Percona XtraDB Cluster Documentation

Release 5.6.15-25.4

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CONTENTS

Percona XtraDB Cluster is High Availability and Scalability solution for MySQL Users.

Percona XtraDB Cluster provides:

- Synchronous replication. Transaction either committed on all nodes or none.
- Multi-master replication. You can write to any node.
- Parallel applying events on slave. Real "parallel replication".
- Automatic node provisioning.
- Data consistency. No more unsynchronized slaves.

Percona XtraDB Cluster is fully compatible with *MySQL* or *Percona Server* in the following meaning:

- Data compatibility. *Percona XtraDB Cluster* works with databases created in *MySQL* / *Percona Server*.
- Application compatibility. There is no or minimal application changes required to start work with *Percona XtraDB Cluster*.

CHAPTER

ONE

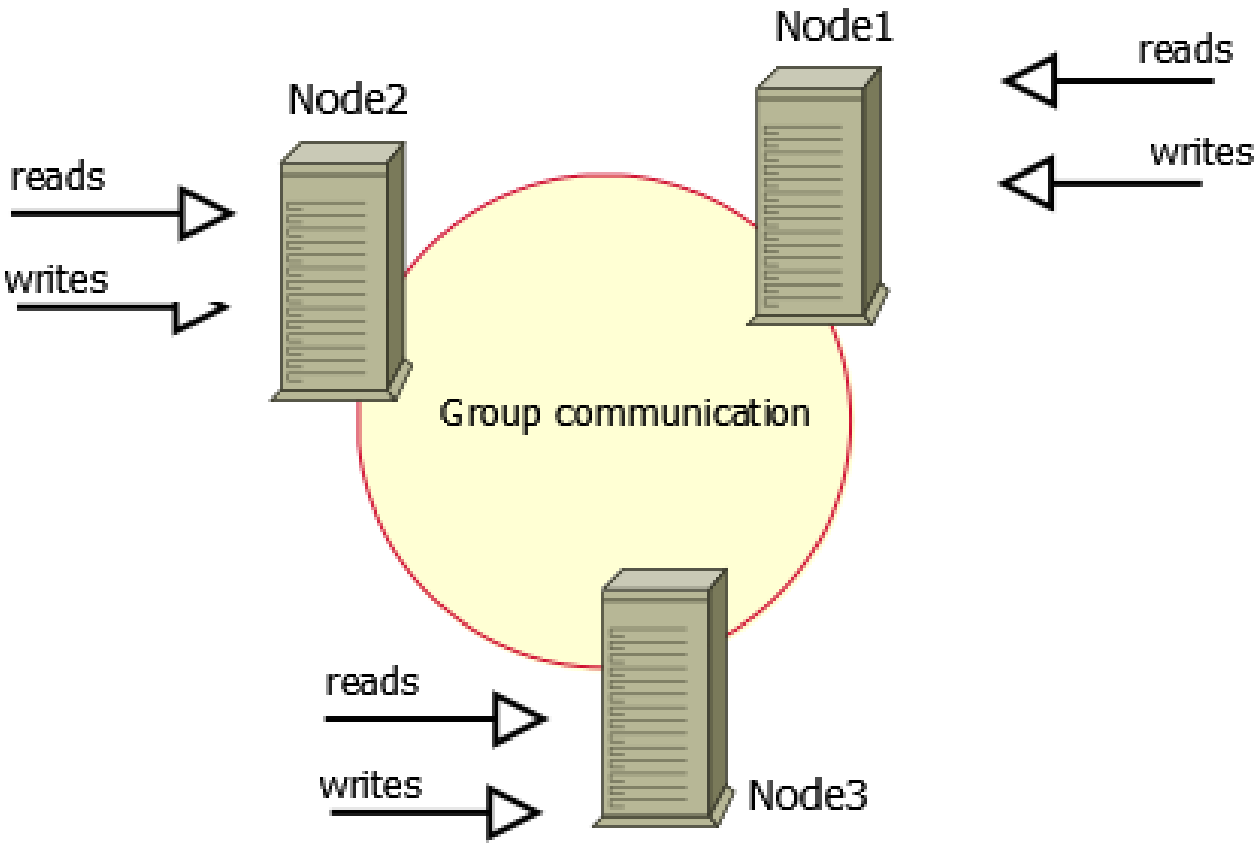
INTRODUCTION

1.1 About Percona XtraDB Cluster

Percona XtraDB Cluster is open-source, free *MySQL* High Availability software

1.1.1 General introduction

1. The Cluster consists of Nodes. Recommended configuration is to have at least 3 nodes, but you can make it running with 2 nodes as well.
2. Each Node is regular *MySQL* / *Percona Server* setup. The point is that you can convert your existing MySQL / Percona Server into Node and roll Cluster using it as a base. Or otherwise – you can detach Node from Cluster and use it as just a regular server.
3. Each Node contains the full copy of data. That defines XtraDB Cluster behavior in many ways. And obviously there are benefits and drawbacks.



Benefits of such approach:

- 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.
- Good solution for scaling a read workload. You can put read queries to any of the nodes.

Drawbacks:

- Overhead of joining new node. The new node has to copy full dataset 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 vs 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 data, for 3 nodes – 3 duplicates.

1.1.2 What is core difference Percona XtraDB Cluster from MySQL Replication ?

Let's take look into the well known CAP theorem for Distributed systems. Characteristics of Distributed systems:

C - Consistency (all your data is consistent on all nodes),

A - Availability (your system is AVAILABLE to handle requests in case of failure of one or several nodes),

P - Partitioning tolerance (in case of inter-node connection failure, each node is still available to handle requests).

CAP theorem says that each Distributed system can have only two out of these three.

MySQL replication has: Availability and Partitioning tolerance.

Percona XtraDB Cluster has: Consistency and Availability.

That is *MySQL* replication does not guarantee Consistency of your data, while *Percona XtraDB Cluster* provides data Consistency (but it looses Partitioning tolerance property).

1.1.3 Components

Percona XtraDB Cluster is based on Percona Server with XtraDB and includes Write Set Replication patches. It uses the Galera library, version 3.x, a generic Synchronous Multi-Master replication plugin for transactional applications.

Galera library is developed by Codership Oy.

Galera 3.x supports such new features as:

- Incremental State Transfer (*IST*), especially useful for WAN deployments,
- RSU, Rolling Schema Update. Schema change does not block operations against table.

1.2 Percona XtraDB Cluster Limitations

There are some limitations which you should be aware of. Some of them will be eliminated later as product is improved and some are design limitations.

- Currently 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.
- Unsupported queries:
  - `LOCK/UNLOCK TABLES` cannot be supported in multi-master setups.
  - lock functions (GET_LOCK(), RELEASE_LOCK()...)
- 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 `wsrep_max_ws_rows` and `wsrep_max_ws_size` variables. `LOAD DATA INFILE` processing will commit every 10K 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 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 can not be supported due to possible rollback on commit.

- The write throughput of the whole cluster is limited by weakest node. If one node becomes slow, whole cluster is slow. 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.

