is not able to reach/connect to vault server, an error is notified during the server boot, and node refuses to start:

```
2018-05-29T03:54:33.859613Z 0 [Warning] Plugin keyring_vault reported: 'There is no␣
↪vault_ca specified in keyring_vault's configuration file. Please make sure that␣
↪Vault's CA certificate is trusted by the machine from which you intend to connect␣
↪to Vault.'
2018-05-29T03:54:33.977145Z 0 [ERROR] Plugin keyring_vault reported: 'CURL returned␣
↪this error code: 7 with error message : Failed to connect to 127.0.0.1 port 8200:␣
↪Connection refused'
```

If some nodes of the cluster are unable to connect to vault-server, this relates only to these specific nodes: e.g. if node-1 is able to connect, and node-2 is not, only node-2 will refuse to start. Also, if server has pre-existing encrypted object and on reboot server fails to connect to vault-server, the object is not accessible.

In case when vault-server is accessible but authentication credential are wrong, consequences are the same, and the corresponding error looks like following:

```
2018-05-29T03:58:54.461911Z 0 [Warning] Plugin keyring_vault reported: 'There is no␣
↪vault_ca specified in keyring_vault's configuration file. Please make sure that␣
↪Vault's CA certificate is trusted by the machine from which you intend to connect␣
↪to Vault.'
2018-05-29T03:58:54.577477Z 0 [ERROR] Plugin keyring_vault reported: 'Could not␣
↪retrieve list of keys from Vault. Vault has returned the following error(s): [
↪"permission denied"]'
```

In case of accessible vault-server with the wrong mount point, there is no error during server boot, but sitll node refuses to start:

```
mysql> CREATE TABLE t1 (c1 INT, PRIMARY KEY pk(c1)) ENCRYPTION='Y';
ERROR 3185 (HY000): Can't find master key from keyring, please check keyring plugin␣
↪is loaded.

2018-05-29T04:01:33.774684Z 5 [ERROR] Plugin keyring_vault reported: 'Could not write␣
↪key to Vault. Vault has returned the following error(s): ["no handler for route
↪'secret1/NDhfSU5OT0RCS2V5LTkzNzVmZWQ0LTVjZTQtMTFlOC05YTc3LTM0MDI4NmI4ODhiZS0xMF8='"]
↪'
2018-05-29T04:01:33.774786Z 5 [ERROR] Plugin keyring_vault reported: 'Could not flush␣
↪keys to keyring'
```

Mix-match keyring plugins

With **xtrabackup** introducing transition-key logic it is now possible to mix-match keyring plugins. For example, user has node-1 configured to use `keyring_file` plugin and node-2 configured to use `keyring_vault`.

Note: Percona recommends same configuration for all the nodes of the cluster. Mix-match (in keyring plugins) is recommended only during transition from one keying to other.

Upgrade and compatibility issues

Percona XtraDB Cluster server before `5.7.22` only supported `keyring_file` and the dependent **xtrabackup** didn't had concept of transition-key then. This makes mix-match of old Percona XtraDB Cluster server (pre-5.7.21) using `keyring_file` with new Percona XtraDB Cluster server (post-5.7.22) using `keyring_vault` not possible. User should first upgrade Percona XtraDB Cluster server to version 5.7.22 or newer using `keyring_file` plugin and then let it act as DONOR to new booting `keyring_vault` running JOINER.

If all the nodes are using Percona XtraDB Cluster 5.7.22, then user can freely configure some nodes to use `keyring_file` and other to use `keyring_vault`, but still this setup is not recommended and should be used during transitioning to vault only.

If all the nodes are using Percona XtraDB Cluster 5.7.21 and user would like to move to use `keyring_vault` plugin, all the nodes should be upgraded to use Percona XtraDB Cluster 5.7.22 (that's where vault plugin support was introduced in PXC). Once all nodes are configured to use Percona XtraDB Cluster 5.7.22, user can switch one node at a time to use `vault-plugin`.

Note: *MySQL* 5.7.21 has support for migration between keystores. Although a restart is required.

Temporary file encryption

Percona Server 5.7.22 added support for encrypting temporary file storage enabled using `encrypt-tmp-files`. This storage or files are local to the node and has no direct effect on Percona XtraDB Cluster replication. Percona XtraDB Cluster recommends enabling it on all the nodes of the cluster, though that is not mandatory. Parameter to enable this option is same as in Percona Server:

```
[mysqld]
encrypt-tmp-files=ON
```

Migrating Keys Between Keyring Keystores

Percona XtraDB Cluster supports key migration between keystores. The migration can be performed offline or online.

Offline Migration

In offline migration, the node to migrate is shutdown, and the migration server takes care of migrating keys for the said server to a new keystore.

Following example illustrates this scenario:

1. Let's say there are 3 Percona XtraDB Cluster nodes n1, n2, n3 - all using `keyring_file`, and n2 should be migrated to use `keyring_vault`
2. User shuts down n2 node.
3. User start's Migration Server (`mysqld` with a special option).
4. Migration Server copies keys from n2 keyring file and adds them to the vault server.
5. User starts n2 node with the vault parameter, and keys should be available.

Here is how the migration server output should look like:

```
/dev/shm/pxc57/bin/mysqld --defaults-file=/dev/shm/pxc57/copy_mig.cnf \
--keyring-migration-source=keyring_file.so \
--keyring_file_data=/dev/shm/pxc57/node2/keyring \
--keyring-migration-destination=keyring_vault.so \
--keyring_vault_config=/dev/shm/pxc57/vault/keyring_vault.cnf &

2018-05-30T03:44:11.803459Z 0 [Warning] TIMESTAMP with implicit DEFAULT value is␣
↪deprecated. Please use
--explicit_defaults_for_timestamp server option (see documentation for more details).
2018-05-30T03:44:11.803534Z 0 [Note] --secure-file-priv is set to NULL. Operations␣
↪related to importing and
exporting data are disabled
2018-05-30T03:44:11.803550Z 0 [Warning] WSREP: Node is not a cluster node. Disabling␣
↪pxc_strict_mode
2018-05-30T03:44:11.803564Z 0 [Note] /dev/shm/pxc57/bin/mysqld (mysqld 5.7.21-21-29.
↪26-debug) starting as process
5710 ...
2018-05-30T03:44:11.805917Z 0 [Warning] Can't create test file /dev/shm/pxc57/copy_
↪mig/qaserver-06.lower-test
2018-05-30T03:44:11.805932Z 0 [Warning] Can't create test file /dev/shm/pxc57/copy_
↪mig/qaserver-06.lower-test
2018-05-30T03:44:11.945989Z 0 [Note] Keyring migration successful.
```

```
2018-05-30T03:44:11.946015Z 0 [Note] Binlog end
2018-05-30T03:44:11.946047Z 0 [Note] Shutting down plugin 'keyring_vault'
2018-05-30T03:44:11.946166Z 0 [Note] Shutting down plugin 'keyring_file'
2018-05-30T03:44:11.947334Z 0 [Note] /dev/shm/pxc57/bin/mysqld: Shutdown complete
```

On successful migration, destination keystore will get additional migrated keys (pre-existing keys in destination keystore are not touched or removed). Source keystore continues to retain the keys as migration performs copy operation and not move operation.

If migration fails, then destination keystore will be left untouched.

Online Migration

In online migration, node to migrate is kept running and migration server takes care of migrating keys for the said server to a new keystore by connecting to the node.

Following example illustrates this scenario:

1. Let's say there are 3 Percona XtraDB Cluster nodes n1, n2, n3 - all using `keyring_file`, and n3 should be migrated to use `keyring_vault`
2. User start's Migration Server (`mysqld` with a special option).
3. Migration Server copies keys from n3 keyring file and adds them to the vault server.
4. User restarts n3 node with the vault parameter, and keys should be available.

Here is how the migration server output should look like:

```
/dev/shm/pxc57/bin/mysqld --defaults-file=/dev/shm/pxc57/copy_mig.cnf \
--keyring-migration-source=keyring_vault.so \
--keyring_vault_config=/dev/shm/pxc57/keyring_vault3.cnf \
--keyring-migration-destination=keyring_file.so \
--keyring_file_data=/dev/shm/pxc57/node3/keyring \
--keyring-migration-host=localhost \
--keyring-migration-user=root \
--keyring-migration-port=16300 \
--keyring-migration-password='' &

2018-05-29T14:07:32.789673Z 0 [Warning] TIMESTAMP with implicit DEFAULT value is␣
↪deprecated. Please use
--explicit_defaults_for_timestamp server option (see documentation for more details).
2018-05-29T14:07:32.789748Z 0 [Note] --secure-file-priv is set to NULL. Operations␣
↪related to importing and
exporting data are disabled
2018-05-29T14:07:32.789766Z 0 [Warning] WSREP: Node is not a cluster node. Disabling␣
↪pxc_strict_mode
2018-05-29T14:07:32.789780Z 0 [Note] /dev/shm/pxc57/bin/mysqld (mysqld 5.7.21-21-29.
↪26-debug) starting as process
4936 ...
2018-05-29T14:07:32.792036Z 0 [Warning] Can't create test file /dev/shm/pxc57/copy_
↪mig/qaserver-06.lower-test
2018-05-29T14:07:32.792052Z 0 [Warning] Can't create test file /dev/shm/pxc57/copy_
↪mig/qaserver-06.lower-test
2018-05-29T14:07:32.927612Z 0 [Note] Keyring migration successful.
2018-05-29T14:07:32.927636Z 0 [Note] Binlog end
2018-05-29T14:07:32.927671Z 0 [Note] Shutting down plugin 'keyring_vault'
2018-05-29T14:07:32.927793Z 0 [Note] Shutting down plugin 'keyring_file'
2018-05-29T14:07:32.928864Z 0 [Note] /dev/shm/pxc57/bin/mysqld: Shutdown complete
```

On successful migration, destination keystore will get additional migrated keys (pre-existing keys in destination keystore are not touched or removed). Source keystore continues to retain the keys as migration performs copy operation and not move operation.

If migration fails, then destination keystore will be left untouched.

Migration server options

- `--keyring-migration-source`: The source keyring plugin that manages the keys to be migrated.
- `--keyring-migration-destination`: The destination keyring plugin to which the migrated keys are to be copied

---

Note: For an offline migration, no additional key migration options are needed.

- `--keyring-migration-host`: The host where the running server is located. This is always the local host.
- `--keyring-migration-user`, `--keyring-migration-password`: The username and password for the account to use to connect to the running server.
- `--keyring-migration-port`: For TCP/IP connections, the port number to connect to on the running server.
- `--keyring-migration-socket`: For Unix socket file or Windows named pipe connections, the socket file or named pipe to connect to on the running server.

Prerequisite for migration:

Make sure to pass required kerying options and other configuration parameters for the two keyring plugins. For example, if `keyring_file` is one of the plugins, you must set the `keyring_file_data` system variable if the keyring data file location is not the default location.

Other non-keyring options may be required as well. One way to specify these options is by using `--defaults-file` to name an option file that contains the required options.

```
[mysqld]
basedir=/dev/shm/pxc57
datadir=/dev/shm/pxc57/copy_mig
log-error=/dev/shm/pxc57/logs/copy_mig.err
socket=/tmp/copy_mig.sock
port=16400
```

Part VI

Flexibility

CHAPTER

TWENTYFIVE

BINLOGGING AND REPLICATION IMPROVEMENTS

Due to continuous development, Percona Server incorporated a number of improvements related to replication and binary logs handling. This resulted in replication specifics, which distinguishes it from *MySQL*.

Temporary tables and mixed logging format

Summary of the fix:

As soon as some statement involving temporary table was met when using mixed binlog format, *MySQL* was switching to row-based logging of all statements the end of the session or until all temporary tables used in this session are dropped. It is inconvenient in case of long lasting connections, including replication-related ones. Percona Server fixes the situation by switching between statement-based and row-based logging as and when necessary.

Version Specific Information

- `5.7.10-1` Fix ported from Percona Server 5.6

Details:

Mixed binary logging format supported by Percona Server means that server runs in statement-based logging by default, but switches to row-based logging when replication would be unpredictable - in the case of a nondeterministic SQL statement that may cause data divergence if reproduced on a slave server. The switch is done upon any condition from the long list, and one of these conditions is the use of temporary tables.

Temporary tables are **never** logged using row-based format, but any statement, that touches a temporary table, is logged in row mode. This way all the side effects that temporary tables may produce on non-temporary ones are intercepted.

There is no need to use row logging format for any other statements solely because of the temp table presence. However *MySQL* was undertaking such an excessive precaution: once some statement with temporary table had appeared and the row-based logging was used, *MySQL* logged unconditionally all subsequent statements in row format.

Percona Server have implemented more accurate behavior: instead of switching to row-based logging until the last temporary table is closed, the usual rules of row vs statement format apply, and presence of currently opened temporary tables is no longer considered. This change was introduced with the fix of a bug #151 (upstream #72475).

Temporary table drops and binloging on GTID-enabled server

Summary of the fix:

MySQL logs DROP statements for all temporary tables irrelative of the logging mode under which these tables were created. This produces binlog writes and errand GTIDs on slaves with row and mixed logging. Percona Server fixes this by tracking the binlog format at temporary table create time and using it to decide whether a DROP should be logged or not.

Version Specific Information

- `5.7.17-11` Fix ported from Percona Server 5.6

Details:

Even with read_only mode enabled, the server permits some operations, including ones with temporary tables. With the previous fix, temporary table operations are not binlogged in row or mixed mode. But *MySQL* doesn't track what was the logging mode when temporary table was created, and therefore unconditionally logs `DROP` statements for all temporary tables. These `DROP` statements receive `IF EXISTS` addition, which is intended to make them harmless.

Percona Server have fixed this with the bug fixes #964, upstream #83003, and upstream #85258. Moreover, after all the binlogging fixes discussed so far nothing involving temporary tables is logged to binary log in row or mixed format, and so there is no need to consider `CREATE/DROP TEMPORARY TABLE` unsafe for use in stored functions, triggers, and multi-statement transactions in row/mixed format. Therefore an additional fix was introduced to mark creation and drop of temporary tables as unsafe inside transactions in statement-based replication only (bug fixed #1816, upstream #89467)).

Safety of statements with a `LIMIT` clause

Summary of the fix:

MySQL considers all `UPDATE/DELETE/INSERT ... SELECT` statements with `LIMIT` clause to be unsafe, no matter wether they are really producing non-deterministic result or not, and switches from statement-based logging to row-based one. Percona Server is more accurate, it acknowledges such instructions as safe when they include `ORDER BY PK` or `WHERE` condition. This fix has been ported from the upstream bug report #42415 (#44).

Version Specific Information

- `5.7.10.1` Fix ported from Percona Server 5.6

Performance improvement on relay log position update

Summary of the fix:

MySQL always updated relay log position in multi-source replications setups regardless of whether the committed transaction has already been executed or not. Percona Server omitts relay log position updates for the already logged GTIDs.

Version Specific Information

- `5.7.18-14` Fix implemented in Percona Server 5.7

Details

Particularly, such unconditional relay log position updates caused additional fsync operations in case of `relay-log-info-repository=TABLE`, and with the higher number of channels transmitting such duplicate (already executed) transactions the situation became proportionally worse. Bug fixed #1786 (upstream #85141).

Performance improvement on master and connection status updates

Summary of the fix:

Slave nodes configured to update master status and connection information only on log file rotation did not experience the expected reduction in load. *MySQL* was additionaly updating this information in case of multi-source replication when slave had to skip the already executed GTID event.

Version Specific Information

- `5.7.20-19` Fix implemented in Percona Server 5.7

Details

The configuration with `master_info_repository=TABLE` and `sync_master_info=0` makes slave to update master status and connection information in this table on log file rotation and not after each sync_master_info event, but it didn't work on multi-source replication setups. Heartbeats sent to the slave to skip GTID events which it had already executed previously, were evaluated as relay log rotation events and reacted with `mysql.slave_master_info` table sync. This inaccuracy could produce huge (up to 5 times on some setups) increase in write load on the slave, before this problem was fixed in Percona Server. Bug fixed #1812 (upstream #85158).

CHAPTER

TWENTYSIX

INNODB FULL-TEXT SEARCH IMPROVEMENTS

Ignoring Stopword list

By default all Full-Text Search indexes check the stopwords list, to see if any indexed elements *contain* one of the words on that list.

Using this list for n-gram indexes isn't always suitable, as an example, any item that contains `a` or `i` will be ignored. Another word that can't be searched is `east`, this one will find no matches because `a` is on the FTS stopword list.

To resolve this issue, in Percona Server `5.7.20-18` a new *`innodb_ft_ignore_stopwords`* variable has been implemented which controls whether *InnoDB* Full-Text Search should ignore stopword list.

Although this variable is introduced to resolve n-gram issues, it affects all Full-Text Search indexes as well.

Being a stopword doesn't just mean to be a one of the predefined words from the list. Tokens shorter than innodb_ft_min_token_size or longer than innodb_ft_max_token_size are also considered stopwords. Therefore, when *`innodb_ft_ignore_stopwords`* is set to `ON` even for non-ngram FTS, `innodb_ft_min_token_size` / `innodb_ft_max_token_size` will be ignored meaning that in this case very short and very long words will also be indexed.

System Variables

variable `innodb_ft_ignore_stopwords`

Command Line Yes

Config File Yes

Scope Session, Global

Dynamic Yes

Variable Type Boolean

Default Value `OFF`

When enabled, this variable will instruct *InnoDB* Full Text Search parser to ignore the stopword list when building/updating an FTS index.

Punctuation Marks in Full-Text Search

By default, full text search is unable to find words with various punctuation characters in boolean search mode, although those characters are indexed with ngram parser. A new variable *ft_query_extra_word_chars* was introduced in Percona Server 5.7.21-20 to solve this issue.

When it's enabled, all the non-whitespace symbols are considered to be word symbols by FTS query parser, except for the boolean search syntax symbols (which are specified by ft_boolean_syntax variable). The latter ones are also considered to be word symbols inside double quotes. This only applies for the query tokenizer, and the indexing tokenizer is not changed in any way. Because of this, the double quote symbol itself is never considered a word symbol, as no existing indexing tokenizer does so, thus searching for it would never return documents.

System Variables

variable ft_query_extra_word_chars

Command Line Yes

Config File Yes

Scope Session, Global

Dynamic Yes

Variable Type Boolean

Default Value OFF

When enabled, this variable will make all non-whitespace symbols (including punctuation marks) to be treated as word symbols in full-text search queries.

CHAPTER

TWENTYSEVEN

INNODB PAGE FRAGMENTATION COUNTERS

InnoDB page fragmentation is caused by random insertion or deletion from a secondary index. This means that the physical ordering of the index pages on the disk is not same as the index ordering of the records on the pages. As a consequence this means that some pages take a lot more space and that queries which require a full table scan can take a long time to finish.

To provide more information about the *InnoDB* page fragmentation Percona Server now provides the following counters as status variables: *Innodb_scan_pages_contiguous*, *Innodb_scan_pages_disjointed*, *Innodb_scan_data_size*, *Innodb_scan_deleted_recs_size*, and *Innodb_scan_pages_total_seek_distance*.

Version Specific Information

- `5.7.20-18`: Feature Implemented

Status Variables

variable `Innodb_scan_pages_contiguous`

Variable Type Numeric

Scope Session

This variable shows the number of contiguous page reads inside a query.

variable `Innodb_scan_pages_disjointed`

Variable Type Numeric

Scope Session

This variable shows the number of disjointed page reads inside a query.

variable `Innodb_scan_data_size`

Variable Type Numeric

Scope Session

This variable shows the size of data in all *InnoDB* pages read inside a query (in bytes) - calculated as the sum of `page_get_data_size(page)` for every page scanned.

variable `Innodb_scan_deleted_recs_size`

Variable Type Numeric

Scope Session

This variable shows the size of deleted records (marked as `deleted` in `page_delete_rec_list_end()`) in all *InnoDB* pages read inside a query (in bytes) - calculated as the sum of `page_header_get_field(page, PAGE_GARBAGE)` for every page scanned.

variable `Innodb_scan_pages_total_seek_distance`

Variable Type Numeric

Scope Session

This variable shows the total seek distance when moving between pages.

Related Reading

- InnoDB: look after fragmentation
- Defragmenting a Table

CHAPTER

TWENTYEIGHT

MULTIPLE PAGE ASYNCHRONOUS I/O REQUESTS

I/O unit size in *InnoDB* is only one page, even if doing read ahead. 16KB I/O unit size is too small for sequential reads, and much less efficient than larger I/O unit size.

InnoDB uses Linux asynchronous I/O (`aio`) by default. By submitting multiple consecutive 16KB read requests at once, Linux internally can merge requests and reads can be done more efficiently.

On a HDD RAID 1+0 environment, more than 1000MB/s disk reads can be achieved by submitting 64 consecutive pages requests at once, while only 160MB/s disk reads is shown by submitting single page request.

With this feature *InnoDB* submits multiple page I/O requests.

Version Specific Information

- `5.7.20-18`- Feature ported from the *Facebook MySQL* patch.

Status Variables

variable `Innodb_buffered_aio_submitted`

Version Info

- **`5.7.20-18`** – Implemented

Variable Type Numeric

Scope Global

This variable shows the number of submitted buffered asynchronous I/O requests.

Other Reading

- Making full table scan 10x faster in InnoDB
- Bug #68659 InnoDB Linux native aio should submit more i/o requests at once

Part VII

How-tos

CHAPTER

TWENTYNINE

UPGRADING PERCONA XTRADB CLUSTER

This guide describes the procedure for upgrading Percona XtraDB Cluster without downtime (*rolling upgrade*) to the latest 5.7 version. A "rolling upgrade" means there is no need to take down the complete cluster during the upgrade.

Both major upgrades (from 5.6 to 5.7 version) and minor ones (from 5.7.x to 5.7.y) can be done in this way. Rolling upgrades to 5.7 from versions older than 5.6 are not supported. Therefore if you are running Percona XtraDB Cluster version 5.5, it is recommended to shut down all nodes, then remove and re-create the cluster from scratch. Alternatively, you can perform a rolling upgrade from PXC 5.5 to 5.6, and then follow the current procedure to upgrade from 5.6 to 5.7.

The following documents contain details about relevant changes in the 5.7 series of MySQL and Percona Server. Make sure you deal with any incompatible features and variables mentioned in these documents when upgrading to Percona XtraDB Cluster 5.7.

- Changed in Percona Server 5.7
- Upgrading MySQL
- Upgrading from MySQL 5.6 to 5.7

Major upgrade

To upgrade the cluster, follow these steps for each node:

1. Make sure that all nodes are synchronized.
2. Stop the `mysql` service:

   ```
   $ sudo service mysql stop
   ```

3. Remove existing Percona XtraDB Cluster and Percona XtraBackup packages, then install Percona XtraDB Cluster version 5.7 packages. For more information, see *Installing Percona XtraDB Cluster*.

   For example, if you have Percona software repositories configured, you might use the following commands:

   - On CentOS or RHEL:

```
$ sudo yum remove percona-xtrabackup* Percona-XtraDB-Cluster*
$ sudo yum install Percona-XtraDB-Cluster-57
```

- On Debian or Ubuntu:

```
$ sudo apt-get remove percona-xtrabackup* percona-xtradb-cluster*
$ sudo apt-get install percona-xtradb-cluster-57
```

4. In case of Debian or Ubuntu, the `mysql` service starts automatically after install. Stop the service:

```
$ sudo service mysql stop
```

5. Back up `grastate.dat`, so that you can restore it if it is corrupted or zeroed out due to network issue.
6. Start the node outside the cluster (in standalone mode) by setting the *wsrep_provider* variable to `none`. For example:

```
sudo mysqld --skip-grant-tables --user=mysql --wsrep-provider='none'
```

Note: As of Percona XtraDB Cluster 5.7.6, the `--skip-grant-tables` option is not required.

Note: To prevent any users from accessing this node while performing work on it, you may add –skip-networking to the startup options and use a local socket to connect, or alternatively you may want to divert any incoming traffic from your application to other operational nodes.

7. Open another session and run `mysql_upgrade`.
8. When the upgrade is done, stop the `mysqld` process. You can either run `sudo kill` on the `mysqld` process ID, or `sudo mysqladmin shutdown` with the MySQL root user credentials.

Note: On CentOS, the `my.cnf` configuration file is renamed to `my.cnf.rpmsave`. Make sure to rename it back before joining the upgraded node back to the cluster.

9. Now you can join the upgraded node back to the cluster.

   In most cases, starting the `mysql` service should run the node with your previous configuration:

```
$ sudo service mysql start
```

   For more information, see *Adding Nodes to Cluster*.

Note: As of version 5.7, Percona XtraDB Cluster runs with *PXC Strict Mode* enabled by default. This will deny any unsupported operations and may halt the server upon encountering a failed validation.

If you are not sure, it is recommended to first start the node with the *pxc_strict_mode* variable set to `PERMISSIVE` in the in the *MySQL* configuration file, `my.cnf`.

After you check the log for any experimental or unsupported features and fix any encountered incompatibilities, you can set the variable back to `ENFORCING` at run time:

```
mysql> SET pxc_strict_mode=ENFORCING;
```

Also switch back to `ENFORCING` may be done by restarting the node with updated `my.cnf`.

10. Repeat this procedure for the next node in the cluster until you upgrade all nodes.

It is important that on rejoining, the node should synchronize using *IST*. For this, it is best not to leave the cluster node being upgraded offline for an extended period. More on this below.

When performing any upgrade (major or minor), *SST* could be initiated by the joiner node after the upgrade if the server was offline for some time. After *SST* completes, the data directory structure needs to be upgraded (using mysql_upgrade) once more time to ensure compatibility with the newer version of binaries.

Note: In case of *SST* synchronization, the error log contains statements like "Check if state gap can be serviced using IST ... State gap can't be serviced using IST. Switching to SST" instead of "Receiving IST: ..." lines appropriate to *IST* synchronization.

Minor upgrade

To upgrade the cluster, follow these steps for each node:

1. Make sure that all nodes are synchronized.
2. Stop the `mysql` service:

```
$ sudo service mysql stop
```

3. Upgrade Percona XtraDB Cluster and Percona XtraBackup packages. For more information, see *Installing Percona XtraDB Cluster*.

   For example, if you have Percona software repositories configured, you might use the following commands:

   - On CentOS or RHEL:

   ```
   $ sudo yum update Percona-XtraDB-Cluster-57
   ```

   - On Debian or Ubuntu:

   ```
   $ sudo apt-get install --only-upgrade percona-xtradb-cluster-57
   ```

4. In case of Debian or Ubuntu, the `mysql` service starts automatically after install. Stop the service:

```
$ sudo service mysql stop
```

5. Back up `grastate.dat`, so that you can restore it if it is corrupted or zeroed out due to network issue.
6. Start the node outside the cluster (in standalone mode) by setting the *`wsrep_provider`* variable to `none`. For example:

```
sudo mysqld --skip-grant-tables --user=mysql --wsrep-provider='none'
```

Note: As of Percona XtraDB Cluster 5.7.6, the `--skip-grant-tables` option is not required.

Note: To prevent any users from accessing this node while performing work on it, you may add –skip-networking to the startup options and use a local socket to connect, or alternatively you may want to divert any incoming traffic from your application to other operational nodes.

7. Open another session and run `mysql_upgrade`.
8. When the upgrade is done, stop the `mysqld` process. You can either run `sudo kill` on the `mysqld` process ID, or `sudo mysqladmin shutdown` with the MySQL root user credentials.

Note: On CentOS, the `my.cnf` configuration file is renamed to `my.cnf.rpmsave`. Make sure to rename it back before joining the upgraded node back to the cluster.

9. Now you can join the upgraded node back to the cluster.

   In most cases, starting the `mysql` service should run the node with your previous configuration:

   ```
   $ sudo service mysql start
   ```

   For more information, see *Adding Nodes to Cluster*.

   Note: As of version 5.7, Percona XtraDB Cluster runs with *PXC Strict Mode* enabled by default. This will deny any unsupported operations and may halt the server upon encountering a failed validation.

   If you are not sure, it is recommended to first start the node with the *pxc_strict_mode* variable set to `PERMISSIVE` in the in the *MySQL* configuration file, `my.cnf`.

   After you check the log for any experimental or unsupported features and fix any encountered incompatibilities, you can set the variable back to `ENFORCING` at run time:

   ```
   mysql> SET pxc_strict_mode=ENFORCING;
   ```

   Also switch back to `ENFORCING` may be done by restarting the node with updated `my.cnf`.