1.3 Percona XtraDB Cluster Errata

1.3.1 Known Issues

Following are issues which may impact you while running PXC:

- Create Table As Select (CTAS) under highly concurent DDL workload (other than CTAS) may deadlock.
- clustercheck looks for my.cnf under /etc for defaults-extra-file and returns 503 if that file is not there. Workaround is to provide location of my.cnf (or its variants) in server_args of xinetd config. You can also symlink to /etc/my.cnf to fix this. Bug:1276076
- For fresh installs, it is highly recommended to use the meta-packages to install packages. Refer to *Installing Percona XtraDB Cluster from Binaries* guide for more details.

Also make sure to check limitations page *here*. You can also review this milestone for features/bugfixes to be included in future releases (i.e. releases after the upcoming/recent release).

1.3.2 Incompatibilities

Following are incompatibilities between PXC 5.5.33 (and higher) and older versions:

- wsrep_sst_donor now supports comma separated list of nodes as a consequence of bug #1129512. This only affects if you use this option as a list. This is not compatible with nodes running older PXC, hence **entire** cluster will be affected as far as SST is concerned, since donor nodes won't recognise the request from joiner nodes if former are not upgraded. Minimal workaround is to upgrade Galera package or to not use this new feature (wsrep_sst_donor with single node can still be used). However, upgrading the full PXC is strongly recommended, however, just upgrading PXC galera package will do for this.

CHAPTER

TWO

INSTALLATION

2.1 Installing Percona XtraDB Cluster from Binaries

Ready-to-use binaries are available from the *Percona XtraDB Cluster* download page, including:

- `RPM` packages for *RHEL* 5 and *RHEL* 6
- *Debian* packages
- Generic `.tar.gz` packages

2.1.1 Using Percona Software Repositories

Percona yum Repository

The *Percona* **yum** repository supports popular *RPM*-based operating systems, including the *Amazon Linux AMI*.

The easiest way to install the *Percona Yum* repository is to install an *RPM* that configures **yum** and installs the Percona GPG key. Installation can also be done manually.

Automatic Installation

Execute the following command as a `root` user, replacing `x86_64` with `i386` if you are not running a 64-bit operating system:

```
$ yum install http://www.percona.com/downloads/percona-release/percona-release-0.0-1.x86_64.rpm
```

The RPMs for the automatic installation are available at http://www.percona.com/downloads/percona-release/ and include source code.

You should see some output such as the following:

```
Retrieving http://www.percona.com/downloads/percona-release/percona-release-0.0-1.x86_64.rpm
Preparing...                ########################################### [100%]
   1:percona-release        ########################################### [100%]
```

The RPMs for the automatic installation are available at http://www.percona.com/downloads/percona-release/ and include source code.

Install XtraDB Cluster

Make sure to remove existing PXC-5.5 and PS-5.5/5.6 packages before proceeding.

Following command will install Cluster packages:

```
$ yum install Percona-XtraDB-Cluster-56
```

Instead of `Percona-XtraDB-Cluster-56` you can install `Percona-XtraDB-Cluster-full-56` meta-package which will install `Percona-XtraDB-Cluster-devel-56`, `Percona-XtraDB-Cluster-test-56`, `Percona-XtraDB-Cluster-debuginfo-56`, `Percona-XtraDB-Cluster-galera-3-debuginfo`, and `Percona-XtraDB-Cluster-shared-56` packages in addition.

Warning: In order to sucessfully install *Percona XtraDB Cluster* `socat` package will need to be installed first.

Percona *yum* Experimental repository

Percona offers fresh beta builds from the experimental repository. To subscribe to the experimental repository, install the experimental *RPM*:

```
yum install http://repo.percona.com/testing/centos/6/os/noarch/percona-testing-0.0-1.noarch.rpm
```

Note: This repository works for both RHEL/CentOS 5 and RHEL/CentOS 6

Percona apt Repository

Debian and *Ubuntu* packages from *Percona* are signed with a key. Before using the repository, you should add the key to **apt**. To do that, run the following commands:

```
$ apt-key adv --keyserver keys.gnupg.net --recv-keys 1C4CBDCDCD2EFD2A
```

Add this to `/etc/apt/sources.list`, replacing `VERSION` with the name of your distribution:

```
deb http://repo.percona.com/apt VERSION main
deb-src http://repo.percona.com/apt VERSION main
```

Remember to update the local cache:

```
$ apt-get update
```

Supported Architectures

- x86_64 (also known as amd64)
- x86

Supported Releases

Debian

- 6.0 squeeze

- 7.0 wheezy

Ubuntu

- 10.04LTS lucid
- 12.04LTS precise
- 12.10 quantal
- 13.04 raring
- 13.10 saucy

Install XtraDB Cluster

Make sure to remove existing *Percona XtraDB Cluster* 5.5 and *Percona Server* 5.5/5.6 packages before proceeding.

Following command will install *Percona XtraDB Cluster* packages:

```
$ sudo apt-get install percona-xtradb-cluster-56
```

Instead of `percona-xtradb-cluster-56` you can install `percona-xtradb-cluster-full-56` meta-package which will install `percona-xtradb-cluster-test-5.6`, `percona-xtradb-cluster-5.6-dbg`, `percona-xtradb-cluster-garbd-3.x`, `percona-xtradb-cluster-galera-3.x-dbg`, `percona-xtradb-cluster-garbd-3.x-dbg` and `libmysqlclient18` packages in addition.

Note: Garbd is packaged separately as part of debian split packaging. The garbd debian package is `percona-xtradb-cluster-garbd-3.x`. The package contains, garbd, daemon init script and related config files. This package will be installed if you install the `percona-xtradb-cluster-56-full` meta package.

Percona *apt* Experimental repository

Percona offers fresh beta builds from the experimental repository. To enable it add the following lines to your `/etc/apt/sources.list` , replacing `VERSION` with the name of your distribution:

```
deb http://repo.percona.com/apt VERSION main experimental
deb-src http://repo.percona.com/apt VERSION main experimental
```

Percona provides repositories for **yum** (`RPM` packages for *Red Hat*, *CentOS* and *Amazon Linux AMI*) and **apt** (`.deb` packages for *Ubuntu* and *Debian*) for software such as *Percona Server*, *XtraDB*, *XtraBackup*, and *Percona Toolkit*. This makes it easy to install and update your software and its dependencies through your operating system's package manager.

This is the recommend way of installing where possible. Make sure to remove existing PXC-5.5 and PS-5.5/5.6 packages before proceeding.

YUM-Based Systems

Once the repository is set up, use the following commands:

```
$ yum install Percona-XtraDB-Cluster-56
```

More detailed example of the *Percona XtraDB Cluster* installation and configuration can be seen in *Installing Percona XtraDB Cluster on CentOS* tutorial.

DEB-Based Systems

Once the repository is set up, use the following commands:

```
$ sudo apt-get install percona-xtradb-cluster-56
```

More detailed example of the *Percona XtraDB Cluster* installation and configuration can be seen in *Installing Percona XtraDB Cluster on Ubuntu* tutorial.

2.1.2 Prerequisites

In order for *Percona XtraDB Cluster* to work correctly firewall has to be set up to allow connections on the following ports: 3306, 4444, 4567 and 4568. *Percona XtraDB Cluster* currently doesn't work with `SELinux` or `apparmor` so they should be disabled, otherwise individual nodes won't be able to communicate and form the cluster.

2.1.3 Initial configuration

In order to start using the *Percona XtraDB Cluster*, following options are needed in the *MySQL* configuration file `my.cnf`:

```
[mysqld]

wsrep_provider -- a path to Galera library.
wsrep_cluster_address -- Cluster connection URL containing the IPs of other nodes in the cluster
wsrep_sst_method - method used for the state snapshot transfer

binlog_format=ROW - In order for Galera to work correctly binlog format should be ROW
default_storage_engine=InnoDB - MyISAM storage engine has only experimental support
innodb_autoinc_lock_mode=2 - This changes how InnoDB autoincrement locks are managed
```

Additional parameters to specify:

```
wsrep_sst_auth=user:password
```

If any other *State Snapshot Transfer* method beside the **rsync** is specified in the `wsrep_sst_method`, credentials for *SST* need to be specified.

Example:

```
wsrep_provider=/usr/lib64/libgalera_smm.so
wsrep_cluster_address=gcomm://10.11.12.206
wsrep_slave_threads=8
wsrep_sst_method=rsync
binlog_format=ROW
default_storage_engine=InnoDB
innodb_autoinc_lock_mode=2
```

Detailed list of variables can be found in *Index of wsrep system variables* and *Index of wsrep status variables*.

2.2 Compiling and Installing from Source Code

The source code is available from the *Launchpad* project here. The easiest way to get the code is with **bzr branch** of the desired release, such as the following:

```
bzr branch lp:percona-xtradb-cluster/5.6
```

You should then have a directory named after the release you branched, such as `percona-xtradb-cluster`.

2.2.1 Compiling on Linux

Prerequisites

The following packages and tools must be installed to compile *Percona XtraDB Cluster* from source. These might vary from system to system.

In Debian-based distributions, you need to:

```
$ apt-get install build-essential flex bison automake autoconf bzr \
  libtool cmake libaio-dev mysql-client libncurses-dev zlib1g-dev
```

In `RPM`-based distributions, you need to:

```
$ yum install cmake gcc gcc-c++ libaio libaio-devel automake autoconf bzr \
  bison libtool ncurses5-devel
```

Compiling

The most esiest way to build binaries is to run script:

```
BUILD/compile-pentium64-wsrep
```

If you feel confident to use cmake, you make compile with cmake adding -DWITH_WSREP=1 to parameters.

Examples how to build RPM and DEB packages you can find in packaging/percona directory in the source code.

2.3 Percona XtraDB Cluster In-Place Upgrading Guide: From 5.5 to 5.6

Warning:

- Some variables (possibly deprecated) in PS 5.5 may have been removed in PS 5.6 (hence in PXC 5.6), please check that the variable is still valid before upgrade.
- Also, make sure to avoid SST during upgrade since a SST between nodes with 5.5 and 5.6 may not work as expected (especially, if 5.5 is donor and 5.6 is joiner, mysql_upgrade will be required on joiner; vice-versa, package upgrade will be required on joiner). You can also avoid automatic SST for the duration of upgrade by setting `'wsrep-sst-method'` to 'skip' for the duration of upgrade. (Note that `'wsrep-sst-method'` is a dynamic variable.) Having a large enough gcache helps here. Also, setting it to `skip` ensures that you can handle SST manually if and when required.

Upgrading cluster involves following major stages:

1. Upgrade a single node.

2. Upgrade the whole cluster while not breaking replication.
3. [Optional] Restarting nodes with non-compat options.

Note: Following upgrade process is for a **rolling** upgrade, ie. an upgrade without downtime for the cluster. If you intend to allow for downtime - bring down all nodes, upgrade them, bootstrap and start nodes - then you can just follow Stage I sans the compatibility variables part. Make sure to bootstrap the first node in the cluster after upgrade.

2.3.1 Following is the upgrade process on CentOS 6.4

Step #1 Make sure all the nodes in cluster are upgraded to the latest 5.5 version and are in synced state.

Stage I

Assuming we are going to upgrade node A, (and other nodes B and C are on 5.5)

Step #2 On node A stop the mysql process and remove the old packages:

```
# service mysql stop
# yum remove 'Percona*'
```

Step #3 Install the new packages:

```
# yum install Percona-XtraDB-Cluster-56
```

Note: For more details on installation, refer to *Installing Percona XtraDB Cluster from Binaries* guide. You may also want to install Percona-XtraDB-Cluster-full-56 which installs other ancillary packages like '-shared-56', '-test-56', debuginfos and so on.

Step #4 Fix the variables in the *MySQL* configuration file `my.cnf` which are not compatible with *Percona Server* 5.6. Detailed list can be checked in Changed in Percona Server 5.6 documentation. In case you are not sure after this, you can also do following:

```
# mysqld --user=mysql --wsrep-provider='none'
```

If there are any invalid variables, it will print it there without affect galera grastate or any other things.

Note: It may also be worthwhile to backup the grastate.dat to use it if it gets zeroed (or sequence number to -1) accidentally (or due to network issues) since this can avoid SST.

Step #5 Add the following to `my.cnf` for compatibility with 5.5 replication for the duration of upgrade, and set the following options:

```
# Required for compatibility with galera-2
# Append socket.checksum=1 to other options if others are in wsrep_provider_options. Eg.: "gmcast.li
wsrep_provider_options="socket.checksum=1"
# Required for replication compatibility
log_bin_use_v1_row_events=1
gtid_mode=0
binlog_checksum=NONE
# Required under certain conditions
read_only=ON
```

Step #5.1 "read_only=ON" is required only when the tables you have contain timestamp/datetime/time data types as those data types are incompatible across replication from higher version to lower. This is currently a limitation of mysql itself. Also, refer to Replication compatibility guide. Any DDLs during migration are not recommended for the same reason.

Note: `read_only` does not apply to root connections (as per mysql specifications).

Step #5.2 To ensure 5.6 read-only nodes are not written to during migration, clustercheck (usually used with xinetd and HAProxy) distributed with PXC has been modified to return 503 when the node is read-only so that HAProxy doesn't send writes to it. Refer to clustercheck script for more details. Instead, you can also opt for read-write splitting at load-balancer/proxy level or at application level.

Note: On the last 5.5 node to upgrade to 5.6, the compatibility options of Step #5 are not required since all other nodes will already be upgrade and their compat. options are compatible with a 5.6 node without them.

Step #6 Next, start the node with the variable `wsrep_provider` set to `none`:

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

This is to ensure that other hosts are not affected by this upgrade (hence provider is none here).