10. Repeat this procedure for the next node in the cluster until you upgrade all nodes.

Dealing with IST/SST synchronization while upgrading

It is important that on rejoining, the node should synchronize using *IST*. For this, it is best not to leave the cluster node being upgraded offline for an extended period. More on this below.

When performing any upgrade (major or minor), *SST* could be initiated by the joiner node after the upgrade if the server was offline for some time. After *SST* completes, the data directory structure needs to be upgraded (using mysql_upgrade) once more time to ensure compatibility with the newer version of binaries.

Note: In case of *SST* synchronization, the error log contains statements like “Check if state gap can be serviced using IST ... State gap can’t be serviced using IST. Switching to SST” instead of “Receiving IST: ...” lines appropriate to *IST* synchronization.

The following additional steps should be made to upgrade the data directory structure after *SST* (after the normal major or minor upgrade steps):

1. shutdown the node that rejoined the cluster using *SST*:

```
$ sudo service mysql stop
```

2. restart the node in standalone mode by setting the *wsrep_provider* variable to `none`, e.g.:

```
sudo mysqld --skip-grant-tables --user=mysql --wsrep-provider='none'
```

3. run `mysql-upgrade`
4. restart the node in cluster mode (e.g by executing `sudo service mysql start` and make sure the cluster joins back using *IST*.

CHAPTER

THIRTY

CONFIGURING PERCONA XTRADB CLUSTER ON CENTOS

This tutorial describes how to install and configure three Percona XtraDB Cluster nodes on CentOS 6.8 servers, using the packages from Percona repositories.

- Node 1
  - Host name: `percona1`
  - IP address: `192.168.70.71`
- Node 2
  - Host name: `percona2`
  - IP address: `192.168.70.72`
- Node 3
  - Host name: `percona3`
  - IP address: `192.168.70.73`

Prerequisites

The procedure described in this tutorial requires the following:

- All three nodes have CentOS 6.8 installed.
- The firewall on all nodes is configured to allow connecting to ports 3306, 4444, 4567 and 4568.
- SELinux on all nodes is disabled.

Step 1. Installing PXC

Install Percona XtraDB Cluster on all three nodes as described in *Installing Percona XtraDB Cluster on Red Hat Enterprise Linux and CentOS*.

Step 2. Configuring the first node

Individual nodes should be configured to be able to bootstrap the cluster. For more information about bootstrapping the cluster, see *Bootstrapping the First Node*.

1. Make sure that the configuration file `/etc/my.cnf` on the first node (`percona1`) contains the following:

```
[mysqld]

datadir=/var/lib/mysql
user=mysql

# Path to Galera library
wsrep_provider=/usr/lib64/libgalera_smm.so

# Cluster connection URL contains the IPs of node#1, node#2 and node#3
wsrep_cluster_address=gcomm://192.168.70.71,192.168.70.72,192.168.70.73

# In order for Galera to work correctly binlog format should be ROW
binlog_format=ROW

# MyISAM storage engine has only experimental support
default_storage_engine=InnoDB

# This InnoDB autoincrement locking mode is a requirement for Galera
innodb_autoinc_lock_mode=2

# Node 1 address
wsrep_node_address=192.168.70.71

# SST method
wsrep_sst_method=xtrabackup-v2

# Cluster name
wsrep_cluster_name=my_centos_cluster

# Authentication for SST method
wsrep_sst_auth="sstuser:s3cret"
```

2. Start the first node with the following command:

```
[root@percona1 ~]# /etc/init.d/mysql bootstrap-pxc
```

Note: In case you're running CentOS 7, the bootstrap service should be used instead:

```
[root@percona1 ~]#  systemctl start mysql@bootstrap.service
```

The previous command will start the cluster with initial *wsrep_cluster_address* variable set to `gcomm://`. If the node or *MySQL* are restarted later, there will be no need to change the configuration file.

3. After the first node has been started, cluster status can be checked with the following command:

```
mysql> show status like 'wsrep%';
+----------------------------+--------------------------------------+
| Variable_name              | Value                                |
+----------------------------+--------------------------------------+
| wsrep_local_state_uuid     | c2883338-834d-11e2-0800-03c9c68e41ec |
...
| wsrep_local_state          | 4                                    |
| wsrep_local_state_comment  | Synced                               |
...
| wsrep_cluster_size         | 1                                    |
| wsrep_cluster_status       | Primary                              |
```

```
| wsrep_connected              | ON                                      |
...
| wsrep_ready                  | ON                                      |
+------------------------------+-----------------------------------------+
40 rows in set (0.01 sec)
```

This output shows that the cluster has been successfully bootstrapped.

Note: It is not recommended to leave an empty password for the root account. Password can be changed as follows:

```
mysql@percona1> UPDATE mysql.user SET password=PASSWORD("Passw0rd") where user='root';
mysql@percona1> FLUSH PRIVILEGES;
```

To perform *State Snapshot Transfer* using *XtraBackup*, set up a new user with proper privileges:

```
mysql@percona1> CREATE USER 'sstuser'@'localhost' IDENTIFIED BY 's3cret';
mysql@percona1> GRANT PROCESS, RELOAD, LOCK TABLES, REPLICATION CLIENT ON *.* TO
↪'sstuser'@'localhost';
mysql@percona1> FLUSH PRIVILEGES;
```

Note: MySQL root account can also be used for performing SST, but it is more secure to use a different (non-root) user for this.

Step 3. Configuring the second node

1. Make sure that the onfiguration file `/etc/my.cnf` on the second node (`percona2`) contains the following:

```
[mysqld]

datadir=/var/lib/mysql
user=mysql

# Path to Galera library
wsrep_provider=/usr/lib64/libgalera_smm.so

# Cluster connection URL contains IPs of node#1, node#2 and node#3
wsrep_cluster_address=gcomm://192.168.70.71,192.168.70.72,192.168.70.73

# In order for Galera to work correctly binlog format should be ROW
binlog_format=ROW

# MyISAM storage engine has only experimental support
default_storage_engine=InnoDB

# This InnoDB autoincrement locking mode is a requirement for Galera
innodb_autoinc_lock_mode=2

# Node 2 address
wsrep_node_address=192.168.70.72

# Cluster name
wsrep_cluster_name=my_centos_cluster
```

```
# SST method
wsrep_sst_method=xtrabackup-v2

#Authentication for SST method
wsrep_sst_auth="sstuser:s3cret"
```

2. Start the second node with the following command:

```
[root@percona2 ~]# /etc/init.d/mysql start
```

1. After the server has been started, it should receive *SST* automatically. This means that the second node won't have empty root password anymore. In order to connect to the cluster and check the status, the root password from the first node should be used. Cluster status can be checked on both nodes. The following is an example of status from the second node (`percona2`):

```
mysql> show status like 'wsrep%';
+----------------------------+--------------------------------------+
| Variable_name              | Value                                |
+----------------------------+--------------------------------------+
| wsrep_local_state_uuid     | c2883338-834d-11e2-0800-03c9c68e41ec |
...
| wsrep_local_state          | 4                                    |
| wsrep_local_state_comment  | Synced                               |
...
| wsrep_cluster_size         | 2                                    |
| wsrep_cluster_status       | Primary                              |
| wsrep_connected            | ON                                   |
...
| wsrep_ready                | ON                                   |
+----------------------------+--------------------------------------+
40 rows in set (0.01 sec)
```

This output shows that the new node has been successfully added to the cluster.

Step 4. Configuring the third node

1. Make sure that the MySQL configuration file `/etc/my.cnf` on the third node (`percona3`) contains the following:

```
[mysqld]

datadir=/var/lib/mysql
user=mysql

# Path to Galera library
wsrep_provider=/usr/lib64/libgalera_smm.so

# Cluster connection URL contains IPs of node#1, node#2 and node#3
wsrep_cluster_address=gcomm://192.168.70.71,192.168.70.72,192.168.70.73

# In order for Galera to work correctly binlog format should be ROW
binlog_format=ROW

# MyISAM storage engine has only experimental support
```

```
default_storage_engine=InnoDB

# This InnoDB autoincrement locking mode is a requirement for Galera
innodb_autoinc_lock_mode=2

# Node #3 address
wsrep_node_address=192.168.70.73

# Cluster name
wsrep_cluster_name=my_centos_cluster

# SST method
wsrep_sst_method=xtrabackup-v2

#Authentication for SST method
wsrep_sst_auth="sstuser:s3cret"
```

2. Start the third node with the following command:

```
[root@percona3 ~]# /etc/init.d/mysql start
```

1. After the server has been started, it should receive SST automatically. Cluster status can be checked on all three nodes. The following is an example of status from the third node (`percona3`):

```
mysql> show status like 'wsrep%';
+----------------------------+--------------------------------------+
| Variable_name              | Value                                |
+----------------------------+--------------------------------------+
| wsrep_local_state_uuid     | c2883338-834d-11e2-0800-03c9c68e41ec |
...
| wsrep_local_state          | 4                                    |
| wsrep_local_state_comment  | Synced                               |
...
| wsrep_cluster_size         | 3                                    |
| wsrep_cluster_status       | Primary                              |
| wsrep_connected            | ON                                   |
...
| wsrep_ready                | ON                                   |
+----------------------------+--------------------------------------+
40 rows in set (0.01 sec)
```

This output confirms that the third node has joined the cluster.

Testing replication

To test replication, lets create a new database on second node, create a table for that database on the third node, and add some records to the table on the first node.

1. Create a new database on the second node:

```
mysql@percona2> CREATE DATABASE percona;
Query OK, 1 row affected (0.01 sec)
```

2. Create a table on the third node:

```
mysql@percona3> USE percona;
Database changed

mysql@percona3> CREATE TABLE example (node_id INT PRIMARY KEY, node_name␣
↪VARCHAR(30));
Query OK, 0 rows affected (0.05 sec)
```

3. Insert records on the first node:

```
mysql@percona1> INSERT INTO percona.example VALUES (1, 'percona1');
Query OK, 1 row affected (0.02 sec)
```

4. Retrieve all the rows from that table on the second node:

```
mysql@percona2> SELECT * FROM percona.example;
+---------+-----------+
| node_id | node_name |
+---------+-----------+
|       1 | percona1  |
+---------+-----------+
1 row in set (0.00 sec)
```

This simple procedure should ensure that all nodes in the cluster are synchronized and working as intended.

CHAPTER

THIRTYONE

CONFIGURING PERCONA XTRADB CLUSTER ON UBUNTU

This tutorial describes how to install and configure three Percona XtraDB Cluster nodes on Ubuntu 12.04.2 LTS servers, using the packages from Percona repositories.

- Node 1
  - Host name: `pxc1`
  - IP address: `192.168.70.61`
- Node 2
  - Host name: `pxc2`
  - IP address: `192.168.70.62`
- Node 3
  - Host name: `pxc3`
  - IP address: `192.168.70.63`

Prerequisites

The procedure described in this tutorial requires he following:

- All three nodes have Ubuntu 12.04.2 LTS installed.
- Firewall on all nodes is configured to allow connecting to ports 3306, 4444, 4567 and 4568.
- AppArmor profile for *MySQL* is disabled.

Step 1. Installing PXC

Install Percona XtraDB Cluster on all three nodes as described in *Installing Percona XtraDB Cluster on Debian or Ubuntu*.

Note: Debian/Ubuntu installation prompts for root password. For this tutorial, set it to `Passw0rd`. After the packages have been installed, `mysqld` will start automatically. Stop `mysqld` on all three nodes using `/etc/init.d/mysql stop`.

Step 2. Configuring the first node

Individual nodes should be configured to be able to bootstrap the cluster. For more information about bootstrapping the cluster, see *Bootstrapping the First Node*.

1. Make sure that the configuration file `/etc/mysql/my.cnf` for the first node (`pxc1`) contains the following:

```
[mysqld]

datadir=/var/lib/mysql
user=mysql

# Path to Galera library
wsrep_provider=/usr/lib/libgalera_smm.so

# Cluster connection URL contains the IPs of node#1, node#2 and node#3
wsrep_cluster_address=gcomm://192.168.70.61,192.168.70.62,192.168.70.63

# In order for Galera to work correctly binlog format should be ROW
binlog_format=ROW

# MyISAM storage engine has only experimental support
default_storage_engine=InnoDB

# This InnoDB autoincrement locking mode is a requirement for Galera
innodb_autoinc_lock_mode=2

# Node #1 address
wsrep_node_address=192.168.70.61

# SST method
wsrep_sst_method=xtrabackup-v2

# Cluster name
wsrep_cluster_name=my_ubuntu_cluster

# Authentication for SST method
wsrep_sst_auth="sstuser:s3cretPass"
```

2. Start the first node with the following command:

```
[root@pxc1 ~]# /etc/init.d/mysql bootstrap-pxc
```

   This command will start the first node and bootstrap the cluster.

3. After the first node has been started, cluster status can be checked with the following command:

```
mysql> show status like 'wsrep%';
+----------------------------+--------------------------------------+
| Variable_name              | Value                                |
+----------------------------+--------------------------------------+
| wsrep_local_state_uuid     | b598af3e-ace3-11e2-0800-3e90eb9cd5d3 |
...
| wsrep_local_state          | 4                                    |
| wsrep_local_state_comment  | Synced                               |
...
| wsrep_cluster_size         | 1                                    |
| wsrep_cluster_status       | Primary                              |
```

```
| wsrep_connected              | ON                                      |
...
| wsrep_ready                  | ON                                      |
+------------------------------+-----------------------------------------+
40 rows in set (0.01 sec)
```

This output shows that the cluster has been successfully bootstrapped.

To perform *State Snapshot Transfer* using *XtraBackup*, set up a new user with proper privileges:

```
mysql@pxc1> CREATE USER 'sstuser'@'localhost' IDENTIFIED BY 's3cretPass';
mysql@pxc1> GRANT PROCESS, RELOAD, LOCK TABLES, REPLICATION CLIENT ON *.* TO 'sstuser
↪'@'localhost';
mysql@pxc1> FLUSH PRIVILEGES;
```

Note: MySQL root account can also be used for performing SST, but it is more secure to use a different (non-root) user for this.

Step 3. Configuring the second node

1. Make sure that the configuration file `/etc/mysql/my.cnf` on the second node (`pxc2`) contains the following:

```
[mysqld]

datadir=/var/lib/mysql
user=mysql

# Path to Galera library
wsrep_provider=/usr/lib/libgalera_smm.so

# Cluster connection URL contains IPs of node#1, node#2 and node#3
wsrep_cluster_address=gcomm://192.168.70.61,192.168.70.62,192.168.70.63

# In order for Galera to work correctly binlog format should be ROW
binlog_format=ROW

# MyISAM storage engine has only experimental support
default_storage_engine=InnoDB

# This InnoDB autoincrement locking mode is a requirement for Galera
innodb_autoinc_lock_mode=2

# Node #2 address
wsrep_node_address=192.168.70.62

# Cluster name
wsrep_cluster_name=my_ubuntu_cluster

# SST method
wsrep_sst_method=xtrabackup-v2

#Authentication for SST method
wsrep_sst_auth="sstuser:s3cretPass"
```

2. Start the second node with the following command:

```
[root@pxc2 ~]# /etc/init.d/mysql start
```

3. After the server has been started, it should receive *SST* automatically. Cluster status can now be checked on both nodes. The following is an example of status from the second node (`pxc2`):

```
mysql> show status like 'wsrep%';
+----------------------------+--------------------------------------+
| Variable_name              | Value                                |
+----------------------------+--------------------------------------+
| wsrep_local_state_uuid     | b598af3e-ace3-11e2-0800-3e90eb9cd5d3 |
...
| wsrep_local_state          | 4                                    |
| wsrep_local_state_comment  | Synced                               |
...
| wsrep_cluster_size         | 2                                    |
| wsrep_cluster_status       | Primary                              |
| wsrep_connected            | ON                                   |
...
| wsrep_ready                | ON                                   |
+----------------------------+--------------------------------------+
40 rows in set (0.01 sec)
```

This output shows that the new node has been successfully added to the cluster.

Step 4. Configuring the third node

1. Make sure that the MySQL configuration file `/etc/mysql/my.cnf` on the third node (`pxc3`) contains the following:

```
[mysqld]

datadir=/var/lib/mysql
user=mysql

# Path to Galera library
wsrep_provider=/usr/lib/libgalera_smm.so

# Cluster connection URL contains IPs of node#1, node#2 and node#3
wsrep_cluster_address=gcomm://192.168.70.61,192.168.70.62,192.168.70.63

# In order for Galera to work correctly binlog format should be ROW
binlog_format=ROW

# MyISAM storage engine has only experimental support
default_storage_engine=InnoDB

# This InnoDB autoincrement locking mode is a requirement for Galera
innodb_autoinc_lock_mode=2

# Node #3 address
wsrep_node_address=192.168.70.63

# Cluster name
wsrep_cluster_name=my_ubuntu_cluster
```

```
# SST method
wsrep_sst_method=xtrabackup-v2

#Authentication for SST method
wsrep_sst_auth="sstuser:s3cretPass"
```

2. Start the third node with the following command:

```
[root@pxc3 ~]# /etc/init.d/mysql start
```

3. After the server has been started, it should receive SST automatically. Cluster status can be checked on all nodes. The following is an example of status from the third node (`pxc3`):

```
mysql> show status like 'wsrep%';
+----------------------------+--------------------------------------+
| Variable_name              | Value                                |
+----------------------------+--------------------------------------+
| wsrep_local_state_uuid     | b598af3e-ace3-11e2-0800-3e90eb9cd5d3 |
...
| wsrep_local_state          | 4                                    |
| wsrep_local_state_comment  | Synced                               |
...
| wsrep_cluster_size         | 3                                    |
| wsrep_cluster_status       | Primary                              |
| wsrep_connected            | ON                                   |
...
| wsrep_ready                | ON                                   |
+----------------------------+--------------------------------------+
40 rows in set (0.01 sec)
```

This output confirms that the third node has joined the cluster.

Testing replication

To test replication, lets create a new database on the second node, create a table for that database on the third node, and add some records to the table on the first node.

1. Create a new database on the second node:

```
mysql@pxc2> CREATE DATABASE percona;
Query OK, 1 row affected (0.01 sec)
```

2. Create a table on the third node:

```
mysql@pxc3> USE percona;
Database changed

mysql@pxc3> CREATE TABLE example (node_id INT PRIMARY KEY, node_name VARCHAR(30));
Query OK, 0 rows affected (0.05 sec)
```

3. Insert records on the first node:

```
mysql@pxc1> INSERT INTO percona.example VALUES (1, 'percona1');
Query OK, 1 row affected (0.02 sec)
```

4. Retrieve all the rows from that table on the second node:

```
mysql@pxc2> SELECT * FROM percona.example;
+---------+-----------+
| node_id | node_name |
+---------+-----------+
|       1 | percona1  |
+---------+-----------+
1 row in set (0.00 sec)
```

This simple procedure should ensure that all nodes in the cluster are synchronized and working as intended.

CHAPTER

THIRTYTWO

SETTING UP GALERA ARBITRATOR

Galera Arbitrator <http://galeracluster.com/documentation-webpages/arbitrator.html> is a member of *Percona XtraDB Cluster* that is used for voting in case you have a small number of servers (usually two) and don't want to add any more resources. Galera Arbitrator does not need a dedicated server. It can be installed on a machine running some other application. Just make sure it has good network connectivity.

Galera Arbitrator is a member of the cluster that participates in the voting, but not in actual replication (although it receives the same data as other nodes). Also, it is not included in flow control calculations.

This document will show how to add Galera Arbitrator node to an existing cluster.

Note: For more information on how to set up a cluster you can read in the *Configuring Percona XtraDB Cluster on Ubuntu* or *Configuring Percona XtraDB Cluster on CentOS* manuals.

Installation

Galera Arbitrator can be installed from Percona's repository by running:

```
root@ubuntu:~# apt-get install percona-xtradb-cluster-garbd-5.7
```

on Debian/Ubuntu distributions, or:

```
[root@centos ~]# yum install Percona-XtraDB-Cluster-garbd-57
```

on CentOS/RHEL distributions.

Configuration

To configure *Galera Arbitrator* on *Ubuntu/Debian* you need to edit the `/etc/default/garbd` file. On *CentOS/RHEL* configuration can be found in `/etc/sysconfig/garb` file.

Configuration file should look like this after installation:

```
# Copyright (C) 2012 Codership Oy
# This config file is to be sourced by garb service script.

# REMOVE THIS AFTER CONFIGURATION

# A comma-separated list of node addresses (address[:port]) in the cluster
# GALERA_NODES=""
```

```
# Galera cluster name, should be the same as on the rest of the nodes.
# GALERA_GROUP=""

# Optional Galera internal options string (e.g. SSL settings)
# see http://galeracluster.com/documentation-webpages/galeraparameters.html
# GALERA_OPTIONS=""

# Log file for garbd. Optional, by default logs to syslog
# Deprecated for CentOS7, use journalctl to query the log for garbd
# LOG_FILE=""
```

To set it up you'll need to add the information about the cluster you've set up. This example is using cluster information from the *Configuring Percona XtraDB Cluster on Ubuntu*.

```
# Copyright (C) 2012 Codership Oy
# This config file is to be sourced by garb service script.

# A comma-separated list of node addresses (address[:port]) in the cluster
GALERA_NODES="192.168.70.61:4567, 192.168.70.62:4567, 192.168.70.63:4567"

# Galera cluster name, should be the same as on the rest of the nodes.
GALERA_GROUP="my_ubuntu_cluster"

# Optional Galera internal options string (e.g. SSL settings)
# see http://galeracluster.com/documentation-webpages/galeraparameters.html
# GALERA_OPTIONS=""

# Log file for garbd. Optional, by default logs to syslog
# Deprecated for CentOS7, use journalctl to query the log for garbd
# LOG_FILE=""
```

Note: Please note that you need to remove the `# REMOVE THIS AFTER CONFIGURATION` line before you can start the service.

You can now start the *Galera Arbitrator* daemon (`garbd`) by running:

- On Debian or Ubuntu:

```
root@server:~# service garbd start
[ ok ] Starting /usr/bin/garbd: :.
```

- On Red Hat Enterprise Linux or CentOS:

```
root@server:~# service garb start
[ ok ] Starting /usr/bin/garbd: :.
```

You can additionally check the `arbitrator` status by running:

- On Debian or Ubuntu:

```
root@server:~# service garbd status
[ ok ] garb is running.
```

- On Red Hat Enterprise Linux or CentOS:

```
root@server:~# service garb status
[ ok ] garb is running.
```

CHAPTER

THIRTYTHREE

HOW TO SET UP A THREE-NODE CLUSTER ON A SINGLE BOX

This tutorial describes how to set up a 3-node cluster on a single physical box.

For the purposes of this tutorial, assume the following:

- The local IP address is `192.168.2.21`.
- Percona XtraDB Cluster is extracted from binary tarball into `/usr/local/Percona-XtraDB-Cluster-5.7.11-rel4beta-25.14.2.beta.Linux.x86_64`

To set up the cluster:

1. Create three MySQL configuration files for the corresponding nodes:
   - `/etc/my.4000.cnf`

```
[mysqld]
port = 4000
socket=/tmp/mysql.4000.sock
datadir=/data/bench/d1
basedir=/usr/local/Percona-XtraDB-Cluster-5.7.11-rel4beta-25.14.2.beta.Linux.
↪x86_64
user=mysql
log_error=error.log
binlog_format=ROW
wsrep_cluster_address='gcomm://192.168.2.21:5030,192.168.2.21:6030'
wsrep_provider=/usr/local/Percona-XtraDB-Cluster-5.7.11-rel4beta-25.14.2.beta.
↪Linux.x86_64/lib/libgalera_smm.so
wsrep_sst_receive_address=192.168.2.21:4020
wsrep_node_incoming_address=192.168.2.21
wsrep_slave_threads=2
wsrep_cluster_name=trimethylxanthine
wsrep_provider_options = "gmcast.listen_addr=tcp://192.168.2.21:4030;"
wsrep_sst_method=rsync
wsrep_node_name=node4000
innodb_autoinc_lock_mode=2
```

   - `/etc/my.5000.cnf`

```
[mysqld]
port = 5000
socket=/tmp/mysql.5000.sock
datadir=/data/bench/d2
basedir=/usr/local/Percona-XtraDB-Cluster-5.7.11-rel4beta-25.14.2.beta.Linux.
↪x86_64
user=mysql
log_error=error.log
binlog_format=ROW
```

```
wsrep_cluster_address='gcomm://192.168.2.21:4030,192.168.2.21:6030'
wsrep_provider=/usr/local/Percona-XtraDB-Cluster-5.7.11-rel4beta-25.14.2.beta.
↪Linux.x86_64/lib/libgalera_smm.so
wsrep_sst_receive_address=192.168.2.21:5020
wsrep_node_incoming_address=192.168.2.21
wsrep_slave_threads=2
wsrep_cluster_name=trimethylxanthine
wsrep_provider_options = "gmcast.listen_addr=tcp://192.168.2.21:5030;"
wsrep_sst_method=rsync
wsrep_node_name=node5000
innodb_autoinc_lock_mode=2
```

- `/etc/my.6000.cnf`

```
[mysqld]
port = 6000
socket=/tmp/mysql.6000.sock
datadir=/data/bench/d3
basedir=/usr/local/Percona-XtraDB-Cluster-5.7.11-rel4beta-25.14.2.beta.Linux.
↪x86_64
user=mysql
log_error=error.log
binlog_format=ROW
wsrep_cluster_address='gcomm://192.168.2.21:4030,192.168.2.21:5030'
wsrep_provider=/usr/local/Percona-XtraDB-Cluster-5.7.11-rel4beta-25.14.2.beta.
↪Linux.x86_64/lib/libgalera_smm.so
wsrep_sst_receive_address=192.168.2.21:6020
wsrep_node_incoming_address=192.168.2.21
wsrep_slave_threads=2
wsrep_cluster_name=trimethylxanthine
wsrep_provider_options = "gmcast.listen_addr=tcp://192.168.2.21:6030;"
wsrep_sst_method=rsync
wsrep_node_name=node6000
innodb_autoinc_lock_mode=2
```

2. Create three data directories for the nodes:
   - `/data/bench/d1`
   - `/data/bench/d2`
   - `/data/bench/d3`
3. Start the first node using the following command (from the Percona XtraDB Cluster install directory):

```
$ bin/mysqld_safe --defaults-file=/etc/my.4000.cnf --wsrep-new-cluster
```

If the node starts correctly, you should see the following output:

```
111215 19:01:49 [Note] WSREP: Shifting JOINED -> SYNCED (TO: 0)
111215 19:01:49 [Note] WSREP: New cluster view: global state: 4c286ccc-2792-11e1-
↪0800-94bd91e32efa:0, view# 1: Primary, number of nodes: 1, my index: 0,␣
↪protocol version 1
```

To check the ports, run the following command:

```
$ netstat -anp | grep mysqld
tcp        0      0 192.168.2.21:4030           0.0.0.0:*                   ␣
↪LISTEN      21895/mysqld
```

```
tcp        0      0 0.0.0.0:4000                0.0.0.0:*                   ␣
↪LISTEN      21895/mysqld
```

4. Start the second and third nodes:

```
bin/mysqld_safe --defaults-file=/etc/my.5000.cnf
bin/mysqld_safe --defaults-file=/etc/my.6000.cnf
```

If the nodes start and join the cluster successful, you should see the following output:

```
111215 19:22:26 [Note] WSREP: Shifting JOINER -> JOINED (TO: 2)
111215 19:22:26 [Note] WSREP: Shifting JOINED -> SYNCED (TO: 2)
111215 19:22:26 [Note] WSREP: Synchronized with group, ready for connections
```

To check the cluster size, run the following command:

```
$ mysql -h127.0.0.1 -P6000 -e "show global status like 'wsrep_cluster_size';"
+--------------------+-------+
| Variable_name      | Value |
+--------------------+-------+
| wsrep_cluster_size | 3     |
+--------------------+-------+
```

After that you can connect to any node and perform queries, which will be automatically synchronized with other nodes. For example, to create a database on the second node, you can run the following command:

```
$ mysql -h127.0.0.1 -P5000 -e "CREATE DATABASE hello_peter"
```

CHAPTER

THIRTYFOUR

HOW TO SET UP A THREE-NODE CLUSTER IN EC2 ENVIROMENT

This manual assumes you are running *m1.xlarge* instances with Red Hat Enterprise Linux 6.1 64-bit.