Step #7 While Step #5 is running, in the background or in another session run:

```
# mysql_upgrade

Other options like socket, user, pass may need to provided here if not defined in my.cnf.
```

Step #8 Step #7 must complete successfully, upon which, process started in Step #6 can be stopped/killed.

Step #9 If all the steps above have completed successfully node can be started with:

```
# service mysql start
```

Note: If this is the first node of cluster, then replace start with `bootstrap-pxc`. This shouldn't apply to rolling upgrade in general (since other nodes are up during this) but only for downtime-based upgrades (where you bring up nodes one by one).

Step #10 At this point, other nodes (B, C) should acknowledge that this node is up and synced!

Stage II

Step #11 After this has been set up all 5.5 nodes can be upgraded, one-by-one, as described in the Stage I.

1. If `read_only` was turned on in Step #5.1, then after all nodes in the cluster are upgraded to 5.6 or equivalently, after the last 5.5 has been take down for upgrade, option `read_only` can be set to `OFF` (since this is a dynamic variable, it can done without restart).
2. If read-write splitting was done in applications and/or in load-balancer then in previous step, instead of `read_only`, writes need to be directed to 5.6 nodes.

Stage III [Optional]

Step #12 This step is required to turn off the options added in #Step 5. Note, that this step is not required immediately after upgrade and can be done at a latter stage. The aim here is to turn off the compatibility options for

performance reasons (only socket.checksum=1 fits this). This requires restart of each node. Hence, following can be removed/commented-out:

```
# Remove socket.checksum=1 from other options if others are in wsrep_provider_options. Eg.: "gmcast..
# Removing this makes socket.checksum=2 which uses hardware accelerated CRC32 checksumming.
wsrep_provider_options="socket.checksum=1"

# Options added for replication compatibility, being removed here.
# You can keep some of these if you wish.

log_bin_use_v1_row_events=1

# You can keep if you are not adding async-slaves.
# Apropos, you may need to enable this if you are adding async-slaves, refer to MySQL 5.6 gtid_mode c
gtid_mode=0

# Galera already has full writeset checksumming, so
# you can keep this if async-slaves are not there and
# binlogging is not turned on.
binlog_checksum=NONE

# Remove it from cnf even though it was turned off at runtime in Step #11.
read_only=ON
```

2.3.2 Following is the upgrade process on Ubuntu 12.04 (precise)

Step #1 Make sure all the nodes in cluster are upgraded to the latest 5.5 version and are in synced state.

Stage I

Assuming we are going to upgrade node A, (and other nodes B and C are on 5.5)

Step #2 On node A stop the mysql process and remove the old packages:

```
# /etc/init.d/mysql stop
# apt-get remove percona-xtradb-cluster-server-5.5 percona-xtradb-cluster-galera-2.x percona-xtradb-c
```

Step #3 Fix the variables in the *MySQL* configuration file `my.cnf` which are not compatible with *Percona Server* 5.6. Detailed list can be checked in Changed in Percona Server 5.6 documentation. Add the following to `my.cnf` for compatibility with 5.5 replication for the duration of upgrade, add 'socket.checksum=1' to the `wsrep_provider_options` variable and set `wsrep_provider` set to `none`

```
# Required for compatibility with galera-2
# Append socket.checksum=1 to other options if others are in wsrep_provider_options. Eg.: "gmcast.lis
wsrep_provider_options="socket.checksum=1"
# Required for replication compatibility
log_bin_use_v1_row_events=1
gtid_mode=0
binlog_checksum=NONE
# Required under certain conditions
read_only=ON
wsrep_provider=none
```

Step #3.1 "read_only=ON" is required only when the tables you have contain timestamp/datetime/time data types as those data types are incompatible across replication from higher version to lower. This is currently a limitation of mysql itself. Also, refer to Replication compatibility guide. Any DDLs during migration are not recommended for the same reason.

Note: `read_only` does not apply to root connections (as per mysql specifications).

Step #3.2 To ensure 5.6 read-only nodes are not written to during migration, clustercheck (usually used with xinetd and HAProxy) distributed with PXC has been modified to return 503 when the node is read-only so that HAProxy doesn't send writes to it. Refer to clustercheck script for more details. Instead, you can also opt for read-write splitting at load-balancer/proxy level or at application level.

Note: It may also be worthwhile to backup the grastate.dat to use it if it gets zeroed (or sequence number to -1) accidentally (or due to network issues).

Note: On the last 5.5 node to upgrade to 5.6, the compatibility options of Step #3 are not required since all other nodes will already be upgrade and their configuration options are compatible with a 5.6 node without them.

Step #4 Install the new packages:

```
# apt-get install percona-xtradb-cluster-56
```

Note: For more details on installation, refer to *Installing Percona XtraDB Cluster from Binaries* guide. You may also want to install percona-xtradb-cluster-full-56 which installs other ancillary packages like '-shared-56', '-test-56', debuginfos and so on.

Step #5 After node has been started you'll need to run `mysql_upgrade`:

```
# mysql_upgrade

Other options like socket, user, pass may need to provided here if not defined in my.cnf.
```

Step #6 If all the steps above have completed successfully, shutdown the server, set the `wsrep_provider` to the location of the Galera library (from 'none' to something like /usr/lib/libgalera_smm.so) in my.cnf, and node can be started with:

```
# service mysql start
```

Note: If this is the first node of cluster, then replace start with `bootstrap-pxc`. This shouldn't apply to rolling upgrade in general (since other nodes are up during this) but only for downtime-based upgrades (where you bring up nodes one by one).

Step #7 At this point, other nodes (B, C) should acknowledge that this node is up and synced!

Stage II

Step #8 After this has been set up all 5.5 nodes can be upgraded, one-by-one, as described in the Stage I.

1. If `read_only` was turned on in Step #3.1, then after all nodes in the cluster are upgraded to 5.6 or equivalently, after the last 5.5 has been take down for upgrade, option `read_only` can be set to `OFF` (since this is a dynamic variable, it can done without restart).
2. If read-write splitting was done in applications and/or in load-balancer then in previous step, instead of `read_only`, writes need to be directed to 5.6 nodes.

Stage III [Optional]

Step #9 This step is required to turn off the options added in #Step 3. Note, that this step is not required immediately after upgrade and can be done at a latter stage. The aim here is to turn off the compatibility options for performance reasons (only socket.checksum=1 fits this). This requires restart of each node. Hence, following can be removed/commented-out:

```
# Remove socket.checksum=1 from other options if others are in wsrep_provider_options. Eg.: "gmcast..
# Removing this makes socket.checksum=2 which uses hardware accelerated CRC32 checksumming.
wsrep_provider_options="socket.checksum=1"

# Options added for replication compatibility, being removed here.
# You can keep some of these if you wish.

log_bin_use_v1_row_events=1

# You can keep if you are not adding async-slaves.
# Apropos, you may need to enable this if you are adding async-slaves, refer to MySQL 5.6 gtid_mode c
gtid_mode=0

# Galera already has full writeset checksumming, so
# you can keep this if async-slaves are not there and
# binlogging is not turned on.
binlog_checksum=NONE

# Remove it from cnf even though it was turned off at runtime in Step #8.
read_only=ON
```

CHAPTER

THREE

FEATURES

3.1 High Availability

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

In case there were changes to data while node was down, there are two options that Node may use when it joins the cluster: State Snapshot Transfer: (SST) and Incremental State Transfer (IST).

- SST 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 your cluster 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 *.frm* files (the same as with regular backup).
- Even with that, SST may be intrusive, that's why there is IST mechanism. If you put your node down for a short period of time and then start it, the node is able to fetch only those changes made during the period it was down. This is done using 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 current state of Node by using

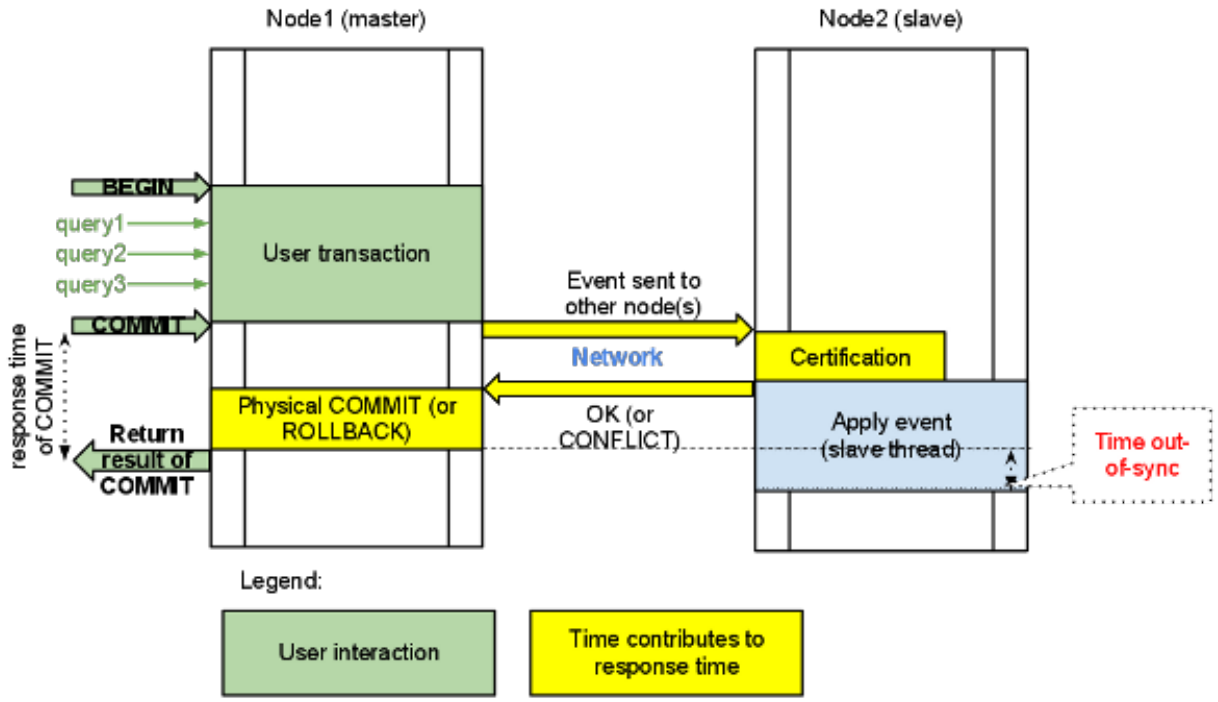
```
SHOW STATUS LIKE 'wsrep_local_state_comment';
```

When it is *Synced (6)*, the node is ready to handle traffic.

3.2 Multi-Master replication

Multi-Master replication stands for the ability to write to any node in the cluster, and not to worry that eventually it will get out-of-sync situation, as it regularly happens with regular MySQL replication if you imprudently write to the wrong server. This is a long-waited feature and there has been growing demand for it for the last two years, or even more.

With *Percona XtraDB Cluster* you can write to any node, and the Cluster guarantees consistency of writes. That is, the write is either committed on all the nodes or not committed at all. For the simplicity, this diagram shows the use of the two-node example, but the same logic is applied with the N nodes:



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

Response time of *COMMIT* consists of several parts:

- Network round-trip time,
- Certification time,
- Local applying

Please note that applying the transaction on remote nodes does not affect the response time of *COMMIT*, as it happens in the background after the response on certification.

The two important consequences of this architecture:

- First: we can have several appliers working in parallel. This gives us a true parallel replication. Slave can have many parallel threads, and this can be tuned by variable `wsrep_slave_threads`.
- Second: There might be a small period of time when the slave is out-of-sync from master. This happens because the master may apply event faster than a 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 using variable `wsrep_causal_reads=ON`. In this case, the read on the slave will wait until event is applied (this however will increase the response time of the read). This 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 the second serious implication. If you run write transactions to two different nodes, the cluster will use an optimistic locking model. That 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. In InnoDB usually *DEADLOCK* and *LOCK TIMEOUT* errors happen in response on particular query, but not on *COMMIT*. It's good practice to check the error codes after *COMMIT* query, but there are still many applications that do not do that.

If you plan to use Multi-Master capabilities of *XtraDB Cluster* and run write transactions on several nodes, you may need to make sure you handle response on *COMMIT* query.

CHAPTER

FOUR

USER'S MANUAL

4.1 Bootstrapping the cluster

Bootstrapping refers to getting the initial cluster up and running. By bootstrapping you are defining which node is has the correct information, that all the other nodes should synchronize to (via *SST*). In the event of a cluster-wide crash, bootstrapping functions the same way: by picking the initial node, you are essentially deciding which cluster node contains the database you want to go forward with.

The *MySQL* configuration file should contain necessary configuration options to start the *Percona XtraDB Cluster*:

```
[mysqld]
# Path to Galera library
wsrep_provider=/usr/lib64/libgalera_smm.so
# Cluster connection URL
wsrep_cluster_address=gcomm://
# 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 changes how |InnoDB| autoincrement locks are managed and is a requirement for Galera
innodb_autoinc_lock_mode=2
```

Bootstrapping the cluster is a bit of a manual process. On the initial node, variable `wsrep_cluster_address` should be set to the value: `gcomm://`. The `gcomm://` tells the node it can bootstrap without any cluster to connect to. Setting that and starting up the first node should result in a cluster with a `wsrep_cluster_conf_id` of 1. After this single-node cluster is started, variable `wsrep_cluster_address` should be updated to the list of all nodes in the cluster. For example:

```
wsrep_cluster_address=gcomm://192.168.70.2,192.168.70.3,192.168.70.4
```

Although note that cluster membership is not defined by this setting, it is defined by the nodes that join the cluster with the proper cluster name configured Variable `wsrep_cluster_name` is used for that, if not explicitly set it will default to `my_wsrep_cluster`. Hence, variable `wsrep_cluster_address` does not need to be identical on all nodes, it's just a best practice because on restart the node will try all other nodes in that list and look for any that are currently up and running the cluster.