- `node1`: `10.93.46.58`
- `node2`: `10.93.46.59`
- `node3`: `10.93.46.60`

To set up Percona XtraDB Cluster:

1. Remove any Percona XtraDB Cluster 5.5, Percona Server 5.5, and Percona Server 5.6 packages.
2. nstall Percona XtraDB Cluster as described in *Installing Percona XtraDB Cluster on Red Hat Enterprise Linux and CentOS*.
3. Create data directories:

```
mkdir -p /mnt/data
mysql_install_db --datadir=/mnt/data --user=mysql
```

4. Stop the firewall service:

```
service iptables stop
```

Note: Alternatively, you can keep the firewall running, but open ports 3306, 4444, 4567, 4568. For example to open port 4567 on 192.168.0.1:

```
iptables -A INPUT -i eth0 -p tcp -m tcp --source 192.168.0.1/24 --dport 4567 -j␣
↪ACCEPT
```

5. Create `/etc/my.cnf` files:

   Contents of the configuration file on the first node:

```
[mysqld]
datadir=/mnt/data
user=mysql

binlog_format=ROW

wsrep_provider=/usr/lib64/libgalera_smm.so
wsrep_cluster_address=gcomm://10.93.46.58,10.93.46.59,10.93.46.60

wsrep_slave_threads=2
wsrep_cluster_name=trimethylxanthine
```

```
wsrep_sst_method=rsync
wsrep_node_name=node1

innodb_autoinc_lock_mode=2
```

For the second and third nodes change the following lines:

```
wsrep_node_name=node2

wsrep_node_name=node3
```

6. Start and bootstrap Percona XtraDB Cluster on the first node:

```
[root@node1 ~]# /etc/init.d/mysql bootstrap-pxc
```

You should see the following output:

```
2014-01-30 11:52:35 23280 [Note] /usr/sbin/mysqld: ready for connections.
Version: '5.6.15-56'  socket: '/var/lib/mysql/mysql.sock'  port: 3306  Percona␣
↪XtraDB Cluster (GPL), Release 25.3, Revision 706, wsrep_25.3.r4034
```

7. Start the second and third nodes:

```
[root@node2 ~]# /etc/init.d/mysql start
```

You should see the following output:

```
2014-01-30 09:52:42 26104 [Note] WSREP: Flow-control interval: [28, 28]
2014-01-30 09:52:42 26104 [Note] WSREP: Restored state OPEN -> JOINED (2)
2014-01-30 09:52:42 26104 [Note] WSREP: Member 2 (percona1) synced with group.
2014-01-30 09:52:42 26104 [Note] WSREP: Shifting JOINED -> SYNCED (TO: 2)
2014-01-30 09:52:42 26104 [Note] WSREP: New cluster view: global state: 4827a206-
↪876b-11e3-911c-3e6a77d54953:2, view# 7: Primary, number of nodes: 3, my index:␣
↪2, protocol version 2
2014-01-30 09:52:42 26104 [Note] WSREP: SST complete, seqno: 2
2014-01-30 09:52:42 26104 [Note] Plugin 'FEDERATED' is disabled.
2014-01-30 09:52:42 26104 [Note] InnoDB: The InnoDB memory heap is disabled
2014-01-30 09:52:42 26104 [Note] InnoDB: Mutexes and rw_locks use GCC atomic␣
↪builtins
2014-01-30 09:52:42 26104 [Note] InnoDB: Compressed tables use zlib 1.2.3
2014-01-30 09:52:42 26104 [Note] InnoDB: Using Linux native AIO
2014-01-30 09:52:42 26104 [Note] InnoDB: Not using CPU crc32 instructions
2014-01-30 09:52:42 26104 [Note] InnoDB: Initializing buffer pool, size = 128.0M
2014-01-30 09:52:42 26104 [Note] InnoDB: Completed initialization of buffer pool
2014-01-30 09:52:43 26104 [Note] InnoDB: Highest supported file format is␣
↪Barracuda.
2014-01-30 09:52:43 26104 [Note] InnoDB: 128 rollback segment(s) are active.
2014-01-30 09:52:43 26104 [Note] InnoDB: Waiting for purge to start
2014-01-30 09:52:43 26104 [Note] InnoDB:  Percona XtraDB (http://www.percona.com)␣
↪5.6.15-rel62.0 started; log sequence number 1626341
2014-01-30 09:52:43 26104 [Note] RSA private key file not found: /var/lib/mysql//
↪private_key.pem. Some authentication plugins will not work.
2014-01-30 09:52:43 26104 [Note] RSA public key file not found: /var/lib/mysql//
↪public_key.pem. Some authentication plugins will not work.
2014-01-30 09:52:43 26104 [Note] Server hostname (bind-address): '*'; port: 3306
2014-01-30 09:52:43 26104 [Note] IPv6 is available.
2014-01-30 09:52:43 26104 [Note]   - '::' resolves to '::';
2014-01-30 09:52:43 26104 [Note] Server socket created on IP: '::'.
```

```
2014-01-30 09:52:43 26104 [Note] Event Scheduler: Loaded 0 events
2014-01-30 09:52:43 26104 [Note] /usr/sbin/mysqld: ready for connections.
Version: '5.6.15-56'  socket: '/var/lib/mysql/mysql.sock'  port: 3306  Percona␣
↪XtraDB Cluster (GPL), Release 25.3, Revision 706, wsrep_25.3.r4034
2014-01-30 09:52:43 26104 [Note] WSREP: inited wsrep sidno 1
2014-01-30 09:52:43 26104 [Note] WSREP: wsrep_notify_cmd is not defined, skipping␣
↪notification.
2014-01-30 09:52:43 26104 [Note] WSREP: REPL Protocols: 5 (3, 1)
2014-01-30 09:52:43 26104 [Note] WSREP: Assign initial position for␣
↪certification: 2, protocol version: 3
2014-01-30 09:52:43 26104 [Note] WSREP: Service thread queue flushed.
2014-01-30 09:52:43 26104 [Note] WSREP: Synchronized with group, ready for␣
↪connections
```

When all nodes are in SYNCED state, your cluster is ready.

8. You can try connecting to MySQL on any node and create a database:

```
$ mysql -uroot
> CREATE DATABASE hello_tom;
```

The new database will be propagated to all nodes.

CHAPTER

THIRTYFIVE

LOAD BALANCING WITH HAPROXY

This manual describes how to configure HAProxy to work with Percona XtraDB Cluster.

The following is an example of the configuration file for HAProxy:

```
# this config requires haproxy-1.4.20

global
        log 127.0.0.1   local0
        log 127.0.0.1   local1 notice
        maxconn 4096
        uid 99
        gid 99
        daemon
        #debug
        #quiet

defaults
        log     global
        mode    http
        option  tcplog
        option  dontlognull
        retries 3
        redispatch
        maxconn 2000
        contimeout      5000
        clitimeout      50000
        srvtimeout      50000

listen mysql-cluster 0.0.0.0:3306
    mode tcp
    balance roundrobin
    option mysql-check user root

    server db01 10.4.29.100:3306 check
    server db02 10.4.29.99:3306 check
    server db03 10.4.29.98:3306 check
```

With this configuration, HAProxy will balance the load between three nodes. In this case, it only checks if `mysqld` listens on port 3306, but it doesn't take into an account the state of the node. So it could be sending queries to the node that has `mysqld` running even if it's in `JOINING` or `DISCONNECTED` state.

To check the current status of a node we need a more complex check. This idea was taken from codership-team google groups.

To implement this setup, you will need two scripts:

- **clustercheck** (located in `/usr/local/bin`) and a config for `xinetd`
- **mysqlchk** (located in `/etc/xinetd.d`) on each node

Both scripts are available in binaries and source distributions of Percona XtraDB Cluster.

Change the `/etc/services` file by adding the following line on each node:

```
mysqlchk        9200/tcp                # mysqlchk
```

The following is an example of the HAProxy configuration file in this case:

```
# this config needs haproxy-1.4.20

global
        log 127.0.0.1   local0
        log 127.0.0.1   local1 notice
        maxconn 4096
        uid 99
        gid 99
        #daemon
        debug
        #quiet

defaults
        log     global
        mode    http
        option  tcplog
        option  dontlognull
        retries 3
        redispatch
        maxconn 2000
        contimeout      5000
        clitimeout      50000
        srvtimeout      50000

listen mysql-cluster 0.0.0.0:3306
    mode tcp
    balance roundrobin
    option  httpchk

    server db01 10.4.29.100:3306 check port 9200 inter 12000 rise 3 fall 3
    server db02 10.4.29.99:3306 check port 9200 inter 12000 rise 3 fall 3
    server db03 10.4.29.98:3306 check port 9200 inter 12000 rise 3 fall 3
```

CHAPTER

THIRTYSIX

LOAD BALANCING WITH PROXYSQL

ProxySQL is a high-performance SQL proxy. ProxySQL runs as a daemon watched by a monitoring process. The process monitors the daemon and restarts it in case of a crash to minimize downtime.

The daemon accepts incoming traffic from *MySQL* clients and forwards it to backend *MySQL* servers.

The proxy is designed to run continuously without needing to be restarted. Most configuration can be done at runtime using queries similar to SQL statements. These include runtime parameters, server grouping, and traffic-related settings.

ProxySQL supports Percona XtraDB Cluster node status check using scheduler.

Note: For more information about ProxySQL, see ProxySQL documentation.

Installing ProxySQL

ProxySQL is available from the Percona software repositories. If that is what you used to *install PXC* or any other Percona software, run the corresponding command:

- On Debian or Ubuntu:

```
$ sudo apt-get install proxysql
```

- On Red Hat Enterprise Linux or CentOS:

```
$ sudo yum install proxysql
```

Alternatively, you can download packages from https://www.percona.com/downloads/proxysql/.

To start ProxySQL, run the following command:

```
$ sudo service proxysql start
```

Warning: Do not run ProxySQL with default credentials in production.

Before starting the `proxysql` service, you can change the defaults in the `/etc/proxysql.cnf` file by changing the `admin_credentials` variable. For more information, see Global Variables.

Automatic Configuration

The `proxysql` package from Percona includes the `proxysql-admin` tool for configuring Percona XtraDB Cluster nodes with ProxySQL.

Note: The `proxysql-admin` tool can only be used for *initial* ProxySQL configuration.

To view usage information, run `proxysql-admin` without any options:

```
Usage: [ options ]
Options:
  --config-file=<config-file>        Read login credentials from a configuration file␣
↪(overrides any login credentials specified on the command line)
  --quick-demo                       Setup a quick demo with no authentication
  --proxysql-datadir=<datadir>       Specify proxysql data directory location
  --proxysql-username=user_name      Username for connecting to the ProxySQL service
  --proxysql-password[=password]     Password for connecting to the ProxySQL service
  --proxysql-port=port_num           Port Nr. for connecting to the ProxySQL service
  --proxysql-hostname=host_name      Hostname for connecting to the ProxySQL service
  --cluster-username=user_name       Username for connecting to the Percona XtraDB␣
↪Cluster node
  --cluster-password[=password]      Password for connecting to the Percona XtraDB␣
↪Cluster node
  --cluster-port=port_num            Port Nr. for connecting to the Percona XtraDB␣
↪Cluster node
  --cluster-hostname=host_name       Hostname for connecting to the Percona XtraDB␣
↪Cluster node
  --cluster-app-username=user_name   Application username for connecting to the␣
↪Percona XtraDB Cluster node
  --cluster-app-password[=password]  Application password for connecting to the␣
↪Percona XtraDB Cluster node
  --without-cluster-app-user         Configure Percona XtraDB Cluster without␣
↪application user
  --monitor-username=user_name       Username for monitoring Percona XtraDB Cluster␣
↪nodes through ProxySQL
  --monitor-password[=password]      Password for monitoring Percona XtraDB Cluster␣
↪nodes through ProxySQL
  --without-check-monitor-user       Configure ProxySQL without checking/attempting␣
↪to create monitor user
  --enable, -e                       Auto-configure Percona XtraDB Cluster nodes into␣
↪ProxySQL
  --disable, -d                      Remove any Percona XtraDB Cluster configurations␣
↪from ProxySQL
  --node-check-interval=3000         Interval for monitoring node checker script (in␣
↪milliseconds)
  --mode=[loadbal|singlewrite]       ProxySQL read/write configuration mode,␣
↪currently supporting: 'loadbal' and 'singlewrite' (the default) modes
  --write-node=host_name:port        Writer node to accept write statments. This␣
↪option is supported only when using --mode=singlewrite
                                     Can accept comma delimited list with the first␣
↪listed being the highest priority.
  --include-slaves=host_name:port    Add specified slave node(s) to ProxySQL, these␣
↪nodes will go into the reader hostgroup and will only be put into
                                     the writer hostgroup if all cluster nodes are␣
↪down.  Slaves must be read only.  Can accept comma delimited list.
                                     If this is used make sure 'read_only=1' is in␣
↪the slave's my.cnf
```

```
  --adduser                           Adds the Percona XtraDB Cluster application user␣
↪to the ProxySQL database
  --syncusers                         Sync user accounts currently configured in MySQL␣
↪to ProxySQL (deletes ProxySQL users not in MySQL)
  --sync-multi-cluster-users          Sync user accounts currently configured in MySQL␣
↪to ProxySQL (Don't delete ProxySQL users not in MySQL)
  --version, -v                       Print version info
```

Note: Before using the `proxysql-admin` tool, ensure that ProxySQL and Percona XtraDB Cluster nodes you want to add are running. For security purposes, please ensure to change the default user settings in the ProxySQL configuration file.

Preparing Configuration File

It is recommended to provide connection and authentication information in the ProxySQL configuration file (`/etc/proxysql-admin.cnf`), instead of specifying it on the command line.

By default, the configuration file contains the following:

```
.. code-block:: text
```

> # proxysql admin interface credentials. export PROXYSQL_USERNAME=”admin” export PROXYSQL_PASSWORD=”admin” export PROXYSQL_HOSTNAME=”localhost” export PROXYSQL_PORT=”6032”
>
> # PXC admin credentials for connecting to pxc-cluster-node. export CLUSTER_USERNAME=”admin” export CLUSTER_PASSWORD=”admin” export CLUSTER_HOSTNAME=”localhost” export CLUSTER_PORT=”3306”
>
> # proxysql monitoring user. proxysql admin script will create this user in pxc to monitor pxc-nodes. export MONITOR_USERNAME=”monitor” export MONITOR_PASSWORD=”monit0r”
>
> # Application user to connect to pxc-node through proxysql export CLUSTER_APP_USERNAME=”proxysql_user” export CLUSTER_APP_PASSWORD=”passw0rd”
>
> # ProxySQL read/write hostgroup export WRITE_HOSTGROUP_ID=”10” export READ_HOSTGROUP_ID=”11”
>
> # ProxySQL read/write configuration mode. export MODE=”singlewrite”

Note: It is recommended to *change default ProxySQL credentials* before running ProxySQL in production. Make sure that you provide ProxySQL location and credentials in the configuration file.

Provide superuser credentials for one of the Percona XtraDB Cluster nodes. The `proxysql-admin` script will detect other nodes in the cluster automatically.

Enabling ProxySQL

Use the `--enable` option to automatically configure a Percona XtraDB Cluster node into ProxySQL. The `proxysql-admin` tool will do the following:

- Add Percona XtraDB Cluster node into the ProxySQL database

- Add the `proxysql_galera_checker` monitoring script into the ProxySQL `scheduler` table if it is not available. This script checks for desynced nodes and temporarily deactivates them. It also calls the `proxysql_node_monitor` script, which checks cluster node membership and re-configures ProxySQL if the membership changes.
- Create two new Percona XtraDB Cluster users with the `USAGE` privilege on the node and add them to ProxySQL configuration, if they are not already configured. One user is for monitoring cluster nodes, and the other one is for communicating with the cluster.

Note: Please make sure to use super user credentials from Cluster to setup the default users.

The following example shows how to add a Percona XtraDB Cluster node using the ProxySQL configuration file with all necessary connection and authentication information:

```
$ proxysql-admin --config-file=/etc/proxysql-admin.cnf --enable

This script will assist with configuring ProxySQL (currently only Percona XtraDB␣
↪cluster in combination with ProxySQL is supported)

ProxySQL read/write configuration mode is singlewrite

Configuring ProxySQL monitoring user..
ProxySQL monitor username as per command line/config-file is monitor

User 'monitor'@'127.%' has been added with USAGE privilege

Configuring the Percona XtraDB Cluster application user to connect through ProxySQL
Percona XtraDB Cluster application username as per command line/config-file is␣
↪proxysql_user

Percona XtraDB Cluster application user 'proxysql_user'@'127.%' has been added with␣
↪the USAGE privilege, please make sure to the grant appropriate privileges

Adding the Percona XtraDB Cluster server nodes to ProxySQL

Configuring singlewrite mode with the following nodes designated as priority order:

Write node info
+-----------+--------------+-------+---------+---------+
| hostname  | hostgroup_id | port  | weight  | comment |
+-----------+--------------+-------+---------+---------+
| 127.0.0.1 | 10           | 25000 | 1000000 | WRITE   |
+-----------+--------------+-------+---------+---------+

ProxySQL configuration completed!

ProxySQL has been successfully configured to use with Percona XtraDB Cluster

You can use the following login credentials to connect your application through␣
↪ProxySQL

mysql --user=proxysql_user -p --host=localhost --port=6033 --protocol=tcp
```

Disabling ProxySQL

Use the `--disable` option to remove a Percona XtraDB Cluster node's configuration from ProxySQL. The `proxysql-admin` tool will do the following:

- Remove Percona XtraDB Cluster node from the ProxySQL database
- Stop the ProxySQL monitoring daemon for this node

The following example shows how to disable ProxySQL and remove the Percona XtraDB Cluster node:

```
$ proxysql-admin --config-file=/etc/proxysql-admin.cnf --disable
ProxySQL configuration removed!
```

Additional Options

The following extra options can be used:

- `--adduser`

  Add Percona XtraDB Cluster application user to ProxySQL database.

  ```
  $ proxysql-admin --config-file=/etc/proxysql-admin.cnf --adduser

  Adding Percona XtraDB Cluster application user to ProxySQL database
  Enter Percona XtraDB Cluster application user name: root
  Enter Percona XtraDB Cluster application user password:
  Added Percona XtraDB Cluster application user to ProxySQL database!
  ```

- `--syncusers`

  Sync user accounts currently configured in Percona XtraDB Cluster to ProxySQL database except users with no password and the `admin` user.

  Note: This option also deletes users that are not in Percona XtraDB Cluster from ProxySQL database.

- `--node-check-interval`

  This option configures the interval for monitoring via the `proxysql_galera_checker` script (in milliseconds).

  ```
  $ proxysql-admin --config-file=/etc/proxysql-admin.cnf \
     --node-check-interval=5000 --enable
  ```

- `--mode`

  Set the read/write mode for Percona XtraDB Cluster nodes in ProxySQL database, based on the hostgroup. Supported modes are `loadbal` and `singlewrite`.

  - `singlewrite` is the default mode, it will accept writes only on one single node (based on the info you provide in `--write-node`). Remaining nodes will accept only read statements.

    With `--write-node` option we can control a priority order of what host is most desired to be the writer at any given time. When used the feature will create a configuration file, which is by default stored as `${CLUSTER_NAME}_host_priority` under your `$PROXYSQL_DATADIR` folder. Servers can be separated by commas, for example:

```
10.0.0.51:3306, 10.0.0.52:3306
```

In the previous example, `10.0.0.51:3306` will be in the writer hostgroup if it is ONLINE. If it is OFFLINE, then `10.0.0.52:3306` will go into the writer hostgroup. And if that node also goes down, then one of the remaining nodes will be randomly chosen for the writer hostgroup. The configuration file is deleted when `--disable` is used.

`singlewrite` mode setup:

```
$ sudo grep "MODE" /etc/proxysql-admin.cnf
export MODE="singlewrite"
$ sudo proxysql-admin --config-file=/etc/proxysql-admin.cnf --write-node=127.
↪0.0.1:25000 --enable
ProxySQL read/write configuration mode is singlewrite
[..]
ProxySQL configuration completed!
```

To check the configuration you can run:

```
mysql> SELECT hostgroup_id,hostname,port,status,comment FROM mysql_servers;
+--------------+-----------+-------+--------+---------+
| hostgroup_id | hostname  | port  | status | comment |
+--------------+-----------+-------+--------+---------+
| 11           | 127.0.0.1 | 25400 | ONLINE | READ    |
| 10           | 127.0.0.1 | 25000 | ONLINE | WRITE   |
| 11           | 127.0.0.1 | 25100 | ONLINE | READ    |
| 11           | 127.0.0.1 | 25200 | ONLINE | READ    |
| 11           | 127.0.0.1 | 25300 | ONLINE | READ    |
+--------------+-----------+-------+--------+---------+
5 rows in set (0.00 sec)
```

– The `loadbal` mode uses a set of evenly weighted read/write nodes.

`loadbal` mode setup:

```
$ sudo proxysql-admin --config-file=/etc/proxysql-admin.cnf --mode=loadbal --
↪enable

This script will assist with configuring ProxySQL (currently only Percona␣
↪XtraDB cluster in combination with ProxySQL is supported)

ProxySQL read/write configuration mode is loadbal
[..]
ProxySQL has been successfully configured to use with Percona XtraDB Cluster

You can use the following login credentials to connect your application␣
↪through ProxySQL

mysql --user=proxysql_user --password=*****  --host=127.0.0.1 --port=6033 --
↪protocol=tcp
```

```
mysql> SELECT hostgroup_id,hostname,port,status,comment FROM mysql_servers;
+--------------+-----------+-------+--------+-----------+
| hostgroup_id | hostname  | port  | status | comment   |
+--------------+-----------+-------+--------+-----------+
| 10           | 127.0.0.1 | 25400 | ONLINE | READWRITE |
| 10           | 127.0.0.1 | 25000 | ONLINE | READWRITE |
| 10           | 127.0.0.1 | 25100 | ONLINE | READWRITE |
```

```
| 10           | 127.0.0.1 | 25200 | ONLINE | READWRITE |
| 10           | 127.0.0.1 | 25300 | ONLINE | READWRITE |
+--------------+-----------+-------+--------+-----------+
5 rows in set (0.01 sec)
```

- `--quick-demo`

  This option is used to setup dummy ProxySQL configuration.

```
$ sudo  proxysql-admin  --enable --quick-demo

You have selected the dry test run mode. WARNING: This will create a test user␣
↪(with all privileges) in the Percona XtraDB Cluster & ProxySQL installations.

You may want to delete this user after you complete your testing!

Would you like to proceed with '--quick-demo' [y/n] ? y

Setting up proxysql test configuration!

Do you want to use the default ProxySQL credentials (admin:admin:6032:127.0.0.1)␣
↪[y/n] ? y
Do you want to use the default Percona XtraDB Cluster credentials (root::3306:127.
↪0.0.1) [y/n] ? n

Enter the Percona XtraDB Cluster username (super user): root
Enter the Percona XtraDB Cluster user password:
Enter the Percona XtraDB Cluster port: 25100
Enter the Percona XtraDB Cluster hostname: localhost


ProxySQL read/write configuration mode is singlewrite

Configuring ProxySQL monitoring user..

User 'monitor'@'127.%' has been added with USAGE privilege

Configuring the Percona XtraDB Cluster application user to connect through␣
↪ProxySQL

Percona XtraDB Cluster application user 'pxc_test_user'@'127.%' has been added␣
↪with ALL privileges, this user is created for testing purposes

Adding the Percona XtraDB Cluster server nodes to ProxySQL

ProxySQL configuration completed!

ProxySQL has been successfully configured to use with Percona XtraDB Cluster

You can use the following login credentials to connect your application through␣
↪ProxySQL

mysql --user=pxc_test_user  --host=127.0.0.1 --port=6033 --protocol=tcp
```

- `--include-slaves=host_name:port`

  This option helps to include specified slave node(s) to ProxySQL database. These nodes will go into the reader hostgroup and will only be put into the writer hostgroup if all cluster nodes are down. Slaves must be read only. Can accept comma delimited list. If this is used, make sure `read_only=1` is included into the slave's

`my.cnf` configuration file.

Note: With `loadbal` mode slave hosts only accept read/write requests when all cluster nodes are down.

ProxySQL Status script

There is a simple script to dump ProxySQL configuration and statistics:

```
Usage:

proxysql-status admin admin 127.0.0.1 6032
```

Manual Configuration

This tutorial describes how to configure ProxySQL with three Percona XtraDB Cluster nodes.

Node	Host Name	IP address
Node 1	pxc1	192.168.70.61
Node 2	pxc2	192.168.70.62
Node 3	pxc3	192.168.70.63
Node 4	proxysql	192.168.70.64

ProxySQL can be configured either using the `/etc/proxysql.cnf` file or through the admin interface. Using the admin interface is preferable, because it allows you to change the configuration dynamically (without having to restart the proxy).

To connect to the ProxySQL admin interface, you need a `mysql` client. You can either connect to the admin interface from Percona XtraDB Cluster nodes that already have the `mysql` client installed (Node 1, Node 2, Node 3) or install the client on Node 4 and connect locally. For this tutorial, install Percona XtraDB Cluster on Node 4:

- On Debian or Ubuntu:

```
root@proxysql:~# apt-get install percona-xtradb-cluster-client-5.7
```

- On Red Hat Enterprise Linux or CentOS:

```
[root@proxysql ~]# yum install Percona-XtraDB-Cluster-client-57
```

To connect to the admin interface, use the credentials, host name and port specified in the global variables.

Warning: Do not use default credentials in production!

The following example shows how to connect to the ProxySQL admin interface with default credentials:

```
root@proxysql:~# mysql -u admin -padmin -h 127.0.0.1 -P 6032

Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 2
Server version: 5.1.30 (ProxySQL Admin Module)

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```

```
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affiliates. Other names may be trademarks of their respective
owners.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

mysql@proxysql>
```

To see the ProxySQL databases and tables use the following commands:

```
mysql@proxysql> SHOW DATABASES;
+-----+---------+-------------------------------+
| seq | name    | file                          |
+-----+---------+-------------------------------+
| 0   | main    |                               |
| 2   | disk    | /var/lib/proxysql/proxysql.db |
| 3   | stats   |                               |
| 4   | monitor |                               |
+-----+---------+-------------------------------+
4 rows in set (0.00 sec)
```

```
mysql@proxysql> SHOW TABLES;
+--------------------------------------+
| tables                               |
+--------------------------------------+
| global_variables                     |
| mysql_collations                     |
| mysql_query_rules                    |
| mysql_replication_hostgroups         |
| mysql_servers                        |
| mysql_users                          |
| runtime_global_variables             |
| runtime_mysql_query_rules            |
| runtime_mysql_replication_hostgroups |
| runtime_mysql_servers                |
| runtime_scheduler                    |
| scheduler                            |
+--------------------------------------+
12 rows in set (0.00 sec)
```

For more information about admin databases and tables, see Admin Tables

---

Note: ProxySQL has 3 areas where the configuration can reside:

- MEMORY (your current working place)
- RUNTIME (the production settings)
- DISK (durable configuration, saved inside an SQLITE database)

When you change a parameter, you change it in MEMORY area. That is done by design to allow you to test the changes before pushing to production (RUNTIME), or save them to disk.

Adding cluster nodes to ProxySQL

To configure the backend Percona XtraDB Cluster nodes in ProxySQL, insert corresponding records into the `mysql_servers` table.

Note: ProxySQL uses the concept of *hostgroups* to group cluster nodes. This enables you to balance the load in a cluster by routing different types of traffic to different groups. There are many ways you can configure hostgroups (for example master and slaves, read and write load, etc.) and a every node can be a member of multiple hostgroups.

This example adds three Percona XtraDB Cluster nodes to the default hostgroup (`0`), which receives both write and read traffic:

```
mysql@proxysql> INSERT INTO mysql_servers(hostgroup_id, hostname, port) VALUES (0,
↪'192.168.70.61',3306);
mysql@proxysql> INSERT INTO mysql_servers(hostgroup_id, hostname, port) VALUES (0,
↪'192.168.70.62',3306);
mysql@proxysql> INSERT INTO mysql_servers(hostgroup_id, hostname, port) VALUES (0,
↪'192.168.70.63',3306);
```

To see the nodes:

```
mysql@proxysql> SELECT * FROM mysql_servers;

+--------------+---------------+------+--------+--------+-------------+---------------
↪--+---------------------+---------+----------------+---------+
| hostgroup_id | hostname      | port | status | weight | compression | max_
↪connections | max_replication_lag | use_ssl | max_latency_ms | comment |
+--------------+---------------+------+--------+--------+-------------+---------------
↪--+---------------------+---------+----------------+---------+
| 0            | 192.168.70.61 | 3306 | ONLINE | 1      | 0           | 1000
↪  | 0                   | 0       | 0              |         |
| 0            | 192.168.70.62 | 3306 | ONLINE | 1      | 0           | 1000
↪  | 0                   | 0       | 0              |         |
| 0            | 192.168.70.63 | 3306 | ONLINE | 1      | 0           | 1000
↪  | 0                   | 0       | 0              |         |
+--------------+---------------+------+--------+--------+-------------+---------------
↪--+---------------------+---------+----------------+---------+
3 rows in set (0.00 sec)
```

Creating ProxySQL Monitoring User

To enable monitoring of Percona XtraDB Cluster nodes in ProxySQL, create a user with `USAGE` privilege on any node in the cluster and configure the user in ProxySQL.

The following example shows how to add a monitoring user on Node 2:

```
mysql@pxc2> CREATE USER 'proxysql'@'%' IDENTIFIED BY 'ProxySQLPa55';
mysql@pxc2> GRANT USAGE ON *.* TO 'proxysql'@'%';
```

The following example shows how to configure this user on the ProxySQL node:

```
mysql@proxysql> UPDATE global_variables SET variable_value='proxysql'
             WHERE variable_name='mysql-monitor_username';
mysql@proxysql> UPDATE global_variables SET variable_value='ProxySQLPa55'
             WHERE variable_name='mysql-monitor_password';
```

To load this configuration at runtime, issue a `LOAD` command. To save these changes to disk (ensuring that they persist after ProxySQL shuts down), issue a `SAVE` command.