Once the first node is configured, then each other node should be started, one at a time. In a bootstrap situation, SST is most likely, so generally multiple nodes joining at once should be avoided.

In case cluster that's being bootstrapped has already been set up before, and to avoid editing the `my.cnf` twice to change the `wsrep_cluster_address` to `gcomm://` and then to change it back to other node addresses, first node can be started with:

```
/etc/init.d/mysql bootstrap-pxc
```

This way values in `my.cnf` would remain unchanged. Next time node is restarted it won't require updating the configuration file. This can be useful in case cluster has been previously set up and for some reason all nodes went down and the cluster needs to be bootstrapped again.

4.1.1 Other Reading

- How to start a Percona XtraDB Cluster

4.2 State Snapshot Transfer

State Snapshot Transfer 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, new node has to transfer data from the node that is already part of the cluster. There are three methods of SST available in Percona XtraDB Cluster: **mysqldump**, **rsync** and **xtrabackup**. The downside of *mysqldump* and *rsync* is that the donor 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 XtraBackup backup). State snapshot transfer method can be configured with the `wsrep_sst_method` variable.

Note: If the variable `gcs.sync_donor` is set to `Yes` (default `No`), whole cluster will get blocked if the donor is blocked by the State Snapshot Transfer and not just the donor node.

4.2.1 Using *Percona Xtrabackup*

This is the default SST method (version 2 of it: xtrabackup-v2). This is the least blocking method as it locks the tables only to copy the *MyISAM* system tables. *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 PXC to perform the SST using the *XtraBackup*, credentials for connecting to the donor node need to be set up in the variable `wsrep_sst_auth`. Beside the credentials, one more important thing is that the *datadir* needs to be specified in the server configuration file `my.cnf`, otherwise the transfer process will fail.

More information about the required credentials can be found in the *XtraBackup* manual. Easy way to test if the credentials will work is to run the **innobackupex** on the donor node with the username and password specified in the variable `wsrep_sst_auth`. For example, if the value of the `wsrep_sst_auth` is `root:Passw0rd` **innobackupex** command should look like:

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

Detailed information on this method are provided in *Xtrabackup SST Configuration* documentation.

4.2.2 Using `mysqldump`

This method uses the standard **mysqldump** to dump all the databases from the donor node and import them to the joining node. For this method to work `wsrep_sst_auth` needs to be set up with the root credentials. This method is the slowest one and it also performs the global lock while doing the *SST* which will block writes to the donor node.

Script used for this method can be found in `/usr/bin/wsrep_sst_mysqldump` and it's provided with the *Percona XtraDB Cluster* binary packages.

4.2.3 Using `rsync`

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

Script used for this method can be found in `/usr/bin/wsrep_sst_rsync` and it's provided with the *Percona XtraDB Cluster* binary packages.

4.2.4 Other Reading

- SST Methods for MySQL
- *Xtrabackup SST configuration*

4.3 Xtrabackup SST Configuration

XtraBackup SST works in two stages:

- Stage I on joiner checks if it is *SST* or *IST* based on presence of `xtrabackup_ist` file.
- In Stage II it starts the data transfer, if it's *SST*, it empties the data directory sans few files (galera.cache, sst_in_progress, grastate.dat) and then proceed with the SST or if it's IST, proceeds as before.

Note: To maintain compatibility with *Percona XtraDB Cluster* older than 5.5.33-23.7.6, use xtrabackup as SST method, else xtrabackup-v2 is recommended. xtrabackup-v2 is also the default SST method now.

Latest *Percona XtraBackup* 2.1.x is strongly recommended for Xtrabackup SST. Refer to Incompatibilities for possible caveats.

4.3.1 Following SST specific options are allowed in my.cnf under [sst]

Note: In following options:

- Non-integer options which have no default are disabled if not set.
- ":Match: Yes" implies that options should match on donor and joiner (in their cnf).
- ":Recommended: Yes" implies the value which is recommended.
- In following options, path always means full path.

---

option `streamfmt`

Values xbstream, tar

Default xbstream

Match Yes

Xbstream is highly recommended. Refer to *Xbstream v/s Tar* for details and caveats of using tar v/s xbstream for SST.

option `transferfmt`

Values socat, nc

Default socat

Match Yes

socat is recommended because it allows for socket options like transfer buffer sizes. Refer to socat(1) for details.

option `tca`

Description CA file for openssl based encryption with socat.

Type Full path to CRT file (.crt).

option `tcert`

Description PEM for openssl based encryption with socat.

Type Full path to PEM (.pem).

Note: For tca and tcert, refer to http://www.dest-unreach.org/socat/doc/socat-openssltunnel.html for an example. 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 so as to be compatible with socat's parameter' names as well as with MySQL's SSL authentication. For testing you can also download certificates from launchpad. **Note** that irrespective of what is shown in the example, you can use same crt and pem files on all nodes and it will work, since there is no server-client paradigm here but a cluster with homogeneous nodes.

---

option `encrypt`

Values 0,1,2,3

Default 0

Match Yes

Decides whether encryption is to be done or not, if this is zero, no encryption is done. `encrypt=2` is recommended if your nodes are over WAN and security constraints are higher, while `encrypt=1` (Xtrabackup-based symmetric encryption) is easier to setup.

- Xtrabackup based encryption with `encrypt=1`.
- OpenSSL based encryption with `encrypt=2`. Socat must be built with openSSL for encryption: `socat -V | grep OPENSSL`.
- Support for SSL encryption for just the key and crt files as implemented in Galera can be enabled with `encrypt=3` option. Information on this option can be found *here*.

Refer to this *document* when enabling with `encrypt=1`.

option `encrypt-algo`

This option is only considered when `encrypt` is equal to 1. Refer to *this* before setting this. This option takes the same value as encrypt option here.

option `sockopt`

Comma separated key/value pairs of socket options. Must begin with a comma. You can use tcpwrap option here to blacklist/whitelist the clients. Refer to socat manual for further details.

Note: You can also enable SSL based compression with `sockopt`. This can be used in place of compress option of Xtrabackup.