```
mysql@proxysql> LOAD MYSQL VARIABLES TO RUNTIME;
mysql@proxysql> SAVE MYSQL VARIABLES TO DISK;
```

To ensure that monitoring is enabled, check the monitoring logs:

```
mysql@proxysql> SELECT * FROM monitor.mysql_server_connect_log ORDER BY time_start_us␣
↪DESC LIMIT 6;
+---------------+------+------------------+----------------------+---------------+
| hostname      | port | time_start_us    | connect_success_time | connect_error |
+---------------+------+------------------+----------------------+---------------+
| 192.168.70.61 | 3306 | 1469635762434625 | 1695                 | NULL          |
| 192.168.70.62 | 3306 | 1469635762434625 | 1779                 | NULL          |
| 192.168.70.63 | 3306 | 1469635762434625 | 1627                 | NULL          |
| 192.168.70.61 | 3306 | 1469635642434517 | 1557                 | NULL          |
| 192.168.70.62 | 3306 | 1469635642434517 | 2737                 | NULL          |
| 192.168.70.63 | 3306 | 1469635642434517 | 1447                 | NULL          |
+---------------+------+------------------+----------------------+---------------+
6 rows in set (0.00 sec)
```

```
mysql> SELECT * FROM monitor.mysql_server_ping_log ORDER BY time_start_us DESC LIMIT␣
↪6;
+---------------+------+------------------+-------------------+------------+
| hostname      | port | time_start_us    | ping_success_time | ping_error |
+---------------+------+------------------+-------------------+------------+
| 192.168.70.61 | 3306 | 1469635762416190 | 948               | NULL       |
| 192.168.70.62 | 3306 | 1469635762416190 | 803               | NULL       |
| 192.168.70.63 | 3306 | 1469635762416190 | 711               | NULL       |
| 192.168.70.61 | 3306 | 1469635702416062 | 783               | NULL       |
| 192.168.70.62 | 3306 | 1469635702416062 | 631               | NULL       |
| 192.168.70.63 | 3306 | 1469635702416062 | 542               | NULL       |
+---------------+------+------------------+-------------------+------------+
6 rows in set (0.00 sec)
```

The previous examples show that ProxySQL is able to connect and ping the nodes you added.

To enable monitoring of these nodes, load them at runtime:

```
mysql@proxysql> LOAD MYSQL SERVERS TO RUNTIME;
```

Creating ProxySQL Client User

ProxySQL must have users that can access backend nodes to manage connections.

To add a user, insert credentials into `mysql_users` table:

```
mysql@proxysql> INSERT INTO mysql_users (username,password) VALUES ('sbuser','sbpass
↪');
Query OK, 1 row affected (0.00 sec)
```

Note: ProxySQL currently doesn't encrypt passwords.

Load the user into runtime space and save these changes to disk (ensuring that they persist after ProxySQL shuts down):

```
mysql@proxysql> LOAD MYSQL USERS TO RUNTIME;
mysql@proxysql> SAVE MYSQL USERS TO DISK;
```

To confirm that the user has been set up correctly, you can try to log in:

```
root@proxysql:~# mysql -u sbuser -psbpass -h 127.0.0.1 -P 6033

Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 1491
Server version: 5.1.30 (ProxySQL)

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owners.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.
```

To provide read/write access to the cluster for ProxySQL, add this user on one of the Percona XtraDB Cluster nodes:

```
mysql@pxc3> CREATE USER 'sbuser'@'192.168.70.64' IDENTIFIED BY 'sbpass';
Query OK, 0 rows affected (0.01 sec)

mysql@pxc3> GRANT ALL ON *.* TO 'sbuser'@'192.168.70.64';
Query OK, 0 rows affected (0.00 sec)
```

Adding Galera Support

Default ProxySQL cannot detect a node which is not in `Synced` state. To monitor status of Percona XtraDB Cluster nodes, use the `proxysql_galera_checker` script. The script is located here: `/usr/bin/proxysql_galera_checker`.

To use this script, load it into ProxySQL Scheduler.

The following example shows how you can load the script for default ProxySQL configuration:

```
INSERT INTO scheduler (active,interval_ms,filename,arg1,comment)
  VALUES (1,10000,'/usr/bin/proxysql_galera_checker','--config-file=/etc/proxysql-
↪admin.cnf
  --write-hg=10 --read-hg=11 --writer-count=1 --mode=singlewrite
  --priority=192.168.100.20:3306,192.168.100.40:3306,192.168.100.10:3306,192.168.100.
↪30:3306
  --log=/var/lib/proxysql/cluster_one_proxysql_galera_check.log','cluster_one');
```

This Scheduler script accepts the following options in the `arg1` argument:

Option	Name	Required	Description
`--config-file`	Configuration File	Yes	Specify `proxysql-admin` configuration file.
`--write-hg`	`HOSTGROUP WRITERS`	No	Specify ProxySQL write hostgroup.
`--read-hg`	`HOSTGROUP READERS`	No	Specify ProxySQL read hostgroup.
`--writer-count`	`NUMBER WRITERS`	No	Specify write nodes count. `0` for `loadbal` mode and `1` for `singlewrite` mode.
`--mode`	`MODE`	No	Specify ProxySQL read/write configuration mode.
`--priority`	`WRITER PRIORITY`	No	Specify write nodes priority.
`--log`	`LOG FILE`	No	Specify `proxysql_galera_checker` log file.

Note: Specify cluster name in *comment* column.

To load the scheduler changes into the runtime space:

```
mysql@proxysql> LOAD SCHEDULER TO RUNTIME;
```

To make sure that the script has been loaded, check the `runtime_scheduler` table:

```
mysql@proxysql> SELECT * FROM scheduler\G
*************************** 1. row ***************************
         id: 1
     active: 1
interval_ms: 10000
   filename: /bin/proxysql_galera_checker
       arg1: --config-file=/etc/proxysql-admin.cnf --write-hg=10 --read-hg=11
             --writer-count=1 --mode=singlewrite
             --priority=192.168.100.20:3306,192.168.100.40:3306,192.168.100.10:3306,
↪192.168.100.30:3306
             --log=/var/lib/proxysql/cluster_one_proxysql_galera_check.log
       arg2: NULL
       arg3: NULL
       arg4: NULL
       arg5: NULL
    comment: cluster_one
1 row in set (0.00 sec)
```

To check the status of available nodes, run the following command:

```
mysql@proxysql> SELECT hostgroup_id,hostname,port,status FROM mysql_servers;
+--------------+---------------+------+--------+
| hostgroup_id | hostname      | port | status |
+--------------+---------------+------+--------+
| 0            | 192.168.70.61 | 3306 | ONLINE |
| 0            | 192.168.70.62 | 3306 | ONLINE |
| 0            | 192.168.70.63 | 3306 | ONLINE |
+--------------+---------------+------+--------+
3 rows in set (0.00 sec)
```

Note: Each node can have the following status:

- `ONLINE`: backend node is fully operational.

- SHUNNED: backend node is temporarily taken out of use, because either too many connection errors hapenned in a short time, or replication lag exceeded the allowed threshold.
- OFFLINE_SOFT: new incoming connections aren't accepted, while existing connections are kept until they become inactive. In other words, connections are kept in use until the current transaction is completed. This allows to gracefully detach a backend node.
- OFFLINE_HARD: existing connections are dropped, and new incoming connections aren't accepted. This is equivalent to deleting the node from a hostgroup, or temporarily taking it out of the hostgroup for maintenance.

Testing Cluster with sysbench

You can install sysbench from Percona software repositories:

- For Debian or Ubuntu:

```
root@proxysql:~# apt-get install sysbench
```

- For Red Hat Enterprise Linux or CentOS

```
[root@proxysql ~]# yum install sysbench
```

Note: sysbench requires ProxySQL client user credentials that you creted in *Creating ProxySQL Client User*.

1. Create the database that will be used for testing on one of the Percona XtraDB Cluster nodes:

```
mysql@pxc1> CREATE DATABASE sbtest;
```

2. Populate the table with data for the benchmark on the ProxySQL node:

```
root@proxysql:~# sysbench --report-interval=5 --num-threads=4 \
  --num-requests=0 --max-time=20 \
  --test=/usr/share/doc/sysbench/tests/db/oltp.lua \
  --mysql-user='sbuser' --mysql-password='sbpass' \
  --oltp-table-size=10000 --mysql-host=127.0.0.1 --mysql-port=6033 \
  prepare
```

3. Run the benchmark on the ProxySQL node:

```
root@proxysql:~# sysbench --report-interval=5 --num-threads=4 \
  --num-requests=0 --max-time=20 \
  --test=/usr/share/doc/sysbench/tests/db/oltp.lua \
  --mysql-user='sbuser' --mysql-password='sbpass' \
  --oltp-table-size=10000 --mysql-host=127.0.0.1 --mysql-port=6033 \
  run
```

ProxySQL stores collected data in the stats schema:

```
mysql@proxysql> SHOW TABLES FROM stats;
+--------------------------------+
| tables                         |
+--------------------------------+
| stats_mysql_query_rules        |
| stats_mysql_commands_counters  |
| stats_mysql_processlist        |
```

```
| stats_mysql_connection_pool    |
| stats_mysql_query_digest       |
| stats_mysql_query_digest_reset |
| stats_mysql_global             |
+--------------------------------+
```

For example, to see the number of commands that run on the cluster:

```
mysql@proxysql> SELECT * FROM stats_mysql_commands_counters;
+-------------------+--------------+-----------+-----------+-----------+---------+---
↪------+---------+---------+-----------+-----------+---------+---------+---------+---
↪-------+
| Command           | Total_Time_us | Total_cnt | cnt_100us | cnt_500us | cnt_1ms |␣
↪cnt_5ms | cnt_10ms | cnt_50ms | cnt_100ms | cnt_500ms | cnt_1s | cnt_5s | cnt_10s |␣
↪cnt_INFs |
+-------------------+--------------+-----------+-----------+-----------+---------+---
↪------+---------+---------+-----------+-----------+---------+---------+---------+---
↪-------+
| ALTER_TABLE       | 0             | 0         | 0         | 0         | 0       | 0␣
↪       | 0        | 0        | 0         | 0         | 0       | 0       | 0       | 0␣
↪       |
| ANALYZE_TABLE     | 0             | 0         | 0         | 0         | 0       | 0␣
↪       | 0        | 0        | 0         | 0         | 0       | 0       | 0       | 0␣
↪       |
| BEGIN             | 2212625       | 3686      | 55        | 2162      | 899     |␣
↪569     | 1        | 0        | 0         | 0         | 0       | 0       | 0       |␣
↪0       |
| CHANGE_MASTER     | 0             | 0         | 0         | 0         | 0       | 0␣
↪       | 0        | 0        | 0         | 0         | 0       | 0       | 0       | 0␣
↪       |
| COMMIT            | 21522591      | 3628      | 0         | 0         | 0       | 0       |␣
↪1765    | 1590     | 272      | 1         | 0         | 0       | 0       | 0       |␣
↪0       |
| CREATE_DATABASE   | 0             | 0         | 0         | 0         | 0       | 0␣
↪       | 0        | 0        | 0         | 0         | 0       | 0       | 0       | 0␣
↪       |
| CREATE_INDEX      | 0             | 0         | 0         | 0         | 0       | 0␣
↪       | 0        | 0        | 0         | 0         | 0       | 0       | 0       | 0␣
↪       |
...
| DELETE            | 2904130       | 3670      | 35        | 1546      | 1346    |␣
↪723     | 19       | 1        | 0         | 0         | 0       | 0       | 0       |␣
↪0       |
| DESCRIBE          | 0             | 0         | 0         | 0         | 0       | 0␣
↪       | 0        | 0        | 0         | 0         | 0       | 0       | 0       | 0␣
↪       |
...
| INSERT            | 19531649      | 3660      | 39        | 1588      | 1292    |␣
↪723     | 12       | 2        | 0         | 1         | 0       | 1       | 2       |␣
↪0       |
...
| SELECT            | 35049794      | 51605     | 501       | 26180     | 16606   |␣
↪8241    | 70       | 3        | 4         | 0         | 0       | 0       | 0       |␣
↪0       |
| SELECT_FOR_UPDATE | 0             | 0         | 0         | 0         | 0       | 0␣
↪       | 0        | 0        | 0         | 0         | 0       | 0       | 0       | 0␣
↪       |
...
```

```
| UPDATE              | 6402302        | 7367       | 75         | 2503       | 3020     |␣
↪1743    | 23        | 3         | 0          | 0          | 0       | 0       | 0       |␣
↪0         |
| USE                 | 0              | 0          | 0          | 0          | 0        | 0␣
↪       | 0         | 0         | 0          | 0          | 0       | 0       | 0␣
↪         |
| SHOW                | 19691          | 2          | 0          | 0          | 0        | 0␣
↪       | 1         | 1         | 0          | 0          | 0       | 0       | 0␣
↪         |
| UNKNOWN             | 0              | 0          | 0          | 0          | 0        | 0␣
↪       | 0         | 0         | 0          | 0          | 0       | 0       | 0␣
↪         |
+--------------------+---------------+-----------+-----------+-----------+---------+---
↪------+----------+----------+-----------+-----------+--------+--------+---------+---
↪-------+
45 rows in set (0.00 sec)
```

Automatic Fail-over

ProxySQL will automatically detect if a node is not available or not synced with the cluster.

You can check the status of all available nodes by running:

```
mysql@proxysql> SELECT hostgroup_id,hostname,port,status FROM mysql_servers;
+--------------+---------------+------+--------+
| hostgroup_id | hostname      | port | status |
+--------------+---------------+------+--------+
| 0            | 192.168.70.61 | 3306 | ONLINE |
| 0            | 192.168.70.62 | 3306 | ONLINE |
| 0            | 192.168.70.63 | 3306 | ONLINE |
+--------------+---------------+------+--------+
3 rows in set (0.00 sec)
```

To test problem detection and fail-over mechanism, shut down Node 3:

```
root@pxc3:~# service mysql stop
```

ProxySQL will detect that the node is down and update its status to `OFFLINE_SOFT`:

```
mysql@proxysql> SELECT hostgroup_id,hostname,port,status FROM mysql_servers;
+--------------+---------------+------+--------------+
| hostgroup_id | hostname      | port | status       |
+--------------+---------------+------+--------------+
| 0            | 192.168.70.61 | 3306 | ONLINE       |
| 0            | 192.168.70.62 | 3306 | ONLINE       |
| 0            | 192.168.70.63 | 3306 | OFFLINE_SOFT |
+--------------+---------------+------+--------------+
3 rows in set (0.00 sec)
```

Now start Node 3 again:

```
root@pxc3:~# service mysql start
```

The script will detect the change and mark the node as `ONLINE`:

```
mysql@proxysql> SELECT hostgroup_id,hostname,port,status FROM mysql_servers;
+--------------+---------------+------+--------+
| hostgroup_id | hostname      | port | status |
+--------------+---------------+------+--------+
| 0            | 192.168.70.61 | 3306 | ONLINE |
| 0            | 192.168.70.62 | 3306 | ONLINE |
| 0            | 192.168.70.63 | 3306 | ONLINE |
+--------------+---------------+------+--------+
3 rows in set (0.00 sec)
```

Assisted Maintenance Mode

Usually, to take a node down for maintenance, you need to identify that node, update its status in ProxySQL to `OFFLINE_SOFT`, wait for ProxySQL to divert traffic from this node, and then initiate the shutdown or perform maintenance tasks. Percona XtraDB Cluster includes a special *maintenance mode* for nodes that enables you to take a node down without adjusting ProxySQL manually. The mode is controlled using the *pxc_maint_mode* variable, which is monitored by ProxySQL and can be set to one of the following values:

- `DISABLED`: This is the default state that tells ProxySQL to route traffic to the node as usual.
- `SHUTDOWN`: This state is set automatically when you initiate node shutdown.

  You may need to shut down a node when upgrading the OS, adding resources, changing hardware parts, relocating the server, etc.

  When you initiate node shutdown, Percona XtraDB Cluster does not send the signal immediately. Intead, it changes the state to `pxc_maint_mode=SHUTDOWN` and waits for a predefined period (10 seconds by default). When ProxySQL detects that the mode is set to `SHUTDOWN`, it changes the status of this node to `OFFLINE_SOFT`, which stops creation of new connections for the node. After the transition period, any long-running transactions that are still active are aborted.
- `MAINTENANCE`: You can change to this state if you need to perform maintenace on a node without shutting it down.

  You may need to isolate the node for some time, so that it does not receive traffic from ProxySQL while you resize the buffer pool, truncate the undo log, defragment or check disks, etc.

  To do this, manually set `pxc_maint_mode=MAINTENANCE`. Control is not returned to the user for a predefined period (10 seconds by default). When ProxySQL detects that the mode is set to `MAINTENANCE`, it stops routing traffic to the node. Once control is returned, you can perform maintenance activity.

  Note: Any data changes will still be replicated across the cluster.

  After you finish maintenance, set the mode back to `DISABLED`. When ProxySQL detects this, it starts routing traffic to the node again.

You can increase the transition period using the *pxc_maint_transition_period* variable to accomodate for long-running transactions. If the period is long enough for all transactions to finish, there should hardly be any disruption in cluster workload.

During the transition period, the node continues to receive existing write-set replication traffic, ProxySQL avoids openning new connections and starting transactions, but the user can still open conenctions to monitor status.

Note: If you increase the transition period, the packaging script may determine it as a server stall.

CHAPTER

THIRTYSEVEN

SETTING UP PXC REFERENCE ARCHITECTURE WITH HAPROXY

This manual describes how to set up Percona XtraDB Cluster in a virtualized test sandbox.

The procedure assumes Amazon EC2 micro instances running CentOS 6. However, it should apply to any virtualization technology (for example, VirtualBox) with any Linux distribution.

This manual requires three virtual machines for Percona XtraDB Cluster nodes, and one for HAProxy client, which redirects requests to the nodes. Running HAProxy on an application server, instead of having it as a dedicated entity, removes the unnecessary extra network roundtrip, because the load balancing layer in Percona XtraDB Cluster scales well with application servers.

1. Install Percona XtraDB Cluster on the three cluster nodes, as described in *Installing Percona XtraDB Cluster on Red Hat Enterprise Linux and CentOS*.
2. Install HAProxy and `sysbench` on the client node:

```
yum -y install haproxy sysbench
```

3. Make sure that the `my.cnf` configuration file on the first node contains the following:

```
[mysqld]
server_id=1
binlog_format=ROW
log_bin=mysql-bin
wsrep_cluster_address=gcomm://
wsrep_provider=/usr/lib/libgalera_smm.so
datadir=/var/lib/mysql

wsrep_slave_threads=2
wsrep_cluster_name=pxctest
wsrep_sst_method=xtrabackup
wsrep_node_name=ip-10-112-39-98

log_slave_updates

innodb_autoinc_lock_mode=2
innodb_buffer_pool_size=400M
innodb_log_file_size=64M
```

4. Start the first node
5. Adjust the `my.cnf` configuration files on the second and third nodes to contain the same configuration settings, except the following:
    - Second node:

```
server_id=2
wsrep_cluster_address=gcomm://10.116.39.76
wsrep_node_name=ip-10-244-33-92
```

- Third node:

```
server_id=3
wsrep_cluster_address=gcomm://10.116.39.76
wsrep_node_name=ip-10-194-10-179
```

Note:

- `server_id` can be any unique number
- `wsrep_cluster_address` is the IP address of the first node
- `wsrep_node_name` can be any unique name, for example, the output of the `hostname` command

6. Start the second and third nodes.

   When a new node joins the cluster, *SST* is performed by taking a backup using XtraBackup, then copying it to the new node with `netcat`. After a successful *SST*, you should see the following in the error log:

```
120619 13:20:17 [Note] WSREP: State transfer required:
     Group state: 77c9da88-b965-11e1-0800-ea53b7b12451:97
     Local state: 00000000-0000-0000-0000-000000000000:-1
120619 13:20:17 [Note] WSREP: New cluster view: global state: 77c9da88-b965-11e1-
↪0800-ea53b7b12451:97, view# 18: Primary, number of nodes: 3, my index: 0,␣
↪protocol version 2
120619 13:20:17 [Warning] WSREP: Gap in state sequence. Need state transfer.
120619 13:20:19 [Note] WSREP: Running: 'wsrep_sst_xtrabackup 'joiner' '10.195.206.
↪117' '' '/var/lib/mysql/' '/etc/my.cnf' '20758' 2>sst.err'
120619 13:20:19 [Note] WSREP: Prepared |SST| request: xtrabackup|10.195.206.
↪117:4444/xtrabackup_sst
120619 13:20:19 [Note] WSREP: wsrep_notify_cmd is not defined, skipping␣
↪notification.
120619 13:20:19 [Note] WSREP: Assign initial position for certification: 97,␣
↪protocol version: 2
120619 13:20:19 [Warning] WSREP: Failed to prepare for incremental state␣
↪transfer: Local state UUID (00000000-0000-0000-0000-000000000000) does not␣
↪match group state UUID (77c9da88-b965-11e1-0800-ea53b7b12451): 1 (Operation not␣
↪permitted)
     at galera/src/replicator_str.cpp:prepare_for_IST():439. IST will be␣
↪unavailable.
120619 13:20:19 [Note] WSREP: Node 0 (ip-10-244-33-92) requested state transfer␣
↪from '*any*'. Selected 1 (ip-10-112-39-98)(SYNCED) as donor.
120619 13:20:19 [Note] WSREP: Shifting PRIMARY -> JOINER (TO: 102)
120619 13:20:19 [Note] WSREP: Requesting state transfer: success, donor: 1
120619 13:20:59 [Note] WSREP: 1 (ip-10-112-39-98): State transfer to 0 (ip-10-244-
↪33-92) complete.
120619 13:20:59 [Note] WSREP: Member 1 (ip-10-112-39-98) synced with group.
120619 13:21:17 [Note] WSREP: |SST| complete, seqno: 105
120619 13:21:17 [Note] Plugin 'FEDERATED' is disabled.
120619 13:21:17 InnoDB: The InnoDB memory heap is disabled
120619 13:21:17 InnoDB: Mutexes and rw_locks use GCC atomic builtins
120619 13:21:17 InnoDB: Compressed tables use zlib 1.2.3
120619 13:21:17 InnoDB: Using Linux native AIO
```

```
120619 13:21:17 InnoDB: Initializing buffer pool, size = 400.0M
120619 13:21:17 InnoDB: Completed initialization of buffer pool
120619 13:21:18 InnoDB: highest supported file format is Barracuda.
120619 13:21:18  InnoDB: Waiting for the background threads to start
120619 13:21:19 Percona XtraDB (http://www.percona.com) 1.1.8-rel25.3 started;␣
↪log sequence number 246661644
120619 13:21:19 [Note] Recovering after a crash using mysql-bin
120619 13:21:19 [Note] Starting crash recovery...
120619 13:21:19 [Note] Crash recovery finished.
120619 13:21:19 [Note] Server hostname (bind-address): '(null)'; port: 3306
120619 13:21:19 [Note]   - '(null)' resolves to '0.0.0.0';
120619 13:21:19 [Note]   - '(null)' resolves to '::';
120619 13:21:19 [Note] Server socket created on IP: '0.0.0.0'.
120619 13:21:19 [Note] Event Scheduler: Loaded 0 events
120619 13:21:19 [Note] WSREP: Signalling provider to continue.
120619 13:21:19 [Note] WSREP: Received |SST|: 77c9da88-b965-11e1-0800-
↪ea53b7b12451:105
120619 13:21:19 [Note] WSREP: |SST| received: 77c9da88-b965-11e1-0800-
↪ea53b7b12451:105
120619 13:21:19 [Note] WSREP: 0 (ip-10-244-33-92): State transfer from 1 (ip-10-
↪112-39-98) complete.
120619 13:21:19 [Note] WSREP: Shifting JOINER -> JOINED (TO: 105)
120619 13:21:19 [Note] /usr/sbin/mysqld: ready for connections.
Version: '5.5.24-log'  socket: '/var/lib/mysql/mysql.sock'  port: 3306  Percona␣
↪XtraDB Cluster (GPL), wsrep_23.6.r340
120619 13:21:19 [Note] WSREP: Member 0 (ip-10-244-33-92) synced with group.
120619 13:21:19 [Note] WSREP: Shifting JOINED -> SYNCED (TO: 105)
120619 13:21:20 [Note] WSREP: Synchronized with group, ready for connections
```

For debugging information about the *SST*, you can check the `sst.err` file and the error log.

After *SST* finishes, you can check the cluster size as follows:

```
mysql> show global status like 'wsrep_cluster_size';
+--------------------+-------+
| Variable_name      | Value |
+--------------------+-------+
| wsrep_cluster_size | 3     |
+--------------------+-------+
1 row in set (0.00 sec)
```

7. When all cluster nodes are started, configure HAProxy on the client node. This will enable the application to connect to localhost as if it were a single MySQL server, instead of a Percona XtraDB Cluster node.

   You can configure HAProxy to connect and write to all cluster nodes or to one node at a time. The former method can lead to rollbacks due to conflicting writes when optimistic locking at commit time is triggered, while the latter method avoids rollbacks.

   However, most good applications should be able to handle rollbacks, so either method is fine in this case.

   To configure HAProxy, add the following to `/etc/haproxy/haproxy.cfg`:

```
global
log 127.0.0.1 local0
log 127.0.0.1 local1 notice
maxconn 4096
chroot /usr/share/haproxy
user haproxy
group haproxy
```

```
daemon

defaults
log global
mode http
option tcplog
option dontlognull
retries 3
option redispatch
maxconn 2000
contimeout 5000
clitimeout 50000
srvtimeout 50000

frontend pxc-front
bind *:3307
mode tcp
default_backend pxc-back

frontend stats-front
bind *:80
mode http
default_backend stats-back

frontend pxc-onenode-front
bind *:3306
mode tcp
default_backend pxc-onenode-back

backend pxc-back
mode tcp
balance leastconn
option httpchk
server c1 10.116.39.76:3306 check port 9200 inter 12000 rise 3 fall 3
server c2 10.195.206.117:3306 check port 9200 inter 12000 rise 3 fall 3
server c3 10.202.23.92:3306 check port 9200 inter 12000 rise 3 fall 3

backend stats-back
mode http
balance roundrobin
stats uri /haproxy/stats
stats auth pxcstats:secret

backend pxc-onenode-back
mode tcp
balance leastconn
option httpchk
server c1 10.116.39.76:3306 check port 9200 inter 12000 rise 3 fall 3
server c2 10.195.206.117:3306 check port 9200 inter 12000 rise 3 fall 3 backup
server c3 10.202.23.92:3306 check port 9200 inter 12000 rise 3 fall 3 backup
```

In this configuration, three frontend-backend pairs are defined:

- The `stats` pair is for HAProxy statistics page (port 80).

  You can access it at `/haproxy/stats` using the credential specified in the `stats auth` parameter.

- The `pxc` pair is for connecting to all three nodes (port 3307).

In this case, the *leastconn* load balancing method is used, instead of round-robin, which means connection is made to the backend with the least connections established.

- The `pxc-onenode` pair is for connecting to one node at a time (port 3306) to avoid rollbacks because of optimistic locking.

  If the node goes offline, HAProxy will connect to another one.

Note: MySQL is checked via `httpchk`. MySQL will not serve these requests by default. You have to set up the `clustercheck` utility, which is distributed with Percona XtraDB Cluster. This will enable HAProxy to check MySQL via HTTP.

The `clustercheck` script is a simple shell script that accepts HTTP requests and checks the node via the *`wsrep_local_state`* variable. If the node's status is fine, it will send a response with HTTP code `200 OK`. Otherwise, it sends `503`.

To create the `clustercheck` user, run the following:

```
mysql> grant process on *.* to 'clustercheckuser'@'localhost' identified by
↪'clustercheckpassword!';
Query OK, 0 rows affected (0.00 sec)

mysql> flush privileges;
Query OK, 0 rows affected (0.00 sec)
```

If you want to use a different user name or password, you have to modify them in the `clustercheck` script.

If you run the script on a running node, you should see the following:

```
# clustercheck
HTTP/1.1 200 OK

Content-Type: Content-Type: text/plain
```

You can use `xinetd` to daemonize the script. If *xinetd* is not installed, you can install it with `yum`:

```
# yum -y install xinetd
```

The service is configured in `/etc/xinetd.d/mysqlchk`:

```
# default: on
# description: mysqlchk
service mysqlchk
{
# this is a config for xinetd, place it in /etc/xinetd.d/
disable = no
flags = REUSE
socket_type = stream
port = 9200
wait = no
user = nobody
server = /usr/bin/clustercheck
log_on_failure += USERID
only_from = 0.0.0.0/0
# recommended to put the IPs that need
# to connect exclusively (security purposes)
per_source = UNLIMITED
}
```

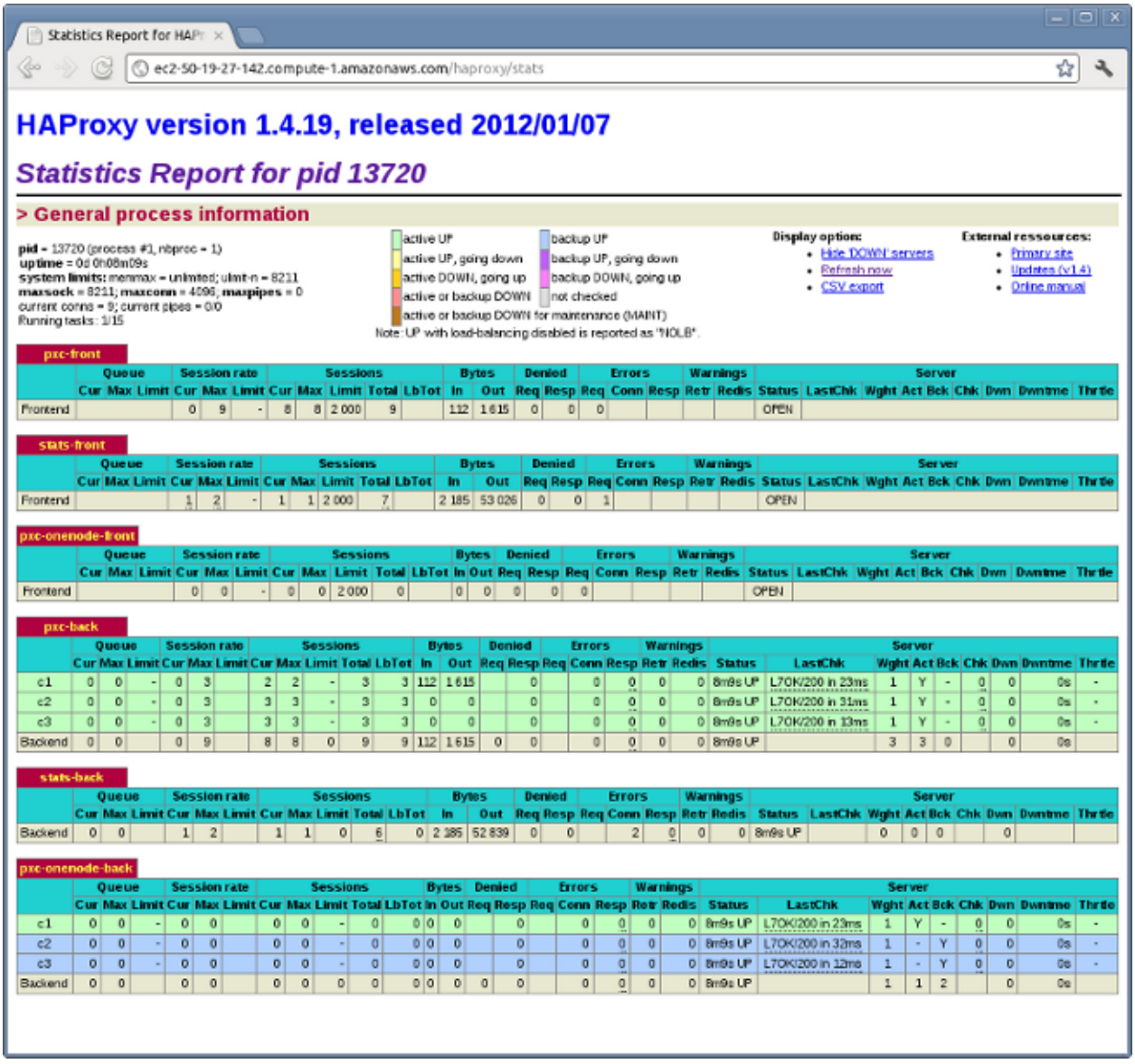
Add the new service to `/etc/services`:

```
mysqlchk 9200/tcp # mysqlchk
```

Clustercheck will now listen on port 9200 after `xinetd` restarts and HAProxy is ready to check MySQL via HTTP:

```
# service xinetd restart
```

If you did everything correctly, the statistics page for HAProxy should look like this:



Testing the cluster with sysbench

After you set up Percona XtraDB Cluster in a sand box, you can test it using sysbench. This example shows how to do it with `sysbench` from the EPEL repository.

1. Create a database and a user for `sysbench`:

```
mysql> create database sbtest;
Query OK, 1 row affected (0.01 sec)

mysql> grant all on sbtest.* to 'sbtest'@'%' identified by 'sbpass';
Query OK, 0 rows affected (0.00 sec)

mysql> flush privileges;
Query OK, 0 rows affected (0.00 sec)
```

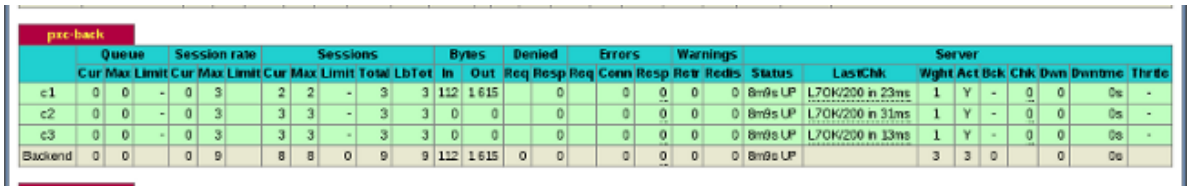
2. Populate the table with data for the benchmark:

```
sysbench --test=oltp --db-driver=mysql --mysql-engine-trx=yes --mysql-table-
↪engine=innodb --mysql-host=127.0.0.1 --mysql-port=3307 --mysql-user=sbtest --
↪mysql-password=sbpass --oltp-table-size=10000 prepare
```

3. Run the benchmark on port 3307:

```
sysbench --test=oltp --db-driver=mysql --mysql-engine-trx=yes --mysql-table-
↪engine=innodb --mysql-host=127.0.0.1 --mysql-port=3307 --mysql-user=sbtest --
↪mysql-password=sbpass --oltp-table-size=10000 --num-threads=8 run
```

   You should see the following in HAProxy statistics for `pxc-back`:



pxc-back

	Queue			Session rate			Sessions					Bytes		Denied		Errors			Warnings		Server								
	Cur	Max	Limit	Cur	Max	Limit	Cur	Max	Limit	Total	LbTot	In	Out	Req	Resp	Req	Conn	Resp	Retr	Redis	Status	LastChk	Wght	Act	Bck	Chk	Dwn	Dwntme	Thrtle
c1	0	0	-	0	3		2	2	-	3	3	112	1615		0		0	0	0	0	8m9s UP	L7OK/200 in 23ms	1	Y	-	0	0	0s	-
c2	0	0	-	0	3		3	3	-	3	3	0	0		0		0	0	0	0	8m9s UP	L7OK/200 in 31ms	1	Y	-	0	0	0s	-
c3	0	0	-	0	3		3	3	-	3	3	0	0		0		0	0	0	0	8m9s UP	L7OK/200 in 13ms	1	Y	-	0	0	0s	-
Backend	0	0		0	9		8	8	0	9	9	112	1615	0	0		0	0	0	0	8m9s UP		3	3	0		0	0s	

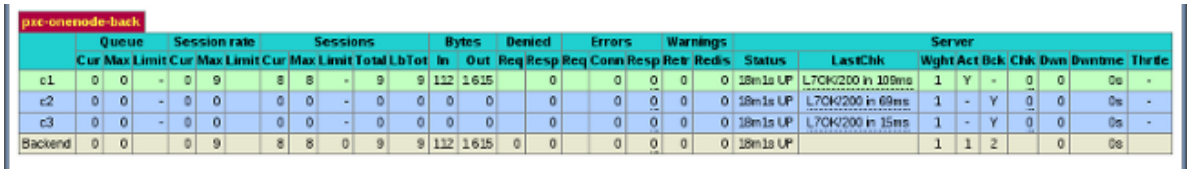
   Note the `Cur` column under `Session`:

   - `c1` has 2 threads connected
   - `c2` and `c3` have 3 threads connected

4. Run the same benchmark on port 3306:

```
sysbench --test=oltp --db-driver=mysql --mysql-engine-trx=yes --mysql-table-
↪engine=innodb --mysql-host=127.0.0.1 --mysql-port=3306 --mysql-user=sbtest --
↪mysql-password=sbpass --oltp-table-size=10000 --num-threads=8 run
```

   You should see the following in HAProxy statistics for `pxc-onenode-back`:



pxc-onenode-back

	Queue			Session rate			Sessions					Bytes		Denied		Errors			Warnings		Server								
	Cur	Max	Limit	Cur	Max	Limit	Cur	Max	Limit	Total	LbTot	In	Out	Req	Resp	Req	Conn	Resp	Retr	Redis	Status	LastChk	Wght	Act	Bck	Chk	Dwn	Dwntme	Thrtle
c1	0	0	-	0	9		8	8	-	9	9	112	1615		0		0	0	0	0	18m1s UP	L7OK/200 in 109ms	1	Y	-	0	0	0s	-
c2	0	0	-	0	0		0	0	-	0	0	0	0		0		0	0	0	0	18m1s UP	L7OK/200 in 69ms	1	-	Y	0	0	0s	-
c3	0	0	-	0	0		0	0	-	0	0	0	0		0		0	0	0	0	18m1s UP	L7OK/200 in 15ms	1	-	Y	0	0	0s	-
Backend	0	0		0	9		8	8	0	9	9	112	1615	0	0		0	0	0	0	18m1s UP		1	1	2		0	0s	

   All 8 threads are connected to the `c1` server. `c2` and `c3` are acting as backup nodes.

If you are using *HAProxy* for *MySQL* you can break the privilege system's host part, because *MySQL* will think that the connections are always coming from the load balancer. You can work this around using T-Proxy patches and some *iptables* magic for the backwards connections. However in the setup described in this how-to this is not an issue, since each application server has it's own *HAProxy* instance, each application server connects to 127.0.0.1, so MySQL will see that connections are coming from the application servers. Just like in the normal case.

Part VIII

Reference

CHAPTER

THIRTYEIGHT

PERCONA XTRADB CLUSTER 5.7 RELEASE NOTES

Percona XtraDB Cluster 5.7.25-31.35

Percona is glad to announce the release of Percona XtraDB Cluster 5.7.25-31.35 on February 28, 2019. Binaries are available from the downloads section or from our *software repositories*.

This release of Percona XtraDB Cluster includes the support of Ubuntu 18.10 (Cosmic Cuttlefish). Percona XtraDB Cluster 5.7.25-31.35 is now the current release, based on the following:

- Percona Server for MySQL 5.7.25
- Galera Replication library 3.25
- Galera/Codership WSREP API Release 5.7.24

Bugs Fixed

- #2346: `mysqld` could crash when executing `mysqldump --single-transaction` while the binary log is disabled. This problem was also reported in #1711, #2371, #2419.
- #2388: In some cases, `DROP FUNCTION` with an explicit name was not replicated.

Other bugs fixed: #1711, #2371, #2419

Percona XtraDB Cluster 5.7.24-31.33

Percona is glad to announce the release of Percona XtraDB Cluster 5.7.24-31.33 on January 4, 2019. Binaries are available from the downloads section or from our *software repositories*.

Percona XtraDB Cluster 5.7.24-31.33 is now the current release, based on the following:

- Percona Server for MySQL 5.7.24
- Galera Replication library 3.25
- Galera/Codership WSREP API Release 5.7.24

Deprecated

The following variables are deprecated starting from this release:

- *wsrep_preordered* was used to turn on transparent handling of preordered replication events applied locally first before being replicated to other nodes in the cluster. It is not needed anymore due to the carried out performance fix eliminating the lag in asynchronous replication channel and cluster replication.
- innodb_disallow_writes usage to make *InnoDB* avoid writes during SST (State Snapshot Transfer) was deprecated in favor of the innodb_read_only variable.
- *wsrep_drupal_282555_workaround* avoided the duplicate value creation caused by buggy auto-increment logic, but the correspondent bug is already fixed.
- session-level variable binlog_format=STATEMENT was enabled only for pt-table-checksum, which would be addressed in following releases of the *Percona Toolkit*.

Fixed Bugs

- PXC-2220: Starting two instances of Percona XtraDB Cluster on the same node could cause writing transactions to a page store instead of a galera.cache ring buffer, resulting in huge memory consumption because of retaining already applied write-sets.
- PXC-2230: gcs.fc_limit=0 not allowed as dynamic setting to avoid generating flow control on every message was still possible in my.cnf due to the inconsistent check.
- PXC-2238: setting read_only=1 caused race condition.
- PXC-1131: mysqld-systemd threw an error at *MySQL* restart in case of non-existing error-log in Centos/RHEL7.
- PXC-2269: being not dynamic, the *pxc_encrypt_cluster_traffic* variable was erroneously allowed to be changed by a SET GLOBAL statement.
- PXC-2275: checking *wsrep_node_address* value in the wsrep_sst_common command line parser caused parsing the wrong variable.

Percona XtraDB Cluster 5.7.23-31.31.2

To resolve a critical regression, Percona announces the release of Percona XtraDB Cluster 5.7.23-31.31.2 on October 2, 2018. Binaries are available from the downloads section or from our *software repositories*.

This release resolves a critical regression in the upstream wsrep library and supersedes *5.7.23-31.31*.

Percona XtraDB Cluster 5.7.23-31.31.2 is now the current release, based on the following:

- Percona Server 5.7.23-23
- Galera Replication library 3.24
- Galera/Codership WSREP API Release 5.7.23

All Percona software is open-source and free.

Fixed Bugs

- #2254: A cluster conflict could cause a crash in Percona XtraDB Cluster 5.7.23 if *autocommit=off*.

Percona XtraDB Cluster 5.7.23-31.31

This release has been superseded by 5.7.23-31.31.2 after a critical regression was found. *Please update to the latest release*.

Percona is glad to announce the release of Percona XtraDB Cluster 5.7.23-31.31 on September 26, 2018. Binaries are available from the downloads section or from our *software repositories*.

Percona XtraDB Cluster 5.7.23-31.31 is now the current release, based on the following:

- Percona Server for MySQL 5.7.23
- Galera Replication library 3.24
- Galera/Codership WSREP API Release 5.7.23

Deprecated

The following variables are deprecated starting from this release:

- *wsrep_convert_lock_to_trx*

This variable, which defines whether locking sessions should be converted to transactions, is deprecated in Percona XtraDB Cluster 5.7.23-31.31 because it is rarely used in practice.

Fixed Bugs

- PXC-1017: Memcached access to InnoDB was not replicated by Galera
- PXC-2164: The SST script prevented SELinux from being enabled
- PXC-2155: `wsrep_sst_xtrabackup-v2` did not delete all folders on cleanup
- PXC-2160: In some cases, the MySQL version was not detected correctly with the `Xtrabackup-v2` method of SST.
- PXC-2199: When the `DROP TRIGGER IF EXISTS` statement was run for a not existing trigger, the node GTID was incremented instead of the cluster GTID.
- PXC-2209: The compression dictionary was not replicated in PXC.
- PXC-2202: In some cases, a disconnected cluster node was not shut down.
- PXC-2165: SST could fail if either `wsrep_node_address` or `wsrep_sst_receive_address` were not specified.
- PXC-2213: NULL/VOID DDL transactions could commit in a wrong order.

Percona XtraDB Cluster 5.7.22-29.26

Percona is glad to announce the release of Percona XtraDB Cluster 5.7.22-29.26 on June 29, 2018. Binaries are available from the downloads section or from our *software repositories*.

Percona XtraDB Cluster 5.7.22-29.26 is now the current release, based on the following:

- Percona Server for MySQL 5.7.22
- Galera Replication library 3.23

- Galera/Codership WSREP API Release 5.7.21

Deprecated

The following variables are deprecated starting from this release:

- `wsrep-force-binlog-format`
- *`wsrep_sst_method`* = `mysqldump`

As long as the use of `binlog_format=ROW` is enforced in 5.7, *`wsrep_forced_binlog_format`* variable is much less significant. The same is related to `mysqldump`, as `xtrabackup` is now the recommended SST method.

New features

- PXC-907: New variable *`wsrep_RSU_commit_timeout`* allows to configure RSU wait for active commit connection timeout (in microseconds).
- PXC-2111: Percona XtraDB Cluster now supports the `keyring_vault` plugin, which allows to store the master key in a vault server.
- Percona XtraDB Cluster 5.7.22 depends on Percona XtraBackup 2.4.12 in order to fully support vault plugin functionality.

Fixed Bugs

- PXC-2127: Percona XtraDB Cluster shutdown process hung if `thread_handling` option was set to `pool-of-threads` due to a regression in `5.7.21`.
- PXC-2128: Duplicated auto-increment values were set for the concurrent sessions on cluster reconfiguration due to the erroneous readjustment.
- PXC-2059: Error message about the necessity of the `SUPER` privilege appearing in case of the `CREATE TRIGGER` statements fail due to enabled WSREP was made more clear.
- PXC-2061: Wrong values could be read, depending on timing, when read causality was enforced with `wsrep_sync_wait=1`, because of waiting on the commit monitor to be flushed instead of waiting on the apply monitor.
- PXC-2073: `CREATE TABLE AS SELECT` statement was not replicated in case if result set was empty.
- PXC-2087: Cluster was entering the deadlock state if table had an unique key and `INSERT ... ON DUPLICATE KEY UPDATE` statement was executed.
- PXC-2091: Check for the maximum number of rows, that can be replicated as a part of a single transaction because of the Galera limit, was enforced even when replication was disabled with `wsrep_on=OFF`.
- PXC-2103: Interruption of the local running transaction in a `COMMIT` state by a replicated background transaction while waiting for the binlog backup protection caused the commit fail and, eventually, an assert in Galera.
- PXC-2130: Percona XtraDB Cluster failed to build with Python 3.
- PXC-2142: Replacing Percona Server with Percona XtraDB Cluster on CentOS 7 with the `yum swap` command produced a broken symlink in place of the `/etc/my.cnf` configuration file.
- PXC-2154: rsync SST is now aborted with error message if used on node with `keyring_vault` plugin configured, because it doesn't support `keyring_vault`. Also Percona doesn't recommend using rsync-based SST for data-at-rest encryption with keyring.

- PXB-1544: `xtrabackup --copy-back` didn't read which encryption plugin to use from `plugin-load` setting of the `my.cnf` configuration file.
- PXB-1540: Meeting a zero sized keyring file, *Percona XtraBackup* was removing and immediately recreating it, and this could affect external software noticing the file had undergo some manipulations.

Other bugs fixed: PXC-2072 "flush table <table> for export should be blocked with mode=ENFORCING".

Percona XtraDB Cluster 5.7.21-29.26

Percona is glad to announce the release of Percona XtraDB Cluster 5.7.21-29.26 on March 02, 2018. Binaries are available from the downloads section or from our *software repositories*.

Percona XtraDB Cluster 5.7.20-29.24 is now the current release, based on the following:

- Percona Server for MySQL 5.7.21
- Galera Replication library 3.23
- Galera/Codership WSREP API Release 5.7.21

Starting from now, Percona XtraDB Cluster issue tracking system was moved from launchpad to JIRA. All Percona software is open-source and free.

Fixed Bugs

- PXC-2039: Node consistency was compromised for `INSERT INTO ... ON DUPLICATE KEY UPDATE` workload because the regression introduced in Percona XtraDB Cluster *`5.7.17-29.20`* made it possible to abort local transactions without further re-evaluation in case of a lock conflict.
- PXC-2054 Redo optimized DDL operations (like sorted index build) were not blocked in case of a running backup process, leading to the SST fail. To fix this, `--lock-ddl` option blocks now all DDL during the **`xtrabackup`** backup stage.
- General code improvement was made in the GTID event handling, when events are captured as a part of the slave replication and appended to the galera replicated write-set. This fixed PXC-2041 (starting async slave on a single node Percona XtraDB Cluster led to a crash) and PXC-2058 (binlog-based master-slave replication broke the cluster) caused by the incorrect handling in the GTID append logic.
- An issue caused by noncoincidence between the order of recovered transaction and the global seqno assigned to the transaction was fixed ensuring that the updated recovery wsrep coordinates are persisted.
- PXC-904: Replication filters were not working with account management statements like `CREATE USER` in case of galera replication; as a result such commands were blocked by the replication filters on async slave nodes but not on galera ones.
- PXC-2043: SST script was trying to use `pv` (the pipe viewer) for *`progress`* and *`rlimit`* options even on nodes with no `pv` installed, resulting in SST fail instead of just ignoring these options for inappropriate nodes.
- PXC-911: When node's own IP address was defined in the *`wsrep_cluster_address`* variable, the node was receiving "no messages seen in" warnings from it's own IP address in the info log.

This release also contains fixes for the following CVE issues: CVE-2018-2565, CVE-2018-2573, CVE-2018-2576, CVE-2018-2583, CVE-2018-2586, CVE-2018-2590, CVE-2018-2612, CVE-2018-2600, CVE-2018-2622, CVE-2018-2640, CVE-2018-2645, CVE-2018-2646, CVE-2018-2647, CVE-2018-2665, CVE-2018-2667, CVE-2018-2668, CVE-2018-2696, CVE-2018-2703, CVE-2017-3737.

Percona XtraDB Cluster 5.7.20-29.24

Percona is glad to announce the release of Percona XtraDB Cluster 5.7.20-29.24 on January 26, 2018. Binaries are available from the downloads section or from our *software repositories*.

Note: Due to new package dependency, Ubuntu/Debian users should use `apt-get dist-upgrade`, `apt upgrade`, or `apt-get install percona-xtradb-cluster-57` to upgrade.

Percona XtraDB Cluster 5.7.20-29.24 is now the current release, based on the following:

- Percona Server 5.7.20-18
- Galera Replication library 3.22
- Galera/Codership WSREP API Release 5.7.20

All Percona software is open-source and free.

NEW FEATURES:

- Ubuntu 17.10 Artful Aardvark is now supported.
- PXC-737: freezing gcache purge was implemented to facilitate node joining through IST, avoiding time consuming SST process.
- PXC-822: a usability improvement was made to timeout error messages, the name of the configuration variable which caused the timeout was added to the message.
- PXC-866: a new variable *wsrep_last_applied*, in addition to *wsrep_last_committed* one, was introduced to clearly separate last committed and last applied transaction numbers.
- PXC-868: on the Joiner, during SST, *tmpdir* variable under `[sst]` section can be used to specify temporary SST files storage different from the default `datadir/.sst` one.

Fixed Bugs

- PXC-889: fixed an issue where a node with an invalid value for *wsrep_provider* was allowed to start up and operate in standalone mode, which could lead to data inconsistency. The node will now abort in this case. Bug fixed #1728774
- PXC-806: fixed an abort caused by an early read of the `query_id`, ensuring valid ids are assigned to subsequent transactions.
- PXC-850: ensured that a node, because of data inconsistency, isolates itself before leaving the cluster, thus allowing pending nodes to re-evaluate the quorum. Bug fixed #1704404
- PXC-867: `wsrep_sst_rsync` script was overwriting *wsrep_debug* configuration setting making it not to be taken into account.
- PXC-873: fixed formatting issue in the error message appearing when SST is not possible due to a timeout. Bug fixed #1720094
- PXC-874: PXC acting as async slave reported unhandled transaction errors, namely “Rolling back unfinished transaction”.
- PXC-875: fixed an issue where toggling *wsrep_provider* off and on failed to reset some internal variables and resulted in PXC logging an “Unsupported protocol downgrade” warning. Bug fixed #1379204

- PXC-877: fixed PXC hang caused by an internal deadlock.
- PXC-878: thread failed to mark exit from the InnoDB server concurrency and therefore never got un-register in InnoDB concurrency system.
- PXC-879: fixed a bug where a `LOAD DATA` command used with GTIDs was executed on one node, but the other nodes would receive less rows than the first one. Bug fixed #1741818
- PXC-880: insert to table without primary key was possible with insertable view if *`pxc_strict_mode`* variable was set to ENFORCING. Bug fixed #1722493
- PXC-883: fixed `ROLLBACK TO SAVEPOINT` incorrect operation on slaves by avoiding useless wsrep plugin register for a savepoint rollback. Bug fixed #1700593
- PXC-885: fixed IST hang when `keyring_file_data` is set. Bug fixed #1728688
- PXC-887: gcache page files were unnecessarily created due to an error in projecting gcache free size when configured to recover on restart.
- PXC-895: fixed transaction loss after recovery by avoiding interruption of the binlog recovery based on wsrep saved position. Bug fixed :bug:1734113
- PXC-897: fixed empty `gtid_executed` variable after recovering the position of a node with `--wsrep_recover`.
- PXC-906: fixed certification failure in the case of a node restarting at the same time when frequent `TRUNCATE TABLE` commands and DML writes occur simultaneously on other nodes. Bug fixed #1737731
- PXC-909: qpress package was turned into a dependency from suggested/recommended one on Debian 9.
- PXC-903 and PXC-910: init.d/systemctl scripts on Debian 9 were updated to avoid starting wsrep-recover if there was no crash, and to fix an infinite loop at mysqladmin ping fail because of nonexistent ping user.
- PXC-915: suppressing DDL/TOI replication in case of `sql_log_bin` zero value didn't work when DDL statement was modifying an existing table, resulting in an error.

Percona XtraDB Cluster 5.7.19-29.22-3

Percona is glad to announce the release of Percona XtraDB Cluster 5.7.19-29.22-3 on October 27, 2017. Binaries are available from the downloads section or from our *software repositories*.

Percona XtraDB Cluster 5.7.19-29.22-3 is now the current release, based on the following:

- Percona Server 5.7.19-17
- Galera Replication library 3.22
- wsrep API version 29

All Percona software is open-source and free.

Fixed Bugs

- Added access checks for DDL commands to make sure they do not get replicated if they failed without proper permissions. Previously, when a user tried to perform certain DDL actions that failed locally due to lack of privileges, the command could still be replicated to other nodes, because access checks were performed after replication.

  This vulnerability is identified as CVE-2017-15365.

Percona XtraDB Cluster 5.7.19-29.22

Percona is glad to announce the release of Percona XtraDB Cluster 5.7.19-29.22 on September 22, 2017. Binaries are available from the downloads section or from our *software repositories*.

Percona XtraDB Cluster 5.7.19-29.22 is now the current release, based on the following:

- Percona Server 5.7.19-17
- Galera Replication library 3.22
- wsrep API version 29

All Percona software is open-source and free.

Upgrade Instructions

After you upgrade each node to Percona XtraDB Cluster 5.7.19-29.22, run the following command on one of the nodes:

```
$ mysql -uroot -p < /usr/share/mysql/pxc_cluster_view.sql
```

Then restart all nodes, one at a time:

```
$ sudo service mysql restart
```

New Features

- Introduced the `pxc_cluster_view` table to get a unified view of the cluster. This table is exposed through the performance schema.