---

option `progress`

Values 1,path/to/file

If equal to:

- 1 it writes to mysql stderr
- path/to/file writes to that 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 only on joiner. 1 implies rebuild indexes. Note that this is independent of compaction, though compaction enables it. Rebuild of indexes may be used as an optimization. Note that #1192834 affects this, hence use of `compact` and `rebuild` are recommended after that is fixed in Percona Xtrabackup and released.

option `time`

Values 0,1

Default 0

Enabling it instruments key stages of backup/restore in SST.

option `rlimit`

Values x(k|m|g|t)

Ratelimit to `x` kilobytes, megabytes etc. Refer to pv(1) for details. Note this rate-limiting happens on donor. The rationale behind this is to not allow SST to saturate the donor's regular cluster operations and/or to ratelimit for other purposes.

option `incremental`

Values 0,1

Default 0

To be set on joiner only, supersedes IST if set. Currently requires manual setup. Hence, not supported currently.

option `use_extra`

Values 0,1

Default 0

If set to 1, SST will use the thread pool's extra_port. Make sure that thread pool is enabled and extra_port option is set in my.cnf before you turn on this option.

option `cpat`

During the SST, the *datadir* is cleaned up so that state of other node can be restored cleanly. This option provides the ability to define the files that need to be deleted before the SST. It can be set like:

```
[sst]
cpat='.*galera\.cache$\|.*sst_in_progress$\|.*grastate\.dat$\|.*\.err$\|.*\.log$\|.*RPM_UPGRADE_MARKE
```

NOTE: This option can only be used when `wsrep_sst_method` is set to xtrabackup-v2.

option `sst_special_dirs`

Values 0,1

Default 0

In order for XtraBackup SST to support `innodb_data_home_dir` and `innodb_log_home_dir` variables in the configuration file this option was introduced in *Percona XtraDB Cluster* `5.6.15-25.2`. This requires sst-special-dirs to be set under [sst] in the configuration file to either 0 or 1. Also, `innodb-data-home-dir` and/or `innodb-log-group-home-dir` need to be defined in `my.cnf` under [mysqld]. *Percona XtraBackup* 2.1.6 or higher is required in order for this to work.

NOTE: This option can only be used when `wsrep_sst_method` is set to xtrabackup-v2.

option `compressor/decompressor`

Values command-lines to compressor/decompressor

Default Not set, hence not enabled.

Example compressor='gzip', decompressor='gzip -dc'

This option introduces stream-based compression/decompression. When these options are set, compression/decompression are done on stream, in contrast to earlier PXB-based one where decompression was done after streaming to disk, involving additional I/O; hence I/O is saved here (almost halved on joiner). You can use any compression utility which works on stream - gzip, pigz (which is multi-threaded and hence, recommended) etc. Also, note that, compressor has to be set on donor and decompressor on joiner (though you can have decompressor set on donor and vice-versa for config homogeneity, it won't affect that particular SST). To use Xtrabackup-based compression as before use `compress` under `[xtrabackup]` as before, also having both enabled won't cause any failure (though you will be wasting CPU cycles with this).

4.3.2 Tar against xbstream

- Features - encryption, compression, parallel streaming, streaming incremental backups, compaction - won't work with tar. Refer to xbstream docs for more.

4.3.3 Xtrabackup SST Dependencies

Following are optional dependencies of PXC introduced by wsrep_sst_xtrabackup: (obvious and direct dependencies are not provided here)

- 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/tar for streaming. tar is default.
- pv. Required for `progress` and `rlimit`. Provided by pv.
- mkfifo. Required for `progress`. Provided by coreutils.
- mktemp. Required for `incremental`. Provided by coreutils.

4.3.4 Galera compatible encryption

Support for SSL encryption for just the key and crt files as implemented in Galera can be enabled with `encrypt=3` option. This has been implemented in `5.5.34-23.7.6` for compatibility with Galera. **NOTE**: This option does not provide certificate validation. In order to work correctly paths to the key and cert files need to be specified as well, like:

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

NOTE: This option can only be used when `wsrep_sst_method` is set to xtrabackup-v2.

4.3.5 Xtrabackup-based encryption

This is enabled when `encrypt` is set to 1 under [sst]. 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 disallow encryption from innobackupex if the above are in my.cnf under [xtrabackup]. For that reason, do the following:

1. If you want to use xtrabackup based encryption for SST but not otherwise, use `encrypt=1` under [sst] and provide xtrabackup_encrypt_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 those xtrabackup_encrypt_options either under [sst] or [xtrabackup].
3. If you don't want xtrabackup based encryption for SST but want it otherwise, use `encrypt=0` or `encrypt=2` and do **NOT** provide xtrabackup_encrypt_options under [xtrabackup]. You can still have them under [sst] though. You will need to provide those options on innobackupex commandline then.
4. If you don't want to use xtrabackup based encryption at all (or only the openssl-based for SST with `encrypt=2`), then you don't need worry about these options! (just don't provide them in my.cnf)

Note: The `encrypt` under [sst] is different from under [xtrabackup]. The former is for disabling/changing encryption mode, latter is to provide encryption algorithm. To disambiguate, if you need to provide latter under [sst] (which you need to, for points #1 and #2 above) then it should be specified as `encrypt-algo`.

Warning: An implication of the above is that if you specify xtrabackup_encrypt_options but `encrypt=0` under [sst], it will **STILL** be encrypted and SST will fail. Look at point#3 above for resolution.

4.4 Restarting the cluster nodes

Restarting a cluster node is as simple as shutting down and restarting standard mysql. The node should gracefully leave the cluster (and the total vote count for *quorum* should decrement). When it rejoins, the node should receive an *IST* of changes since it left so it can get back in sync. If the set of changes needed for IST are not found in the `gcache` file on any other node in the entire cluster, then an *SST* will be performed instead. Therefore, restarting cluster nodes for rolling configuration changes or software upgrades should be fairly trivial to accomplish from the cluster's perspective.

Note: If a configuration change is done and mysql restarted and that change happens to contain a misspelling or some other mistake that prevents mysqld from loading, Galera will generally decide to drop its state and an SST will be forced for that node.

4.5 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 the node (or nodes) is determined to be disconnected, then the remaining nodes cast a quorum vote and if a majority remain from the total nodes connected from before the disconnect, 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 go to the non-Primary state.

Because of this, it's not possible to safely have automatic failover in a 2 node cluster, because the failure of one node will cause the remaining node to go non-Primary. Further, cluster with an even number of nodes (say two nodes in two different switches) have some possibility of a split brain condition when if network connectivity is lost between the two partitions, neither would retain quorum, and so both would go to Non-Primary. Therefore: for automatic failover, the "rule of 3s" is recommended. It applies at various levels of infrastructure, depending on how far 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 be span at least 3 networks
- A cluster spanning data centers should span at least 3 data centers

This is all to prevent split brain situations from preventing automatic failover from working.

4.5.1 Using an arbitrator

In the case where the expense of adding the third node/switch/datacenter/etc. above is prohibitively high, using an arbitrator node may be a viable alternative. An arbitrator is a voting member of the cluster which does receive and can relay replication, but it does not persist any data and does not run mysqld, it is a separate daemon. Placing even a single arbitrator in a 3rd location can add split brain protection to a cluster that is spread only across two nodes/locations.

4.5.2 Recovering a Non-Primary cluster

It is important to note that the rule of 3s only applies for 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 will cause the other to shift to non-Primary and refuse operations. However, that is a recoverable state via a manual 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 exists no other partition operating in Primary as well, or else *Percona XtraDB Cluster* will allow those two partitions to diverge (and now you have two databases that are impossible to remerge automatically). For example, if there are two data centers where one is primary and one is for Disaster Recovery, with 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 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. In this case you could simply tell the secondary data center to bootstrap itself with a single command, but disaster recovery failover remains in your control.