```
mysql> select * from pxc_cluster_view;
------------------------------------------------------------------------------
HOST_NAME  UUID                                  STATUS  LOCAL_INDEX  SEGMENT
------------------------------------------------------------------------------
n1         b25bfd59-93ad-11e7-99c7-7b26c63037a2  DONOR   0            0
n2         be7eae92-93ad-11e7-88d8-92f8234d6ce2  JOINER  1            0
------------------------------------------------------------------------------
2 rows in set (0.01 sec)
```

- PXC-803: Added support for new features in Percona XtraBackup 2.4.7:
  - *`wsrep_debug`* enables debug logging
  - *`encrypt_threads`* specifies the number of threads that XtraBackup should use for encrypting data (when `encrypt=1`). This value is passed using the `--encrypt-threads` option in XtraBackup.
  - *`backup_threads`* specifies the number of threads that XtraBackup should use to create backups. See the `--parallel` option in XtraBackup.

Improvements

- PXC-835: Limited `wsrep_node_name` to 64 bytes.
- PXC-846: Improved logging to report reason of IST failure.
- PXC-851: Added version compatibility check during SST with XtraBackup:

- If donor is 5.6 and joiner is 5.7: A warning is printed to perform `mysql_upgrade`.
- If donor is 5.7 and joiner is 5.6: An error is printed and SST is rejected.

Fixed Bugs

- PXC-825: Fixed script for SST with XtraBackup (`wsrep_sst_xtrabackup-v2`) to include the `--defaults-group-suffix` when logging to syslog. For more information, see #1559498.
- PXC-826: Fixed multi-source replication to PXC node slave. For more information, see #1676464.
- PXC-827: Fixed handling of different binlog names between donor and joiner nodes when GTID is enabled. For more information, see #1690398.
- PXC-830: Rejected the `RESET MASTER` operation when wsrep provider is enabled and `gtid_mode` is set to `ON`. For more information, see #1249284.
- PXC-833: Fixed connection failure handling during SST by making the donor retry connection to joiner every second for a maximum of 30 retries. For more information, see #1696273.
- PXC-839: Fixed GTID inconsistency when setting `gtid_next`.
- PXC-840: Fixed typo in alias for `systemd` configuration.
- PXC-841: Added check to avoid replication of DDL if `sql_log_bin` is disabled. For more information, see #1706820.
- PXC-842: Fixed deadlocks during Load Data Infile (LDI) with `log-bin` disabled by ensuring that a new transaction (of 10 000 rows) starts only after the previous one is committed by both wsrep and InnoDB. For more information, see #1706514.
- PXC-843: Fixed situation where the joiner hangs after SST has failed by dropping all transactions in the receive queue. For more information, see #1707633.
- PXC-853: Fixed cluster recovery by enabling `wsrep_ready` whenever nodes become PRIMARY.
- PXC-862: Fixed script for SST with XtraBackup (`wsrep_sst_xtrabackup-v2`) to use the `ssl-dhparams` value from the configuration file.

Note: As part of fix for PXC-827, version communication was added to the SST protocol. As a result, newer version of PXC (as of 5.7.19 and later) cannot act as donor when joining an older version PXC node (prior to 5.7.19). It will work fine vice versa: old node can act as donor when joining nodes with new version.

Percona XtraDB Cluster 5.7.18-29.20

Percona is glad to announce the release of *Percona XtraDB Cluster* 5.7.18-29.20 on June 2, 2017. Binaries are available from the downloads section or from our *software repositories*.

Note: Due to new package dependency, Ubuntu/Debian users should use `apt-get dist-upgrade` or `apt-get install percona-xtradb-cluster-57` to upgrade.

Percona XtraDB Cluster 5.7.18-29.20 is now the current release, based on the following:

- Percona Server 5.7.18-15
- Galera Replication library 3.20

- wsrep API version 29

All Percona software is open-source and free.

Fixed Bugs

- PXC-749: Fixed memory leak when running `INSERT` on a table without primary key defined and *`wsrep_certify_nonPK`* disabled (set to `0`).

  Note: It is recommended to have primary keys defined on all tables for correct write set replication.

- PXC-812: Fixed SST script to leave the DONOR keyring when JOINER clears the datadir.
- PXC-813: Fixed SST script to use UTC time format.
- PXC-816: Fixed hook for caching GTID events in asynchronous replication. For more information, see #1681831.
- PXC-820: Enabled querying of *`pxc_maint_mode`* by another client during the transition period.
- PXC-823: Fixed SST flow to gracefully shut down JOINER node if SST fails because DONOR leaves the cluster due to network failure. This ensures that the DONOR is then able to recover to synced state when network connectivity is restored For more information, see #1684810.
- PXC-824: Fixed graceful shutdown of Percona XtraDB Cluster node to wait until applier thread finishes.

Other Improvements

- PXC-819: Added five new status variables to expose required values from *`wsrep_ist_receive_status`* and *`wsrep_flow_control_interval`* as numbers, rather than strings that need to be parsed:
  - `wsrep_flow_control_interval_low`
  - `wsrep_flow_control_interval_high`
  - `wsrep_ist_receive_seqno_start`
  - `wsrep_ist_receive_seqno_current`
  - `wsrep_ist_receive_seqno_end`

Percona XtraDB Cluster 5.7.17-29.20

Percona is glad to announce the release of *Percona XtraDB Cluster* 5.7.17-29.20 on April 19, 2017. Binaries are available from the downloads section or from our *software repositories*.

Percona XtraDB Cluster 5.7.17-29.20 is now the current release, based on the following:

- Percona Server 5.7.17-13
- Galera Replication library 3.20
- wsrep API version 29

All Percona software is open-source and free.

Performance Improvements

This release was focused on performance and scaling capability with increasing workload threads. Tests show up to 10 times increase in performance.

Fixed Bugs

- Improved parallelism for better scaling with multiple threads.
- Updated semantics for gcache page cleanup to trigger when either *gcache.keep_pages_size* or *gcache.keep_pages_count* exceeds the limit, instead of both at the same time.
- Improved SST and IST log messages for better readability and unification.
- Excluded the garbd node from flow control calculations.
- Added extra checks to verify that SSL files (certificate, certificate authority, and key) are compatible before opening connection.
- Added validations for DISCARD TABLESPACE and IMPORT TABLESPACE in *PXC Strict Mode* to prevent data inconsistency.
- Added support for passing the XtraBackup buffer pool size with the use-memory option under [xtrabackup] and the innodb_buffer_pool_size option under [mysqld] when the --use-memory option is not passed with the inno-apply-opts option under [sst].
- Added the *wsrep_flow_control_status* variable to indicate if node is in flow control (paused).
- Fixed gcache page cleanup not triggering when limits are exceeded.
- PXC-766: Added the *wsrep_ist_receive_status* variable to show progress during an IST.
- Allowed CREATE TABLE ... AS SELECT (CTAS) statements with temporary tables (CREATE TEMPORARY TABLE ... AS SELECT) in *PXC Strict Mode*. For more information, see #1666899.
- PXC-782: Updated xtrabackup-v2 script to use the *tmpdir* option (if it is set under [sst], [xtrabackup] or [mysqld], in that order).
- PXC-783: Improved the wsrep stage framework.
- PXC-784: Fixed the pc.recovery procedure to abort if the gvwstate.dat file is empty or invalid, and fall back to normal joining process. For more information, see #1669333.
- PXC-794: Updated the *sockopt* option to include a comma at the beginning if it is not set by the user.
- PXC-795: Set --parallel=4 as default option for wsrep_sst_xtrabackup-v2 to run four threads with XtraBackup.
- PXC-797: Blocked *wsrep_desync* toggling while node is paused to avoid halting the cluster when running FLUSH TABLES WITH READ LOCK. For more information, see #1370532.
- PXC-805: Inherited upstream fix to avoid using deprecated variables, such as INFORMATION_SCHEMA.SESSION_VARIABLE. For more information, see #1676401.
- PXC-811: Changed default values for the following variables:
  - fc_limit from 16 to 100
  - send_window from 4 to 10
  - user_send_window from 2 to 4
- Moved wsrep settings into a separate configuration file (/etc/my.cnf.d/wsrep.cnf).

- Fixed `mysqladmin shutdown` to correctly stop the server on systems using `systemd`.
- Fixed several minor packaging and dependency issues.

Percona XtraDB Cluster 5.7.17-27.20

Percona is glad to announce the release of *Percona XtraDB Cluster* 5.7.17-27.20 on March 16, 2017. Binaries are available from the downloads section or from our *software repositories*.

Percona XtraDB Cluster 5.7.17-27.20 is now the current release, based on the following:

- Percona Server 5.7.17-11
- Galera Replication library 3.20
- wsrep API version 27

All Percona software is open-source and free. Details of this release can be found in the 5.7.17-27.20 milestone on Launchpad.

Fixed Bugs

- BLD-512: Fixed startup of `garbd` on Ubuntu 16.04.2 LTS (Xenial Xerus).
- BLD-519: Added the `garbd` debug package to the repository.
- BLD-569: Fixed `grabd` script to return non-zero if it fails to start.
- BLD-570: Fixed service script for `garbd` on Ubuntu 16.04.2 LTS (Xenial Xerus) and Ubuntu 16.10 (Yakkety Yak).
- BLD-593: Limited the use of `rm` and `chown` by `mysqld_safe` to avoid exploits of the CVE-2016-5617 vulnerability. For more information, see #1660265.

  Credit to Dawid Golunski (https://legalhackers.com).
- BLD-610: Added version number to the dependency requirements of the full RPM package.
- BLD-643: Fixed `systemctl` to mark `mysql` process as inactive after it fails to start and not attempt to start it again. For more information, see #1662292.
- BLD-644: Added the `which` package to Percona XtraDB Cluster dependencies on CentOS 7. For more information, see #1661398.
- BLD-645: Fixed `mysqld_safe` to support options with a forward slash (`/`). For more information, see #1652838.
- BLD-647: Fixed `systemctl` to show correct status for `mysql` on CentOS 7. For more information, see #1644382.

Percona XtraDB Cluster 5.7.16-27.19

Percona is glad to announce the release of *Percona XtraDB Cluster* 5.7.16-27.19 on December 15, 2016. Binaries are available from the downloads section or from our *software repositories*.

Percona XtraDB Cluster 5.7.16-27.19 is now the current release, based on the following:

- Percona Server 5.7.16-10

- Galera Replication library 3.19
- wsrep API version 27

All Percona software is open-source and free. Details of this release can be found in the 5.7.16-27.19 milestone on Launchpad.

Deprecated

- The following encryption modes:
  - `encrypt=1`
  - `encrypt=2`
  - `encrypt=3`

  The default is `encrypt=0` with encryption disabled. The recommended mode now is the new `encrypt=4`, which uses SSL files generated by MySQL.

  For more information, see *Encrypting PXC Traffic*.

New Features

- Added `encrypt=4` mode for SST encryption that uses SSL files generated by MySQL. Modes `1`, `2`, and `3` will soon be deprecated.
- ProxySQL assisted maintenance mode that enables you to take a node down without adjusting ProxySQL manually. The mode is controlled using the `pxc_maint_mode` variable, which can be set to one of the following values:
  - `DISABLED`: This is the default state that tells ProxySQL to route traffic to the node as usual.
  - `SHUTDOWN`: This state is set automatically when you initiate node shutdown.
  - `MAINTENANCE`: You can change to this state if you need to perform maintenace on a node without shutting it down.

  For more information, see *Assisted Maintenance Mode*.
- Simplified SSL configuration for Galera/SST traffic with `pxc-encrypt-cluster-traffic` option, which auto-configures SSL encryption.

  For more information, see *SSL Automatic Configuration*.
- Added the *`wsrep_flow_control_interval`* status variable that displays the lower and upper limits of the flow control system used for the Galera receive queue.

Fixed Bugs

- Optimized IST donor selection logic to avoid SST. Child processes are now cleaned-up and node state is resumed if SST fails.
- Added `init.ok` to the list of files that do not get removed during SST.
- Fixed error with ASIO library not acknowledging an `EPOLLIN` event when building Galera.
- Fixed stalling of DML workload on slave node caused by `FLUSH TABLE` executed on master.

  For more information, see #1629296.

- Fixed `super_read_only` to not apply to Galera replication applier.

  For more information, see #1634295.

- Redirected `netcat` output to `stdout` to avoid it in the log.

  For more information, see #1625968.

- Enabled replication of `ALTER USER` statements.

  For more information, see #1376269.

- Changed the *`wsrep_max_ws_rows`* variable to ignore non-replicated write-sets generated by DML action on temporary tables (explict or implicit).

  For more information, see #1638138.

- Fixed SST to fail with an error if SSL is not supported by `socat`, instead of switching to unencrypted mode.
- Fixed SST with SSL to auto-generate a 2048-bit `dhparams` file for versions of `socat` before 1.7.3. These older versions use 512-bit `dhparams` file by default that get rejected by newer clients with `dh key too small` error.
- PXC-731: Changed the *`wsrep_cluster_name`* variable to read-only, because changing it dynamically leads to high overhead.

  For more information, see #1620439.

- PXC-732: Improved error message when any of the SSL files required for SST are missing.
- PXC-735: Fixed SST to fail with an error when `netcat` is used (*`transferfmt`* set to `nc`) with SSL encryption (*`encrypt`* set to `2`, `3` or `4`), instead of silently switching to unencrypted mode.
- Fixed faulty switch case that caused cluster to stall when the *`repl.commit_order`* variable was set to `2` (`LOCAL_OOOC` mode that should allow out-of-order committing for local transactions).

Percona XtraDB Cluster 5.7.14-26.17

Note: This release is dedicated to the memory of Federico Goncalvez, our colleague with Percona's Uruguayan team until his tragic death on September 6, 2016.

Fede, you are missed.

Percona is glad to announce the release of Percona XtraDB Cluster 5.7.14-26.17 on September 29, 2016. Binaries are available from the downloads area or from our *software repositories*.

Percona XtraDB Cluster 5.7.14-26.17 is the first GA release in the 5.7 series, based on the following:

- Percona Server 5.7.14-8
- Galera Replicator 3.17

For information about the changes and new features introduced in Percona Server 5.7, see Changed in Percona Server 5.7.

New Features

This is a list of the most important features introduced in Percona XtraDB Cluster 5.7 compared to version 5.6

- *PXC Strict Mode* saves your workload from experimental and unsupported features.

- Support for monitoring Galera Library instruments and other wsrep instruments as part of Performance Schema.
- Support for encrypted tablespaces in Multi-Master Topology, which enables Percona XtraDB Cluster to wire encrypted tablespace to new booting node.
- Compatibility with ProxySQL, including a quick configuration script.
- Support for monitoring Percona XtraDB Cluster nodes using Percona Monitoring and Management
- More stable and robust operation with MySQL and Percona Server version 5.7.14, as well as Galera 3.17 compatibility. Includes all upstream bug fixes, improved logging and more.
- Simplified packaging for Percona XtraDB Cluster to a single package that installs everything it needs, including the Galera library.
- Support for latest XtraBackup with enhanced security checks.

Bug Fixes

Fixed crash when a local transaction (such as `EXPLAIN` or `SHOW`) is interrupted by a replicated transaction with higher priopiry (like `ALTER` that changes table structure and can thus affect the result of the local transaction).

Fixed DONOR node getting stuck in `Joined` state after successful SST.

Fixed error message when altering non-existent table with `pxc-strict-mode` enabled.

Fixed path to directory in `percona-xtradb-cluster-shared.conf`.

Fixed setting of `seqno` in `grastate.dat` to `-1` on clean shutdown.

Fixed failure of asynchronous TOI actions (like `DROP`) for non-primary nodes.

Fixed replacing of `my.cnf` during upgrade from 5.6 to 5.7.

Security Fixes

- CVE-2016-6662
- CVE-2016-6663
- CVE-2016-6664

For more information, see https://www.percona.com/blog/2016/09/12/database-affected-cve-2016-6662/

Other Improvements

Added support of `defaults-group-suffix` for SST scripts.

Percona XtraDB Cluster 5.7.12-5rc1-26.16

Percona is glad to announce the release of Percona XtraDB Cluster 5.7.12-5rc1-26.16 on August 9, 2016. Binaries are available from the downloads area or from our *software repositories*.

Percona XtraDB Cluster 5.7.12-5rc1-26.16 is based on the following:

- Percona Server 5.7.12
- Galera Replicator 3.16

New Features

- **PXC Strict Mode**: Use the *pxc_strict_mode* variable in the configuration file or the `--pxc-strict-mode` option during `mysqld` startup. For more information, see *PXC Strict Mode*.
- **Galera instruments exposed in Performance Schema**: This includes mutexes, condition variables, file instances, and threads.

Bug Fixes

- Fixed error messages.
- Fixed the failure of SST via `mysqldump` with `gtid_mode=ON`.
- Added check for TOI that ensures node readiness to process DDL+DML before starting the execution.
- Removed protection against repeated calls of `wsrep->pause()` on the same node to allow parallel RSU operation.
- Changed `wsrep_row_upd_check_foreign_constraints` to ensure that `fk-reference-table` is open before marking it open.
- Fixed error when running `SHOW STATUS` during group state update.
- Corrected the return code of `sst_flush_tables()` function to return a non-negative error code and thus pass assertion.
- Fixed memory leak and stale pointer due to stats not freeing when toggling the *wsrep_provider* variable.
- Fixed failure of `ROLLBACK` to register `wsrep_handler`
- Fixed failure of symmetric encryption during SST.

Other Changes

- Added support for sending the keyring when performing encrypted SST. For more information, see *Encrypting PXC Traffic*.
- Changed the code of `THD_PROC_INFO` to reflect what the thread is currently doing.
- Using XtraBackup as the SST method now requires Percona XtraBackup 2.4.4 or later.
- Improved rollback process to ensure that when a transaction is rolled back, any statements open by the transaction are also rolled back.
- Removed the `sst_special_dirs` variable.
- Disabled switching of `slave_preserve_commit_order` to `ON` when running PXC in cluster mode, as it conflicts with existing multi-master commit ordering resolution algorithm in Galera.
- Changed the default `my.cnf` configuration.
- Other low-level fixes and improvements for better stability.

Percona XtraDB Cluster 5.7.11-4beta-25.14.2

Percona is glad to announce the release of Percona XtraDB Cluster 5.7.11-4beta-25.14.2 on June 9, 2016. Binaries are available from downloads area or from our *software repositories*.

Note: This release is available only from the testing repository. It is not meant for upgrade from Percona XtraDB Cluster 5.6 and earlier versions. Only fresh installation is supported.

Percona XtraDB Cluster 5.7.11-4beta-25.14.2 is based on the following:

- Percona Server 5.7.11-4
- Galera Replicator 3.14.2

This is the first beta release in the Percona XtraDB Cluster 5.7 series. It includes all changes from upstream releases and the following changes:

- Percona XtraDB Cluster 5.7 does not include `wsrep_sst_xtrabackup`. It has been replace by `wsrep_sst_xtrabackup_v2`.
- The `wsrep_mysql_replication_bundle` variable has been removed.

CHAPTER

THIRTYNINE

INDEX OF WSREP STATUS VARIABLES

variable `wsrep_apply_oooe`

This variable shows parallelization efficiency, how often writests have been applied out of order.

variable `wsrep_apply_oool`

This variable shows how often a writeset with a higher sequence number was applied before one with a lower sequence number.

variable `wsrep_apply_window`

Average distance between highest and lowest concurrently applied sequence numbers.

variable `wsrep_causal_reads_`

Shows the number of writesets processed while the variable *`wsrep_causal_reads`* was set to `ON`.

variable `wsrep_cert_bucket_count`

This variable, shows the number of cells in the certification index hash-table.

variable `wsrep_cert_deps_distance`

Average distance between highest and lowest sequence number that can be possibly applied in parallel.

variable `wsrep_cert_index_size`

Number of entries in the certification index.

variable `wsrep_cert_interval`

Average number of write-sets received while a transaction replicates.

variable `wsrep_cluster_conf_id`

Number of cluster membership changes that have taken place.

variable `wsrep_cluster_size`

Current number of nodes in the cluster.

variable `wsrep_cluster_state_uuid`

This variable contains *UUID* state of the cluster. When this value is the same as the one in *`wsrep_local_state_uuid`*, node is synced with the cluster.

variable `wsrep_cluster_status`

Status of the cluster component. Possible values are:

- `Primary`
- `Non-Primary`

- Disconnected

variable wsrep_commit_ooe

This variable shows how often a transaction was committed out of order.

variable wsrep_commit_oool

This variable currently has no meaning.

variable wsrep_commit_window

Average distance between highest and lowest concurrently committed sequence number.

variable wsrep_connected

This variable shows if the node is connected to the cluster. If the value is OFF, the node has not yet connected to any of the cluster components. This may be due to misconfiguration.

variable wsrep_evs_delayed

Comma separated list of nodes that are considered delayed. The node format is <uuid>:<address>:<count>, where <count> is the number of entries on delayed list for that node.

variable wsrep_evs_evict_list

List of UUIDs of the evicted nodes.

variable wsrep_evs_repl_latency

This status variable provides information regarding group communication replication latency. This latency is measured in seconds from when a message is sent out to when a message is received.

The format of the output is <min>/<avg>/<max>/<std_dev>/<sample_size>.

variable wsrep_evs_state

Internal EVS protocol state.

variable wsrep_flow_control_interval

This variable shows the lower and upper limits for Galera flow control. The upper limit is the maximum allowed number of requests in the queue. If the queue reaches the upper limit, new requests are denied. As existing requests get processed, the queue decreases, and once it reaches the lower limit, new requests will be allowed again.

variable wsrep_flow_control_interval_high

Shows the upper limit for flow control to trigger.

variable wsrep_flow_control_interval_low

Shows the lower limit for flow control to stop.

variable wsrep_flow_control_paused

Time since the last status query that was paused due to flow control.

variable wsrep_flow_control_paused_ns

Total time spent in a paused state measured in nanoseconds.

variable wsrep_flow_control_recv

Number of FC_PAUSE events received since the last status query.

variable wsrep_flow_control_sent

Number of FC_PAUSE events sent since the last status query.

variable wsrep_flow_control_status

Version Introduced in 5.7.17-29.20

This variable shows whether a node has flow control enabled for normal traffic. It does not indicate the status of flow control during SST.

variable `wsrep_gcache_pool_size`

This variable shows the size of the page pool and dynamic memory allocated for GCache (in bytes).

variable `wsrep_gcomm_uuid`

This status variable exposes UUIDs in `gvwstate.dat`, which are Galera view IDs (thus unrelated to cluster state UUIDs). This UUID is unique for each node. You will need to know this value when using manual eviction feature.

variable `wsrep_incoming_addresses`

Shows the comma-separated list of incoming node addresses in the cluster.

variable `wsrep_ist_receive_status`

Version Introduced in 5.7.17-29.20

Displays the progress of IST for joiner node. If IST is not running, the value is blank. If IST is running, the value is the percentage of transfer completed.

variable `wsrep_ist_receive_seqno_end`

The sequence number of the last transaction in IST.

variable `wsrep_ist_receive_seqno_current`

The sequence number of the current transaction in IST.

variable `wsrep_ist_receive_seqno_start`

The sequence number of the first transaction in IST.

variable `wsrep_last_applied`

Version Introduced in *5.7.20-29.24*

Sequence number of the last applied transaction.

variable `wsrep_last_committed`

Sequence number of the last committed transaction.

variable `wsrep_local_bf_aborts`

Number of local transactions that were aborted by slave transactions while being executed.

variable `wsrep_local_cached_downto`

The lowest sequence number in GCache. This information can be helpful with determining IST and SST. If the value is `0`, then it means there are no writesets in GCache (usual for a single node).

variable `wsrep_local_cert_failures`

Number of writesets that failed the certification test.

variable `wsrep_local_commits`

Number of writesets commited on the node.

variable `wsrep_local_index`

Node's index in the cluster.

variable `wsrep_local_recv_queue`

Current length of the receive queue (that is, the number of writesets waiting to be applied).

variable wsrep_local_recv_queue_avg

Average length of the receive queue since the last status query. When this number is bigger than `0` this means node can't apply writesets as fast as they are received. This could be a sign that the node is overloaded and it may cause replication throttling.

variable wsrep_local_replays

Number of transaction replays due to *asymmetric lock granularity*.

variable wsrep_local_send_queue

Current length of the send queue (that is, the number of writesets waiting to be sent).

variable wsrep_local_send_queue_avg

Average length of the send queue since the last status query. When cluster experiences network throughput issues or replication throttling, this value will be significantly bigger than `0`.

variable wsrep_local_state

variable wsrep_local_state_comment

Internal number and the corresponding human-readable comment of the node's state. Possible values are:

Num	Comment	Description
1	Joining	Node is joining the cluster
2	Donor/Desynced	Node is the donor to the node joining the cluster
3	Joined	Node has joined the cluster
4	Synced	Node is synced with the cluster

variable wsrep_local_state_uuid

The *UUID* of the state stored on the node.

variable wsrep_protocol_version

Version of the wsrep protocol used.

variable wsrep_provider_name

Name of the wsrep provider (usually `Galera`).

variable wsrep_provider_vendor

Name of the wsrep provider vendor (usually `Codership Oy`)

variable wsrep_provider_version

Current version of the wsrep provider.

variable wsrep_ready

This variable shows if node is ready to accept queries. If status is `OFF`, almost all queries will fail with `ERROR 1047 (08S01) Unknown Command` error (unless the *wsrep_on* variable is set to `0`).

variable wsrep_received

Total number of writesets received from other nodes.

variable wsrep_received_bytes

Total size (in bytes) of writesets received from other nodes.

variable wsrep_repl_data_bytes

Total size (in bytes) of data replicated.

variable `wsrep_repl_keys`

Total number of keys replicated.

variable `wsrep_repl_keys_bytes`

Total size (in bytes) of keys replicated.

variable `wsrep_repl_other_bytes`

Total size of other bits replicated.

variable `wsrep_replicated`

Total number of writesets sent to other nodes.

variable `wsrep_replicated_bytes`

Total size (in bytes) of writesets sent to other nodes.

CHAPTER

FORTY

INDEX OF WSREP SYSTEM VARIABLES

Percona XtraDB Cluster introduces a number of MySQL system variables related to write-set replication.

variable `pxc_encrypt_cluster_traffic`

Version Info

- **`5.7.16`** – Variable introduced

Command Line `--pxc-encrypt-cluster-traffic`

Config File Yes

Scope Global

Dynamic No

Default Value `OFF`

Enables automatic configuration of SSL encryption. When disabled, you need to configure SSL manually to encrypt Percona XtraDB Cluster traffic.

Possible values:

- `OFF`, `0`, `false`: Disabled (default)
- `ON`, `1`, `true`: Enabled

For more information, see *SSL Automatic Configuration*.

variable `pxc_maint_mode`

Version Info

- **`5.7.16`** – Variable introduced

Command Line `--pxc-maint-mode`

Config File Yes

Scope Global

Dynamic Yes

Default Value `DISABLED`

Specifies the maintenance mode for taking a node down without adjusting settings in ProxySQL. The following values are available:

- `DISABLED`: This is the default state that tells ProxySQL to route traffic to the node as usual.
- `SHUTDOWN`: This state is set automatically when you initiate node shutdown.

- MAINTENANCE: You can manually change to this state if you need to perform maintenance on a node without shutting it down.

For more information, see *Assisted Maintenance Mode*.

variable pxc_maint_transition_period

Version Info

- **5.7.16** – Variable introduced

Command Line --pxc-maint-transition-period

Config File Yes

Scope Global

Dynamic Yes

Default Value 10 (ten seconds)

Defines the transition period when you change *pxc_maint_mode* to SHUTDOWN or MAINTENANCE. By default, the period is set to 10 seconds, which should be enough for most transactions to finish. You can increase the value to accommodate for longer-running transactions.

For more information, see *Assisted Maintenance Mode*.

variable pxc_strict_mode

Version Info

- **5.7** – Variable introduced

Command Line --pxc-strict-mode

Config File Yes

Scope Global

Dynamic Yes

Default Value ENFORCING or DISABLED

Controls *PXC Strict Mode*, which runs validations to avoid the use of experimental and unsupported features in Percona XtraDB Cluster.

Depending on the actual mode you select, upon encountering a failed validation, the server will either throw an error (halting startup or denying the operation), or log a warning and continue running as normal. The following modes are available:

- DISABLED: Do not perform strict mode validations and run as normal.
- PERMISSIVE: If a validation fails, log a warning and continue running as normal.
- ENFORCING: If a validation fails during startup, halt the server and throw an error. If a validation fails during runtime, deny the operation and throw an error.
- MASTER: The same as ENFORCING except that the validation of *explicit table locking* is not performed. This mode can be used with clusters in which write operations are isolated to a single node.

By default, *pxc_strict_mode* is set to ENFORCING, except if the node is acting as a standalone server or the node is bootstrapping, then *pxc_strict_mode* defaults to DISABLED.

Note: When changing the value of pxc_strict_mode from DISABLED or PERMISSIVE to ENFORCING or MASTER, ensure that the following configuration is used:

- wsrep_replicate_myisam=OFF

- `binlog_format=ROW`
- `log_output=FILE` or `log_output=NONE` or `log_output=FILE,NONE`
- `tx_isolation=SERIALIZABLE`

For more information, see *PXC Strict Mode*.

variable `wsrep_auto_increment_control`

Command Line `--wsrep-auto-increment-control`

Config File Yes

Scope Global

Dynamic Yes

Default Value `ON`

Enables automatic adjustment of auto-increment system variables depending on the size of the cluster:

- `auto_increment_increment` controls the interval between successive `AUTO_INCREMENT` column values
- `auto_increment_offset` determines the starting point for the `AUTO_INCREMENT` column value

This helps prevent auto-increment replication conflicts across the cluster by giving each node its own range of auto-increment values. It is enabled by default.

Automatic adjustment may not be desirable depending on application's use and assumptions of auto-increments. It can be disabled in master-slave clusters.

variable `wsrep_causal_reads`

Version Info

- **`5.6.20-25.7`** – Variable deprecated

Command Line `--wsrep-causal-reads`

Config File Yes

Scope Global, Session

Dynamic Yes

Default Value `OFF`

In some cases, the master may apply events faster than a slave, which can cause master and slave to become out of sync for a brief moment. When this variable is set to `ON`, the slave will wait until that event is applied before doing any other queries. Enabling this variable will result in larger latencies.

Note: This variable was deprecated because enabling it is the equivalent of setting *`wsrep_sync_wait`* to `1`.

variable `wsrep_certify_nonPK`

Command Line `--wsrep-certify-nonpk`

Config File Yes

Scope Global

Dynamic Yes

Default Value `ON`

Enables automatic generation of primary keys for rows that don't have them. Write set replication requires primary keys on all tables to allow for parallel applying of transactions. This variable is enabled by default. As a rule, make sure that all tables have primary keys.

variable `wsrep_cluster_address`

Command Line `--wsrep-cluster-address`

Config File Yes

Scope Global

Dynamic Yes

Defines the back-end schema, IP addresses, ports, and options that the node uses when connecting to the cluster. This variable needs to specify at least one other node's address, which is alive and a member of the cluster. In practice, it is best (but not necessary) to provide a complete list of all possible cluster nodes. The value should be of the following format:

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

The only back-end schema currently supported is `gcomm`. The IP address can contain a port number after a colon. Options are specified after `?` and separated by `&`. You can specify multiple addresses separated by commas.

For example:

```
wsrep_cluster_address="gcomm://192.168.0.1:4567?gmcast.listen_addr=0.0.0.0:5678"
```

If an empty `gcomm://` is provided, the node will bootstrap itself (that is, form a new cluster). It is not recommended to have empty cluster address in production config after the cluster has been bootstrapped initially. If you want to bootstrap a new cluster with a node, you should pass the `--wsrep-new-cluster` option when starting.

variable `wsrep_cluster_name`

Command Line `--wsrep-cluster-name`

Config File Yes

Scope Global

Dynamic Yes

Default Value `my_wsrep_cluster`

Specifies the name of the cluster and should be identical on all nodes.

Note: It should not exceed 32 characters.

---

variable `wsrep_convert_lock_to_trx`

Version Info

- ***`5.7.23-31.31`*** – Variable deprecated

Command Line `--wsrep-convert-lock-to-trx`

Config File Yes

Scope Global

Dynamic Yes

Default Value `OFF`

Defines whether locking sessions should be converted into transactions. By default, this is disabled.

Enabling this variable can help older applications to work in a multi-master setup by converting `LOCK/UNLOCK TABLES` statements into `BEGIN/COMMIT` statements. It is not the same as support for locking sessions, but it does prevent the database from ending up in a logically inconsistent state. Enabling this variable can also result in having huge write-sets.

variable `wsrep_data_home_dir`

Command Line No

Config File Yes

Scope Global

Dynamic No

Default Value `/var/lib/mysql` (or whatever path is specified by *datadir*)

Specifies the path to the directory where the wsrep provider stores its files (such as `grastate.dat`).

variable `wsrep_dbug_option`

Command Line `--wsrep-dbug-option`

Config File Yes

Scope Global

Dynamic Yes

Defines `DBUG` options to pass to the wsrep provider.

variable `wsrep_debug`

Command Line `--wsrep-debug`

Config File Yes

Scope Global

Dynamic Yes

Default Value `OFF`

Enables additional debugging output for the database server error log. By default, it is disabled. This variable can be used when trying to diagnose problems or when submitting a bug.

You can set `wsrep_debug` in the following `my.cnf` groups:

- Under `[mysqld]` it enables debug logging for `mysqld` and the SST script
- Under `[sst]` it enables debug logging for the SST script only

---

Note: Do not enable debugging in production environments, because it logs authentication info (that is, passwords).

---

variable `wsrep_desync`

Command Line No

Config File Yes

Scope Global

Dynamic Yes

Default Value `OFF`

Defines whether the node should participate in Flow Control. By default, this variable is disabled, meaning that if the receive queue becomes too big, the node engages in Flow Control: it works through the receive queue until it reaches a more manageable size. For more information, see *wsrep_local_recv_queue* and *wsrep_flow_control_interval*.

Enabling this variable will disable Flow Control for the node. It will continue to receive write-sets that it is not able to apply, the receive queue will keep growing, and the node will keep falling behind the cluster indefinitely.

Toggling this back to OFF will require an IST or an SST, depending on how long it was desynchronized. This is similar to cluster desynchronization, which occurs during RSU TOI. Because of this, it's not a good idea to enable wsrep_desync for a long period of time or for several nodes at once.

Note: You can also desync a node using the /*! WSREP_DESYNC */ query comment.

variable wsrep_dirty_reads

Command Line --wsrep-dirty-reads

Config File Yes

Scope Session, Global

Dynamic Yes

Default Value OFF

Defines whether the node accepts read queries when in a non-operational state, that is, when it loses connection to the Primary Component. By default, this variable is disabled and the node rejects all queries, because there is no way to tell if the data is correct.

If you enable this variable, the node will permit read queries (USE, SELECT, LOCK TABLE, and UNLOCK TABLES), but any command that modifies or updates the database on a non-operational node will still be rejected (including DDL and DML statements, such as INSERT, DELETE, and UPDATE).

To avoid deadlock errors, set the *wsrep_sync_wait* variable to 0 if you enable wsrep_dirty_reads.

variable wsrep_drupal_282555_workaround

Version Info

- ***5.7.24-31.33*** – Variable deprecated

Command Line --wsrep-drupal-282555-workaround

Config File Yes

Scope Global

Dynamic Yes

Default Value OFF

Enables a workaround for MySQL InnoDB bug that affects Drupal (Drupal bug #282555 and MySQL bug #41984). In some cases, duplicate key errors would occur when inserting the DEFAULT value into an AUTO_INCREMENT column.

variable wsrep_forced_binlog_format

Version Info

- ***5.7.22-29.26*** – Variable deprecated

Command Line --wsrep-forced-binlog-format

Config File Yes

Scope Global

Dynamic Yes

Default Value NONE

Defines a binary log format that will always be effective, regardless of the client session binlog_format variable value.

Possible values for this variable are:

- ROW: Force row-based logging format
- STATEMENT: Force statement-based logging format
- MIXED: Force mixed logging format
- NONE: Do not force the binary log format and use whatever is set by the binlog_format variable (default)

variable wsrep_load_data_splitting

Command Line --wsrep-load-data-splitting

Config File Yes

Scope Global

Dynamic Yes

Default Value ON

Defines whether the node should split large LOAD DATA transactions. This variable is enabled by default, meaning that LOAD DATA commands are split into transactions of 10 000 rows or less.

If you disable this variable, then huge data loads may prevent the node from completely rolling the operation back in the event of a conflict, and whatever gets committed stays committed.

Note: It doesn't work as expected with autocommit=0 when enabled.

---

variable wsrep_log_conflicts

Command Line --wsrep-log-conflicts

Config File Yes

Scope Global

Dynamic No

Default Value OFF

Defines whether the node should log additional information about conflicts. By default, this variable is disabled and Percona XtraDB Cluster uses standard logging features in MySQL.

If you enable this variable, it will also log table and schema where the conflict occurred, as well as the actual values for keys that produced the conflict.

variable wsrep_max_ws_rows

Command Line --wsrep-max-ws-rows

Config File Yes

Scope Global

Dynamic Yes

Default Value 0 (no limit)

Defines the maximum number of rows each write-set can contain.

By default, there is no limit for the maximum number of rows in a write-set. The maximum allowed value is 1048576.

variable wsrep_max_ws_size

Command Line --wsrep_max_ws_size

Config File Yes

Scope Global

Dynamic Yes

Default Value 2147483647 (2 GB)

Defines the maximum write-set size (in bytes). Anything bigger than the specified value will be rejected.

You can set it to any value between 1024 and the default 2147483647.

variable wsrep_node_address

Command Line --wsrep-node-address

Config File Yes

Scope Global

Dynamic No

Default Value IP of the first network interface (eth0) and default port (4567)

Specifies the network address of the node. By default, this variable is set to the IP address of the first network interface (usually eth0 or enp2s0) and the default port (4567).

While default value should be correct in most cases, there are situations when you need to specify it manually. For example:

- 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 Docker
- Cloud deployments, such as Amazon EC2 (use the global DNS name instead of the local IP address)

The value should be specified in the following format:

```
<ip_address>[:port]
```

Note: The value of this variable is also used as the default value for the *wsrep_sst_receive_address* variable and the *ist.recv_addr* option.

variable wsrep_node_incoming_address

Command Line --wsrep-node-incoming-address

Config File Yes

Scope Global

Dynamic No

Default Value `AUTO`

Specifies the network address from which the node expects client connections. By default, it uses the IP address from *wsrep_node_address* and port number 3306.

This information is used for the *wsrep_incoming_addresses* variable which shows all active cluster nodes.

variable wsrep_node_name

Command Line `--wsrep-node-name`

Config File Yes

Scope Global

Dynamic Yes

Default Value The node's host name

Defines a unique name for the node. Defaults to the host name.

The name is used for convenience, to help you identify nodes in the cluster by means other than the node address.

variable wsrep_notify_cmd

Command Line `--wsrep-notify-cmd`

Config File Yes

Scope Global

Dynamic Yes

Specifies the notification command that the node should execute whenever cluster membership or local node status changes. This can be used for alerting or to reconfigure load balancers.

Note: The node will block and wait until the command or script completes and returns before it can proceed. If the script performs any potentially blocking or long-running operations, such as network communication, you should consider initiating such operations in the background and have the script return immediately.

---

variable wsrep_on

Version Info

- **5.6.27-25.13** – Variable available only in session scope

Command Line No

Config File No

Scope Session

Dynamic Yes

Default Value `ON`

Defines whether updates from the current session should be replicated. If disabled, it does not cause the node to leave the cluster and the node continues to communicate with other nodes.

variable wsrep_OSU_method

Command Line `--wsrep-OSU-method`

Config File Yes

Scope Global and Session

Dynamic Yes

Default Value `TOI`

Defines the method for Online Schema Upgrade that the node uses to replicate DDL statements. The following methods are available:

- `TOI`: When the *Total Order Isolation* method is selected, data definition language (DDL) statements are processed in the same order with regards to other transactions in each node. This guarantees data consistency.

  In the case of DDL statements, the cluster will have parts of the database locked and it will behave like a single server. In some cases (like big `ALTER TABLE`) this could have impact on cluster's performance and availability, but it could be fine for quick changes that happen almost instantly (like fast index changes).

  When DDL statements are processed under TOI, the DDL statement will be replicated up front to the cluster. That is, the cluster will assign global transaction ID for the DDL statement before DDL processing begins. Then every node in the cluster has the responsibility to execute the DDL statement in the given slot in the sequence of incoming transactions, and this DDL execution has to happen with high priority.

- `RSU`: When the *Rolling Schema Upgrade* method is selected, DDL statements won't be replicated across the cluster. Instead, it's up to the user to run them on each node separately.

  The node applying the changes will desynchronize from the cluster briefly, while normal work happens on all the other nodes. When a DDL statement is processed, the node will apply delayed replication events.

  The schema changes must be backwards compatible for this method to work, otherwise, the node that receives the change will likely break Galera replication. If replication breaks, SST will be triggered when the node tries to join again but the change will be undone.

Note: This variable's behavior is consistent with MySQL behavior for variables that have both global and session scope. This means if you want to change the variable in current session, you need to do it with `SET wsrep_OSU_method` (without the `GLOBAL` keyword). Setting the variable with `SET GLOBAL wsrep_OSU_method` will change the variable globally but it won't have effect on the current session.

---

variable `wsrep_preordered`

Version Info

- ***`5.7.24-31.33`*** – Variable deprecated

Command Line `--wsrep-preordered`

Config File Yes

Scope Global

Dynamic Yes

Default Value `OFF`

Defines whether the node should use transparent handling of preordered replication events (like replication from traditional master). By default, this is disabled.

If you enable this variable, such events will be applied locally first before being replicated to other nodes in 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.

variable `wsrep_provider`

Command Line `--wsrep-provider`

Config File Yes

Scope Global

Dynamic Yes

Specifies the path to the Galera library. This is usually `/usr/lib64/libgalera_smm.so` on *CentOS/RHEL* and `/usr/lib/libgalera_smm.so` on *Debian/Ubuntu*.

If you do not specify a path or the value is not valid, the node will behave as standalone instance of MySQL.

variable `wsrep_provider_options`

Command Line `--wsrep-provider-options`

Config File Yes

Scope Global

Dynamic No

Specifies optional settings for the replication provider documented in *Index of wsrep_provider options*. These options affect how various situations are handled during replication.

variable `wsrep_recover`

Command Line `--wsrep-recover`

Config File Yes

Scope Global

Dynamic No

Default Value `OFF`

Location mysqld_safe

Recovers database state after crash by parsing GTID from the log. If the GTID is found, it will be assigned as the initial position for server.

variable `wsrep_reject_queries`

Command Line No

Config File Yes

Scope Global

Dynamic Yes

Default Value `NONE`

Defines whether the node should reject queries from clients. Rejecting queries can be useful during upgrades, when you want to keep the node up and apply write-sets without accepting queries.

When a query is rejected, the following error is returned:

```
Error 1047: Unknown command
```

The following values are available:

- `NONE`: Accept all queries from clients (default)
- `ALL`: Reject all new queries from clients, but maintain existing client connections
- `ALL_KILL`: Reject all new queries from clients and kill existing client connections

Note: This variable doesn't affect Galera replication in any way, only the applications that connect to the database are affected. If you want to desync a node, use *wsrep_desync*.

variable wsrep_replicate_myisam

Command Line `--wsrep-replicate-myisam`

Config File Yes

Scope Session, Global

Dynamic No

Default Value `OFF`

Defines whether DML statements for MyISAM tables should be replicated. It is disabled by default, because MyISAM replication is still experimental.

On the global level, *wsrep_replicate_myisam* can be set only during startup. On session level, you can change it during runtime as well.

For older nodes in the cluster, *wsrep_replicate_myisam* should work since the TOI decision (for MyISAM DDL) is done on origin node. Mixing of non-MyISAM and MyISAM tables in the same DDL statement is not recommended when *wsrep_replicate_myisam* is disabled, since if any table in the list is MyISAM, the whole DDL statement is not put under TOI.

Note: You should keep in mind the following when using MyISAM replication:

- DDL (CREATE/DROP/TRUNCATE) statements on MyISAM will be replicated irrespective of `wsrep_replicate_miysam` value
- DML (INSERT/UPDATE/DELETE) statements on MyISAM will be replicated only if *wsrep_replicate_myisam* is enabled
- SST will get full transfer irrespective of *wsrep_replicate_myisam* value (it will get MyISAM tables from donor)
- Difference in configuration of `pxc-cluster` node on enforce_storage_engine front may result in picking up different engine for the same table on different nodes
- `CREATE TABLE AS SELECT` (CTAS) statements use non-TOI replication and are replicated only if there is involvement of InnoDB table that needs transactions (in case of MyISAM table, CTAS statements will not be replicated).

variable wsrep_restart_slave

Command Line `--wsrep-restart-slave`

Config File Yes

Scope Global

Dynamic Yes

Default Value `OFF`

Defines whether replication slave should be restarted when the node joins back to the cluster. Enabling this can be useful because asynchronous replication slave thread is stopped when the node tries to apply the next replication event while the node is in non-primary state.

variable wsrep_retry_autocommit

Command Line `--wsrep-retry-autocommit`

Config File Yes

Scope Global

Dynamic No

Default Value `1`

Specifies the number of times autocommit transactions will be retried in the cluster if it encounters certification errors. In case there is a conflict, it should be safe for the cluster node to simply retry the statement without returning an error to the client, hoping that it will pass next time.

This can be useful to help an application using autocommit to avoid deadlock errors that can be triggered by replication conflicts.

If this variable is set to `0`, autocommit transactions won't be retried.

variable `wsrep_RSU_commit_timeout`

Command Line `--wsrep-RSU-commit-timeout`

Config File Yes

Scope Global

Dynamic Yes

Default Value `5000`

Range From `5000` (5 millisecons) to `31536000000000` (365 days)

Specifies the timeout in microseconds to allow active connection to complete COMMIT action before starting RSU.

While running RSU it is expected that user has isolated the node and there is no active traffic executing on the node. RSU has a check to ensure this, and waits for any active connection in `COMMIT` state before starting RSU.

By default this check has timeout of 5 millisecons, but in some cases COMMIT is taking longer. This variable sets the timeout, and has allowed values from the range of (5 millisecons, 365 days). The value is to be set in microseconds. Unit of variable is in micro-secs so set accordingly.

Note: RSU operation will not auto-stop node from receiving active traffic. So there could be a continuous flow of active traffic while RSU continues to wait, and that can result in RSU starvation. User is expected to block active RSU traffic while performing operation.

---

variable `wsrep_slave_FK_checks`

Command Line `--wsrep-slave-FK-checks`

Config File Yes

Scope Global

Dynamic Yes

Default Value `ON`

Defines whether foreign key checking is done for applier threads. This is enabled by default.

variable `wsrep_slave_threads`

Command Line `--wsrep-slave-threads`

Config File Yes

Scope Global

Dynamic Yes

Default Value `1`

Specifies the number of threads that can apply replication transactions in parallel. Galera supports true parallel replication that applies transactions in parallel only when it is safe to do so. This variable is dynamic. You can increase/decrease it at any time.

Note: When you decrease the number of threads, it won't kill the threads immediately, but stop them after they are done applying current transaction (the effect with an increase is immediate though).

If any replication consistency problems are encountered, it's recommended to set this back to `1` to see if that resolves the issue. The default value can be increased for better throughput.

You may want to increase it as suggested in Codership documentation for flow control: when the node is in `JOINED` state, increasing the number of slave threads can speed up the catchup to `SYNCED`.

You can also estimate the optimal value for this from *`wsrep_cert_deps_distance`* as suggested on this page.

For more configuration tips, see this document.

variable `wsrep_slave_UK_checks`

Command Line `--wsrep-slave-UK-checks`

Config File Yes

Scope Global

Dynamic Yes

Default Value `OFF`

Defines whether unique key checking is done for applier threads. This is disabled by default.

variable `wsrep_sst_auth`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Format <username>:<password>

Specifies authentication information for State Snapshot Transfer (SST). Required information depends on the method specified in the *`wsrep_sst_method`* variable.

For more information about SST authentication, see *State Snapshot Transfer*.

Note: Value of this variable is masked in the log and in the `SHOW VARIABLES` query output.

---

variable `wsrep_sst_donor`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Specifies a list of nodes (using their *wsrep_node_name* values) that the current node should prefer as donors for SST and IST. If the value is empty, the first node in SYNCED state in the index becomes the donor and will not be able to serve requests during state transfer.

If you want to consider other nodes when listed ones are not available, add a comma at the end of the list, for example:

```
wsrep_sst_donor=node1,node2,
```

If you remove the trailing comma from the previous example, then the joining node will consider *only* `node1` and `node2`.

Note: By default, the joiner node does not wait for more than 100 seconds to receive the first packet from a donor. This is implemented via the *sst-initial-timeout* option. If you set the list of preferred donors without a terminating comma or believe that all nodes in the cluster can often be unavailable for SST (this is common for small clusters), then you may want to increase the initial timeout (or disable it completely if you don't mind joiner node waiting for state transfer indefinitely).

---

variable `wsrep_sst_donor_rejects_queries`

Command Line `--wsrep-sst-donor-rejects-queries`

Config File Yes

Scope Global

Dynamic Yes

Default Value OFF

Defines whether the node should reject blocking client sessions when it is serving as a donor during a blocking state transfer method (when *wsrep_sst_method* is set to `mysqldump` or `rsync`). This is disabled by default, meaning that the node accepts such queries.

If you enable this variable, queries will return the `Unknown command` error. This can be used to signal load-balancer that the node isn't available.

variable `wsrep_sst_method`

Command Line `--wsrep-sst-method`

Config File Yes

Scope Global

Dynamic Yes

Default Value xtrabackup-v2

Defines the method or script for *State Snapshot Transfer* (SST).

Available values are:

- `xtrabackup-v2`: Uses *Percona XtraBackup* to perform SST. This method requires *wsrep_sst_auth* to be set up with credentials (`<user>:<password>`) on the donor node. Privileges and perimssions for running *Percona XtraBackup* can be found in Percona XtraBackup documentation.

  This is the **recommended** and default method for Percona XtraDB Cluster. For more information, see *Percona XtraBackup SST Configuration*.

- `rsync`: Uses `rsync` to perform SST. This method doesn't use the *wsrep_sst_auth* variable.

- `mysqldump`: Uses `mysqldump` to perform SST This method requires superuser credentials for the donor node to be specified in the *`wsrep_sst_auth`* variable.

  Note: This method is deprecated as of *`5.7.22-29.26`* and not recommended unless it is required for specific reasons. Also, it is not compatible with `bind_address` set to `127.0.0.1` or `localhost`, and will cause startup to fail in this case.

- `<custom_script_name>`: Galera supports Scriptable State Snapshot Transfer. This enables users to create their own custom scripts for performing SST. For example, you can create a script `/usr/bin/wsrep_MySST.sh` and specify `MySST` for this variable to run your custom SST script.
- `skip`: Use this to skip SST. This can be used when initially starting the cluster and manually restoring the same data to all nodes. It shouldn't be used permanently because it could lead to data inconsistency across the nodes.

Note: Only `xtrabackup-v2` and `rsync` provide support for clusters with GTIDs and async slaves.

variable `wsrep_sst_receive_address`

Command Line `--wsrep-sst-receive-address`

Config File Yes

Scope Global

Dynamic Yes

Default Value `AUTO`

Specifies the network address where donor node should send state transfers. By default, this variable is set to `AUTO`, meaning that the IP address from *`wsrep_node_address`* is used.

variable `wsrep_start_position`

Command Line `--wsrep-start-position`

Config File Yes

Scope Global

Dynamic Yes

Default Value `00000000-0000-0000-0000-000000000000:-1`

Specifies the node's start position as `UUID:seqno`. By setting all the nodes to have the same value for this variable, the cluster can be set up without the state transfer.

variable `wsrep_sync_wait`

Version Info

- **`5.6.20-25.7`** – Variable introduced

Command Line `--wsrep-sync-wait`

Config File Yes

Scope Session

Dynamic Yes

Default Value `0`

Controls cluster-wide causality checks on certain statements. Checks ensure that the statement is executed on a node that is fully synced with the cluster.

Note: Causality checks of any type can result in increased latency.

The type of statements to undergo checks is determined by bitmask:

- `0`: Do not run causality checks for any statements. This is the default.
- `1`: Perform checks for `READ` statements (including `SELECT`, `SHOW`, and `BEGIN` or `START TRANSACTION`).
- `2`: Perform checks for `UPDATE` and `DELETE` statements.
- `3`: Perform checks for `READ`, `UPDATE`, and `DELETE` statements.
- `4`: Perform checks for `INSERT` and `REPLACE` statements.
- `5`: Perform checks for `READ`, `INSERT`, and `REPLACE` statements.
- `6`: Perform checks for `UPDATE`, `DELETE`, `INSERT`, and `REPLACE` statements.
- `7`: Perform checks for `READ`, `UPDATE`, `DELETE`, `INSERT`, and `REPLACE` statements.

Note: Setting *wsrep_sync_wait* to `1` is the equivalent of setting the deprecated *wsrep_causal_reads* to `ON`.

CHAPTER

FORTYONE

INDEX OF `WSREP_PROVIDER` OPTIONS

The following variables can be set and checked in the *wsrep_provider_options* variable. The value of the variable can be changed in the *MySQL* configuration file, `my.cnf`, or by setting the variable value in the *MySQL* client.

To change the value in `my.cnf`, the following syntax should be used:

```
wsrep_provider_options="variable1=value1;[variable2=value2]"
```

For example to set the size of the Galera buffer storage to 512 MB, specify the following in `my.cnf`:

```
wsrep_provider_options="gcache.size=512M"
```

Dynamic variables can be changed from the *MySQL* client using the `SET GLOBAL` command. For example, to change the value of the *pc.ignore_sb*, use the following command:

```
mysql> SET GLOBAL wsrep_provider_options="pc.ignore_sb=true";
```

Index

variable `base_dir`

> **Command Line** Yes
>
> **Config File** Yes
>
> **Scope** Global
>
> **Dynamic** No
>
> **Default Value** value of `datadir`

This variable specifies the data directory.

variable `base_host`

> **Command Line** Yes
>
> **Config File** Yes
>
> **Scope** Global
>
> **Dynamic** No
>
> **Default Value** value of *wsrep_node_address*

This variable sets the value of the node's base IP. This is an IP address on which Galera listens for connections from other nodes. Setting this value incorrectly would stop the node from communicating with other nodes.

variable `base_port`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 4567

This variable sets the port on which Galera listens for connections from other nodes. Setting this value incorrectly would stop the node from communicating with other nodes.

variable `cert.log_conflicts`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value no

This variable is used to specify if the details of the certification failures should be logged.

variable `debug`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value no

When this variable is set to `yes`, it will enable debugging.

variable `evs.auto_evict`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value 0

Number of entries allowed on delayed list until auto eviction takes place. Setting value to `0` disables auto eviction protocol on the node, though node response times will still be monitored. EVS protocol version (*`evs.version`*) `1` is required to enable auto eviction.

variable `evs.causal_keepalive_period`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value value of *`evs.keepalive_period`*

This variable is used for development purposes and shouldn't be used by regular users.

variable `evs.debug_log_mask`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value 0x1

This variable is used for EVS (Extended Virtual Synchrony) debugging. It can be used only when *`wsrep_debug`* is set to `ON`.

variable `evs.delay_margin`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value PT1S

Time period that a node can delay its response from expected until it is added to delayed list. The value must be higher than the highest RTT between nodes.

variable `evs.delayed_keep_period`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value PT30S

Time period that node is required to remain responsive until one entry is removed from delayed list.

variable `evs.evict`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Manual eviction can be triggered by setting the *`evs.evict`* to a certain node value. Setting the *`evs.evict`* to an empty string will clear the evict list on the node where it was set.

variable `evs.inactive_check_period`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value PT0.5S

This variable defines how often to check for peer inactivity.

variable `evs.inactive_timeout`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value PT15S

This variable defines the inactivity limit, once this limit is reached the node will be considered dead.

variable `evs.info_log_mask`

Command Line No

Config File Yes

Scope Global

Dynamic No

Default Value 0

This variable is used for controlling the extra EVS info logging.

variable `evs.install_timeout`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value PT7.5S

This variable defines the timeout on waiting for install message acknowledgments.

variable `evs.join_retrans_period`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value PT1S

This variable defines how often to retransmit EVS join messages when forming cluster membership.

variable `evs.keepalive_period`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value PT1S

This variable defines how often to emit keepalive beacons (in the absence of any other traffic).

variable `evs.max_install_timeouts`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 1

This variable defines how many membership install rounds to try before giving up (total rounds will be *evs.max_install_timeouts* + 2).

variable `evs.send_window`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 4

This variable defines the maximum number of data packets in replication at a time. For WAN setups, the variable can be set to a considerably higher value than default (for example,512). The value must not be less than *evs.user_send_window*.

variable `evs.stats_report_period`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value PT1M

This variable defines the control period of EVS statistics reporting.

variable `evs.suspect_timeout`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value PT5S

This variable defines the inactivity period after which the node is "suspected" to be dead. If all remaining nodes agree on that, the node will be dropped out of cluster even before *evs.inactive_timeout* is reached.

variable `evs.use_aggregate`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value true

When this variable is enabled, smaller packets will be aggregated into one.

variable `evs.user_send_window`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value 2

This variable defines the maximum number of data packets in replication at a time. For WAN setups, the variable can be set to a considerably higher value than default (for example, 512).

variable `evs.version`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 0

This variable defines the EVS protocol version. Auto eviction is enabled when this variable is set to `1`. Default `0` is set for backwards compatibility.

variable `evs.view_forget_timeout`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value P1D

This variable defines the timeout after which past views will be dropped from history.

variable `gcache.dir`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value *datadir*

This variable can be used to define the location of the `galera.cache` file.

variable `gcache.keep_pages_count`

Command Line Yes

Config File Yes

Scope Local, Global

Dynamic Yes

Default Value 0

This variable is used to limit the number of overflow pages rather than the total memory occupied by all overflow pages. Whenever `gcache.keep_pages_count` is set to a non-zero value, excess overflow pages will be deleted (starting from the oldest to the newest).

Whenever either the `gcache.keep_pages_count` or the *gcache.keep_pages_size* variable is updated at runtime to a non-zero value, cleanup is called on excess overflow pages to delete them.

variable `gcache.keep_pages_size`

Command Line Yes

Config File Yes

Scope Local, Global

Dynamic No

Default Value 0

This variable is used to limit the total size of overflow pages rather than the count of all overflow pages. Whenever `gcache.keep_pages_size` is set to a non-zero value, excess overflow pages will be deleted (starting from the oldest to the newest) until the total size is below the specified value.

Whenever either the *gcache.keep_pages_count* or the `gcache.keep_pages_size` variable is updated at runtime to a non-zero value, cleanup is called on excess overflow pages to delete them.

variable `gcache.mem_size`

Version Deprecated in `5.6.22-25.8`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 0

This variable was used to define how much RAM is available for the system.

Warning: This variable has been deprecated and shouldn't be used as it could cause a node to crash.

variable `gcache.name`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value /var/lib/mysql/galera.cache

This variable can be used to specify the name of the Galera cache file.

variable `gcache.page_size`

Command Line No

Config File Yes

Scope Global

Dynamic No

Default Value 128M

This variable can be used to specify the size of the page files in the page storage.

variable `gcache.size`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 128M

Size of the transaction cache for Galera replication. This defines the size of the `galera.cache` file which is used as source for *IST*. The bigger the value of this variable, the better are chances that the re-joining node will get IST instead of *SST*.

variable `gcs.fc_debug`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 0

This variable specifies after how many writesets the debug statistics about SST flow control will be posted.

variable `gcs.fc_factor`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value 1

This variable is used for replication flow control. Replication is resumed when the slave queue drops below *`gcs.fc_factor`* * *`gcs.fc_limit`*.

variable `gcs.fc_limit`

Version *`5.7.17-29.20`*: Default value changed from `16` to `100`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value 100

This variable is used for replication flow control. Replication is paused when the slave queue exceeds this limit. In the default operation mode, flow control limit is dynamically recalculated based on the amount of nodes in the cluster, but this recalculation can be turned off with use of the *`gcs.fc_master_slave`* variable to make manual setting of the

gcs.fc_limit having an effect (e.g. for configurations when writing is done to a single node in Percona XtraDB Cluster).

variable gcs.fc_master_slave

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value NO

This variable is used to specify if there is only one master node in the cluster. It affects whether flow control limit is recalculated dynamically (when `NO`) or not (when `YES`).

variable gcs.max_packet_size

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 64500

This variable is used to specify the writeset size after which they will be fragmented.

variable gcs.max_throttle

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 0.25

This variable specifies how much the replication can be throttled during the state transfer in order to avoid running out of memory. Value can be set to `0.0` if stopping replication is acceptable in order to finish state transfer.

variable gcs.recv_q_hard_limit

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 9223372036854775807

This variable specifies the maximum allowed size of the receive queue. This should normally be `(RAM + swap) / 2`. If this limit is exceeded, Galera will abort the server.

variable gcs.recv_q_soft_limit

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 0.25

This variable specifies the fraction of the *gcs.recv_q_hard_limit* after which replication rate will be throttled.

variable gcs.sync_donor

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value No

This variable controls if the rest of the cluster should be in sync with the donor node. When this variable is set to YES, the whole cluster will be blocked if the donor node is blocked with SST.

variable gmcast.listen_addr

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value tcp://0.0.0.0:4567

This variable defines the address on which the node listens to connections from other nodes in the cluster.

variable gmcast.mcast_addr

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value None

This variable should be set up if UDP multicast should be used for replication.

variable gmcast.mcast_ttl

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 1

This variable can be used to define TTL for multicast packets.

variable gmcast.peer_timeout

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value PT3S

This variable specifies the connection timeout to initiate message relaying.

variable `gmcast.segment`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 0

This variable specifies the group segment this member should be a part of. Same segment members are treated as equally physically close.

variable `gmcast.time_wait`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value PT5S

This variable specifies the time to wait until allowing peer declared outside of stable view to reconnect.

variable `gmcast.version`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 0

This variable shows which gmcast protocol version is being used.

variable `ist.recv_addr`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value value of *`wsrep_node_address`*

This variable specifies the address on which the node listens for Incremental State Transfer (*IST*).

variable `pc.announce_timeout`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value PT3S

Cluster joining announcements are sent every 1/2 second for this period of time or less if other nodes are discovered.

variable `pc.checksum`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value true

This variable controls whether replicated messages should be checksummed or not.

variable `pc.ignore_quorum`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value false

When this variable is set to `TRUE`, the node will completely ignore quorum calculations. This should be used with extreme caution even in master-slave setups, because slaves won't automatically reconnect to master in this case.

variable `pc.ignore_sb`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value false

When this variable is set to `TRUE`, the node will process updates even in the case of a split brain. This should be used with extreme caution in multi-master setup, but should simplify things in master-slave cluster (especially if only 2 nodes are used).

variable `pc.linger`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value PT20S

This variable specifies the period for which the PC protocol waits for EVS termination.

variable `pc.npvo`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value false

When this variable is set to `TRUE`, more recent primary components override older ones in case of conflicting primaries.

variable `pc.recovery`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value true

When this variable is set to `true`, the node stores the Primary Component state to disk. The Primary Component can then recover automatically when all nodes that were part of the last saved state re-establish communication with each other. This feature allows automatic recovery from full cluster crashes, such as in the case of a data center power outage. A subsequent graceful full cluster restart will require explicit bootstrapping for a new Primary Component.

variable `pc.version`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 0

This status variable is used to check which PC protocol version is used.

variable `pc.wait_prim`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value true

When set to `TRUE`, the node waits for a primary component for the period of time specified in *`pc.wait_prim_timeout`*. This is useful to bring up a non-primary component and make it primary with `pc.bootstrap`.

variable `pc.wait_prim_timeout`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value PT30S

This variable is used to specify the period of time to wait for a primary component.

variable `pc.weight`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value 1

This variable specifies the node weight that's going to be used for Weighted Quorum calculations.

variable `protonet.backend`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value asio

This variable is used to define which transport backend should be used. Currently only `ASIO` is supported.

variable `protonet.version`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 0

This status variable is used to check which transport backend protocol version is used.

variable `repl.causal_read_timeout`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value PT30S

This variable specifies the causal read timeout.

variable `repl.commit_order`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 3

This variable is used to specify out-of-order committing (which is used to improve parallel applying performance). The following values are available:

- `0` - BYPASS: all commit order monitoring is turned off (useful for measuring performance penalty)
- `1` - OOOC: allow out-of-order committing for all transactions
- `2` - LOCAL_OOOC: allow out-of-order committing only for local transactions
- `3` - NO_OOOC: no out-of-order committing is allowed (strict total order committing)

variable `repl.key_format`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value FLAT8

This variable is used to specify the replication key format. The following values are available:

- `FLAT8` - short key with higher probability of key match false positives
- `FLAT16` - longer key with lower probability of false positives
- `FLAT8A` - same as `FLAT8` but with annotations for debug purposes
- `FLAT16A` - same as `FLAT16` but with annotations for debug purposes

variable `repl.max_ws_size`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 2147483647

This variable is used to specify the maximum size of a write-set in bytes. This is limited to 2 gygabytes.

variable `repl.proto_max`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 7

This variable is used to specify the highest communication protocol version to accept in the cluster. Used only for debugging.

variable `socket.checksum`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 2

This variable is used to choose the checksum algorithm for network packets. The following values are available:

- `0` - disable checksum
- `1` - plain `CRC32` (used in Galera 2.x)
- `2` - hardware accelerated `CRC32-C`

variable `socket.ssl`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value No

This variable is used to specify if SSL encryption should be used.

variable `socket.ssl_ca`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

This variable is used to specify the path to the Certificate Authority (CA) certificate file.

variable `socket.ssl_cert`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

This variable is used to specify the path to the server's certificate file (in PEM format).

variable `socket.ssl_key`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

This variable is used to specify the path to the server's private key file (in PEM format).

variable `socket.ssl_compression`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value yes

This variable is used to specify if the SSL compression is to be used.

variable `socket.ssl_cipher`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value AES128-SHA

This variable is used to specify what cypher will be used for encryption.

CHAPTER

FORTYTWO

INDEX OF FILES CREATED BY PXC

- **`GRA_*.log`** These files contain binlog events in ROW format representing the failed transaction. That means that the slave thread was not able to apply one of the transactions. For each of those file, a corresponding warning or error message is present in the mysql error log file. Those error can also be false positives like a bad `DDL` statement (dropping a table that doesn't exists for example) and therefore nothing to worry about. However it's always recommended to check these log to understand what's is happening.

  To be able to analyze these files binlog header needs to be added to the log file. To create the `GRA_HEADER` file you need an instance running with `binlog_checksum` set to `NONE` and extract first 120 bytes from the binlog file:

```
$ head -c 123 mysqld-bin.000001 > GRA_HEADER
$ cat GRA_HEADER > /var/lib/mysql/GRA_1_2-bin.log
$ cat /var/lib/mysql/GRA_1_2.log >> /var/lib/mysql/GRA_1_2-bin.log
$ mysqlbinlog -vvv /var/lib/mysql/GRA_1_2-bin.log

/*!50530 SET @@SESSION.PSEUDO_SLAVE_MODE=1*/;
/*!50003 SET @OLD_COMPLETION_TYPE=@@COMPLETION_TYPE,COMPLETION_TYPE=0*/;
DELIMITER /*!*/;
# at 4
#160809  16:04:05 server id 3  end_log_pos 123     Start: binlog v 4, server␣
↪v 5.7.12-5rc1-log created 160809 16:04:05 at startup
# Warning: this binlog is either in use or was not closed properly.
ROLLBACK/*!*/;
BINLOG '
nbGpVw8DAAAAdwAAAHsAAAABAAQANS43LjEyLTVyYzEtbG9nAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAACdsalXEzgNAAgAEgAEBAQEEgAAXwAEGggAAAAICAgCAAAACgoKKioAEjQA
ALfQ8hw=
'/*!*/;
# at 123
#160809  16:05:49 server id 2  end_log_pos 75     Query    thread_id=11    ␣
↪exec_time=0    error_code=0
use `test`/*!*/;
SET TIMESTAMP=1470738949/*!*/;
SET @@session.pseudo_thread_id=11/*!*/;
SET @@session.foreign_key_checks=1, @@session.sql_auto_is_null=0, @@session.
↪unique_checks=1, @@session.autocommit=1/*!*/;
SET @@session.sql_mode=1436549152/*!*/;
SET @@session.auto_increment_increment=1, @@session.auto_increment_offset=1/*!
↪*/;
/*!\C utf8 *//*!*/;
SET @@session.character_set_client=33,@@session.collation_connection=33,
↪@@session.collation_server=8/*!*/;
SET @@session.lc_time_names=0/*!*/;
SET @@session.collation_database=DEFAULT/*!*/;
```

```
drop table t
/*!*/;
SET @@SESSION.GTID_NEXT= 'AUTOMATIC' /* added by mysqlbinlog */ /*!*/;
DELIMITER ;
# End of log file
/*!50003 SET COMPLETION_TYPE=@OLD_COMPLETION_TYPE*/;
/*!50530 SET @@SESSION.PSEUDO_SLAVE_MODE=0*/;
```

This information can be used for checking the *MySQL* error log for the corresponding error message.

```
160805  9:33:37 8:52:21 [ERROR] Slave SQL: Error 'Unknown table 'test'' on␣
↪query. Default database: 'test'. Query: 'drop table test', Error_code: 1051
160805  9:33:37 8:52:21 [Warning] WSREP: RBR event 1 Query apply warning: 1, 3
```

In this example `DROP TABLE` statement was executed on a table that doesn't exist.

- **`galera.cache`** This file is used as a main writeset store. It's implemented as a permanent ring-buffer file that is preallocated on disk when the node is initialized. File size can be controlled with the variable *`gcache.size`*. If this value is bigger, more writesets are cached and chances are better that the re-joining node will get *IST* instead of *SST*. Filename can be changed with the *`gcache.name`* variable.
- **`grastate.dat`** This file contains the Galera state information.
  - `version` - grastate version
  - `uuid` - a unique identifier for the state and the sequence of changes it undergoes.For more information on how UUID is generated see *UUID*.
  - `seqno` - Ordinal Sequence Number, a 64-bit signed integer used to denote the position of the change in the sequence. `seqno` is `0` when no writesets have been generated or applied on that node, i.e., not applied/generated across the lifetime of a `grastate` file. `-1` is a special value for the `seqno` that is kept in the `grastate.dat` while the server is running to allow Galera to distinguish between a clean and an unclean shutdown. Upon a clean shutdown, the correct `seqno` value is written to the file. So, when the server is brought back up, if the value is still `-1` , this means that the server did not shut down cleanly. If the value is greater than `0`, this means that the shutdown was clean. `-1` is then written again to the file in order to allow the server to correctly detect if the next shutdown was clean in the same manner.
  - `cert_index` - cert index restore through grastate is not implemented yet

  Examples of this file look like this:

  In case server node has this state when not running it means that that node crashed during the transaction processing.

```
# GALERA saved state
version: 2.1
uuid:    1917033b-7081-11e2-0800-707f5d3b106b
seqno:   -1
cert_index:
```

In case server node has this state when not running it means that the node was gracefully shut down.

```
# GALERA saved state
version: 2.1
uuid:    1917033b-7081-11e2-0800-707f5d3b106b
seqno:   5192193423942
cert_index:
```

In case server node has this state when not running it means that the node crashed during the DDL.

```
# GALERA saved state
version: 2.1
uuid:    00000000-0000-0000-0000-000000000000
seqno:   -1
cert_index:
```

- `gvwstate.dat` This file is used for Primary Component recovery feature. This file is created once primary component is formed or changed, so you can get the latest primary component this node was in. And this file is deleted when the node is shutdown gracefully.

  First part contains the node *UUID* information. Second part contains the view information. View information is written between `#vwbeg` and `#vwend`. View information consists of:

- view_id: [view_type] [view_uuid] [view_seq]. - `view_type` is always `3` which means primary view. `view_uuid` and `view_seq` identifies a unique view, which could be perceived as identifier of this primary component.
- bootstrap: [bootstarp_or_not]. - It could be `0` or `1`, but it does not affect primary component recovery process now.
- member: [node's uuid] [node's segment]. - it represents all nodes in this primary component.

  Example of this file looks like this:

```
my_uuid: c5d5d990-30ee-11e4-aab1-46d0ed84b408
#vwbeg
view_id: 3 bc85bd53-31ac-11e4-9895-1f2ce13f2542 2
bootstrap: 0
member: bc85bd53-31ac-11e4-9895-1f2ce13f2542 0
member: c5d5d990-30ee-11e4-aab1-46d0ed84b408 0
#vwend
```

CHAPTER

FORTYTHREE

FREQUENTLY ASKED QUESTIONS

How do I report bugs?

All bugs can be reported on JIRA. Please submit `error.log` files from **all** the nodes.

How do I solve locking issues like auto-increment?

For auto-increment, Percona XtraDB Cluster changes `auto_increment_offset` for each new node. In a single-node workload, locking is handled in the same way as *InnoDB*. In case of write load on several nodes, Percona XtraDB Cluster uses optimistic locking and the application may receive lock error in response to `COMMIT` query.

What if a node crashes and InnoDB recovery rolls back some transactions?

When a node crashes, after restarting, it will copy the whole dataset from another node (if there were changes to data since the crash).

How can I check the Galera node health?

To check the health of a Galera node, use the following query:

```
SELECT 1 FROM dual;
```

The following results of the previous query are possible:

- You get the row with `id=1` (node is healthy)
- Unknown error (node is online, but Galera is not connected/synced with the cluster)
- Connection error (node is not online)

You can also check a node's health with the `clustercheck` script. First set up the `clustercheck` user:

```
GRANT USAGE ON *.* TO 'clustercheck'@'localhost' IDENTIFIED BY PASSWORD
↪'*2470C0C06DEE42FD1618BB99005ADCA2EC9D1E19';
```

You can then check a node's health by running the `clustercheck` script:

```
/usr/bin/clustercheck clustercheck password 0
```

If the node is running, you should get the following status:

```
HTTP/1.1 200 OK
Content-Type: text/plain
Connection: close
Content-Length: 40

Percona XtraDB Cluster Node is synced.
```

In case node isn't synced or if it is offline, status will look like:

```
HTTP/1.1 503 Service Unavailable
Content-Type: text/plain
Connection: close
Content-Length: 44

Percona XtraDB Cluster Node is not synced.
```

Note: The `clustercheck` script has the following syntax:

`<user> <pass> <available_when_donor=0|1> <log_file> <available_when_readonly=0|1> <defaults_extra_file>`

Recommended: `server_args = user pass 1 /var/log/log-file 0 /etc/my.cnf.local`

Compatibility: `server_args = user pass 1 /var/log/log-file 1 /etc/my.cnf.local`

How does Percona XtraDB Cluster handle big transactions?

Percona XtraDB Cluster populates write set in memory before replication, and this sets the limit for the size of transactions that make sense. There are wsrep variables for maximum row count and maximum size of write set to make sure that the server does not run out of memory.

Is it possible to have different table structures on the nodes?

For example, if there are four nodes, with four tables: `sessions_a`, `sessions_b`, `sessions_c`, and `sessions_d`, and you want each table in a separate node, this is not possible for InnoDB tables. However, it will work for MEMORY tables.

What if a node fails or there is a network issue between nodes?

The quorum mechanism in Percona XtraDB Cluster will decide which nodes can accept traffic and will shut down the nodes that do not belong to the quorum. Later when the failure is fixed, the nodes will need to copy data from the working cluster.

The algorithm for quorum is Dynamic Linear Voting (DLV). 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.

The mechanism is described in detail in Galera documentation.

How would the quorum mechanism handle split brain?

The quorum mechanism cannot handle split brain. If there is no way to decide on the primary component, Percona XtraDB Cluster has no way to resolve a *split brain*. The minimal recommendation is to have 3 nodes. However, it is possibile to allow a node to handle traffic with the following option:

```
wsrep_provider_options="pc.ignore_sb = yes"
```

Why a node stops accepting commands if the other one fails in a 2-node setup?

This is expected behavior to prevent *split brain*. For more information, see previous question or Galera documentation.

Is it possible to set up a cluster without state transfer?

It is possible in two ways:

1. By default, Galera reads starting position from a text file `<datadir>/grastate.dat`. Make this file identical on all nodes, and there will be no state transfer after starting a node.
2. Use the *`wsrep_start_position`* variable to start the nodes with the same `UUID:seqno` value.

What TCP ports are used by Percona XtraDB Cluster?

You may need to open up to four ports if you are using a firewall:

1. Regular MySQL port (default is 3306).
2. Port for group communication (default is 4567). It can be changed using the following option:

```
wsrep_provider_options ="gmcast.listen_addr=tcp://0.0.0.0:4010; "
```

3. Port for State Snaphot Transfer (default is 4444). It can be changed using the following option:

```
wsrep_sst_receive_address=10.11.12.205:5555
```

4. Port for Incremental State Transfer (default is port for group communication + 1 or 4568). It can be changed using the following option:

```
wsrep_provider_options = "ist.recv_addr=10.11.12.206:7777; "
```

Is there "async" mode or only "sync" commits are supported?

Percona XtraDB Cluster does not support "async" mode, all commits are synchronous on all nodes. To be precise, the commits are "virtually" synchronous, which means that the transaction should pass *certification* on nodes, not physical commit. Certification means a guarantee that the transaction does not have conflicts with other transactions on the corresponding node.

Does it work with regular MySQL replication?

Yes. On the node you are going to use as master, you should enable `log-bin` and `log-slave-update` options.

Why the init script (/etc/init.d/mysql) does not start?

Try to disable SELinux with the following command:

```
echo 0 > /selinux/enforce
```

What does "nc: invalid option – 'd'" in the sst.err log file mean?

This is Debian/Ubuntu specific error. Percona XtraDB Cluster uses `netcat-openbsd` package. This dependency has been fixed in recent releases. Future releases of Percona XtraDB Cluster will be compatible with any `netcat` (see bug #959970).

CHAPTER

FORTYFOUR

GLOSSARY

LSN Each InnoDB page (usually 16kb in size) contains a log sequence number, or LSN. The LSN is the system version number for the entire database. Each page's LSN shows how recently it was changed.

InnoDB Storage engine which provides ACID-compliant transactions and foreign key support, among others improvements over *MyISAM*. It is the default engine for *MySQL* as of the 5.5 series.

MyISAM Previous default storage engine for *MySQL* for versions prior to 5.5. It doesn't fully support transactions but in some scenarios may be faster than *InnoDB*. Each table is stored on disk in 3 files: *.frm*,i `.MYD`, `.MYI`.

GTID Global Transaction ID, in *Percona XtraDB Cluster* it consists of *UUID* and an ordinal sequence number which denotes the position of the change in the sequence.

HAProxy HAProxy is a free, very fast and reliable solution offering high availability, load balancing, and proxying for TCP and HTTP-based applications. It is particularly suited for web sites crawling under very high loads while needing persistence or Layer7 processing. Supporting tens of thousands of connections is clearly realistic with todays hardware. Its mode of operation makes its integration into existing architectures very easy and riskless, while still offering the possibility not to expose fragile web servers to the net.

IST Incremental State Transfer. Functionality which instead of whole state snapshot can catch up with te group by receiving the missing writesets, but only if the writeset is still in the donor's writeset cache.

SST State Snapshot Transfer is the full copy of data from one node to another. It's used when a new node joins the cluster, it has to transfer data from existing node. There are three methods of SST available in *Percona XtraDB Cluster*: **`mysqldump`**, **`rsync`** and **`xtrabackup`**. The downside of *mysqldump* and *rsync* is that the node becomes *READ-ONLY* while data is being copied from one node to another (SST applies `FLUSH TABLES WITH READ LOCK` command). Xtrabackup SST does not require `READ LOCK` for the entire syncing process, only for syncing the *MySQL* system tables and writing the information about the binlog, galera and slave information (same as the regular *Percona XtraBackup* backup). State snapshot transfer method can be configured with the *`wsrep_sst_method`* variable.

UUID Universally Unique IDentifier which uniquely identifies the state and the sequence of changes node undergoes. 128-bit UUID is a classic DCE UUID Version 1 (based on current time and MAC address). Although in theory this UUID could be generated based on the real MAC-address, in the Galera it is always (without exception) based on the generated pseudo-random addresses ("locally administered" bit in the node address (in the UUID structure) is always equal to unity).

Complete structure of the 128-bit UUID field and explanation for its generation are as follows:

From	To	Length	Content
0	31	32	Bits 0-31 of Coordinated Universal Time (UTC) as a count of 100-nanosecond intervals since 00:00:00.00, 15 October 1582, encoded as big-endian 32-bit number.
32	47	16	Bits 32-47 of UTC as a count of 100-nanosecond intervals since 00:00:00.00, 15 October 1582, encoded as big-endian 16-bit number.
48	59	12	Bits 48-59 of UTC as a count of 100-nanosecond intervals since 00:00:00.00, 15 October 1582, encoded as big-endian 16-bit number.
60	63	4	UUID version number: always equal to 1 (DCE UUID).
64	69	6	most-significants bits of random number, which generated from the server process PID and Coordinated Universal Time (UTC) as a count of 100-nanosecond intervals since 00:00:00.00, 15 October 1582.
70	71	2	UID variant: always equal to binary 10 (DCE variant).
72	79	8	8 least-significant bits of random number, which generated from the server process PID and Coordinated Universal Time (UTC) as a count of 100-nanosecond intervals since 00:00:00.00, 15 October 1582.
80	80	1	Random bit (“unique node identifier”).
81	81	1	Always equal to the one (“locally administered MAC address”).
82	127	46	Random bits (“unique node identifier”): readed from the `/dev/urandom` or (if `/dev/urandom` is unavailable) generated based on the server process PID, current time and bits of the default “zero node identifier” (entropy data).

XtraBackup *Percona XtraBackup* is an open-source hot backup utility for *MySQL* - based servers that doesn’t lock your database during the backup.

XtraDB *Percona XtraDB* is an enhanced version of the InnoDB storage engine, designed to better scale on modern hardware, and including a variety of other features useful in high performance environments. It is fully backwards compatible, and so can be used as a drop-in replacement for standard InnoDB. More information here .

XtraDB Cluster *Percona XtraDB Cluster* is a high availability solution for MySQL.

Percona XtraDB Cluster *Percona XtraDB Cluster* (PXC) is a high availability solution for MySQL.

my.cnf This file refers to the database server’s main configuration file. Most Linux distributions place it as `/etc/mysql/my.cnf` or `/etc/my.cnf`, but the location and name depends on the particular installation. Note that this is not the only way of configuring the server, some systems does not have one even and rely on the command options to start the server and its defaults values.

cluster replication Normal replication path for cluster members. Can be encrypted (not by default) and unicast or multicast (unicast by default). Runs on tcp port 4567 by default.

datadir The directory in which the database server stores its databases. Most Linux distribution use `/var/lib/mysql` by default.

donor node The node elected to provide a state transfer (SST or IST).

ibdata Default prefix for tablespace files, e.g. `ibdata1` is a 10MB autoextendable file that *MySQL* creates for the shared tablespace by default.

joiner node The node joining the cluster, usually a state transfer target.

node A cluster node – a single mysql instance that is in the cluster.

primary cluster A cluster with *quorum*. A non-primary cluster will not allow any operations and will give `Unknown command` errors on any clients attempting to read or write from the database.

quorum A majority (> 50%) of nodes. In the event of a network partition, only the cluster partition that retains a quorum (if any) will remain Primary by default.

split brain Split brain occurs when two parts of a computer cluster are disconnected, each part believing that the other is no longer running. This problem can lead to data inconsistency.

.frm For each table, the server will create a file with the `.frm` extension containing the table definition (for all storage engines).

- genindex
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