4.5.3 Other Reading

- PXC - Failure Scenarios with only 2 nodes

4.6 Monitoring the cluster

The important bit about the cluster is that each node should be monitored independently. There is no centralized node, the cluster is the set of active, connected nodes, and each can have a different view of the cluster. Further, many of these variables are relative to the node you query them from: for example, replication sent (from this node) and received (from writes on the rest of the cluster). Having data from all nodes helps tracking down the source of issues (i.e., where are the flow control messages coming from? Where did that 100MB transaction came from?).

4.6.1 Manually

Manual cluster monitoring can be done with myq_gadgets.

4.6.2 Alerting

Standard *MySQL* alerting should apply here. *Percona XtraDB Cluster* specific alerting should include:

- Cluster state of each node (`wsrep_cluster_status` != Primary)
- Node state (`wsrep_connected`, `wsrep_ready` != ON)

Other optional alerting could be done on:

- Excessive replication conflicts (high rate of `wsrep_local_cert_failures` and `wsrep_local_bf_aborts`)
- Excessive Flow control messages (`wsrep_flow_control_sent`/ `wsrep_flow_control_recv`)
- Large replication queues (`wsrep_local_recv_queue`).

4.6.3 Metrics

Metrics collection (i.e., long-term graphing) on the cluster should be done on:

- Queue sizes (`wsrep_local_recv_queue`, `wsrep_local_send_queue`)
- Flow control (`wsrep_flow_control_sent`, `wsrep_flow_control_recv`)
- Number of transactions in and out of this node (`wsrep_replicated`, `wsrep_received`)
- Number of transactions in and out in bytes (`wsrep_replicated_bytes`, `wsrep_received_bytes`)
- Replication conflicts (`wsrep_local_cert_failures` and `wsrep_local_bf_aborts`)

4.6.4 Other Reading

- Realtime stats to pay attention to in PXC and Galera

CHAPTER

FIVE

HOW-TOS

5.1 Installing Percona XtraDB Cluster on *CentOS*

This tutorial will show how to install the *Percona XtraDB Cluster* on three CentOS 6.3 servers, using the packages from Percona repositories.

This cluster will be assembled of three servers/nodes:

```
node #1
hostname: percona1
IP: 192.168.70.71

node #2
hostname: percona2
IP: 192.168.70.72

node #3
hostname: percona3
IP: 192.168.70.73
```

5.1.1 Prerequisites

- All three nodes have a CentOS 6.3 installation.
- Firewall has been set up to allow connecting to ports 3306, 4444, 4567 and 4568
- SELinux is disabled

5.1.2 Installation

Installation information can be found in the *Installing Percona XtraDB Cluster from Binaries* guide.

5.1.3 Configuring the nodes

Individual nodes should be configured to be able to bootstrap the cluster. More details about bootstrapping the cluster can be found in the *Bootstrapping the cluster* guide.

Configuration file `/etc/my.cnf` for the first node should look like:

```
[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 changes how InnoDB autoincrement locks are managed and 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"
```

After this, first node can be started with the following command:

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

This command will start the cluster with initial `wsrep_cluster_address` set to `gcomm://`. This way the cluster will be bootstrapped and in case the node or *MySQL* have to be restarted later, there would be no need to change the configuration file.

After the first node has been started, cluster status can be checked by:

```
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.

It's recommended not to leave the empty password for the root account. Password can be changed with:

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

In order to perform successful *State Snapshot Transfer* using *XtraBackup* new user needs to be set up with proper privileges:

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

Note: MySQL root account can also be used for setting up the SST with Percona XtraBackup, but it's recommended to use a different (non-root) user for this.

Configuration file `/etc/my.cnf` on the second node (`percona2`) should look like this:

```
[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 changes how InnoDB autoincrement locks are managed and 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"
```

Second node can be started with the following command:

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

After the server has been started it should receive the state snapshot transfer automatically. This means that the second node won't have the empty root password anymore. In order to connect to the cluster and check the status changed root password from the first node should be used. Cluster status can now be checked on both nodes. This is the example 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.

MySQL configuration file `/etc/my.cnf` on the third node (`percona3`) should look like this:

```
[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 changes how InnoDB autoincrement locks are managed and 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"
```

Third node can now be started with the following command:

```
[root@percona3 ~]# /etc/init.d/mysql start
```

After the server has been started it should receive the SST same as the second node. Cluster status can now be checked on both nodes. This is the example 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.

5.1.4 Testing the replication

Although the password change from the first node has replicated successfully, this example will show that writing on any node will replicate to the whole cluster. In order to check this, new database will be created on second node and table for that database will be created on the third node.

Creating the new database on the second node:

```
mysql@percona2> CREATE DATABASE percona;
Query OK, 1 row affected (0.01 sec)
```

Creating the `example` 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)
```

Inserting records on the first node:

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

Retrieving 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 small example shows that all nodes in the cluster are synchronized and working as intended.

5.2 Installing Percona XtraDB Cluster on *Ubuntu*

This tutorial will show how to install the *Percona XtraDB Cluster* on three *Ubuntu* 12.04.2 LTS servers, using the packages from Percona repositories.

This cluster will be assembled of three servers/nodes:

```
node #1
hostname: pxc1
IP: 192.168.70.61

node #2
hostname: pxc2
IP: 192.168.70.62

node #3
hostname: pxc3
IP: 192.168.70.63
```

5.2.1 Prerequisites

- All three nodes have a *Ubuntu* 12.04.2 LTS installation.
- Firewall has been set up to allow connecting to ports 3306, 4444, 4567 and 4568
- AppArmor profile for *MySQL* is disabled

5.2.2 Installation

Installation information can be found in the *Installing Percona XtraDB Cluster from Binaries* guide

---

Note: Debian/Ubuntu installation prompts for root password, this was set to: `Passw0rd`. After the packages have been installed, `mysqld` will be started automatically. In this example mysqld is stopped on all three nodes after successful installation with: `/etc/init.d/mysql stop`.

5.2.3 Configuring the nodes

Individual nodes should be configured to be able to bootstrap the cluster. More details about bootstrapping the cluster can be found in the *Bootstrapping the cluster* guide.

Configuration file `/etc/mysql/my.cnf` for the first node should look like:

```
[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 changes how InnoDB autoincrement locks are managed and 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"
```

After this, first node can be started with the following command:

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

This command will start the first node and bootstrap the cluster (more information about bootstrapping cluster can be found in *Bootstrapping the cluster* manual).

After the first node has been started, cluster status can be checked by:

```
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.

In order to perform successful *State Snapshot Transfer* using *Percona XtraBackup* new user needs to be set up with proper privileges:

```
mysql@pxc1> CREATE USER 'sstuser'@'localhost' IDENTIFIED BY 's3cretPass';
mysql@pxc1> GRANT RELOAD, LOCK TABLES, REPLICATION CLIENT ON *.* TO 'sstuser'@'localhost';
mysql@pxc1> FLUSH PRIVILEGES;
```

Note: MySQL root account can also be used for setting up the *State Snapshot Transfer* with *Percona XtraBackup*, but it's recommended to use a different (non-root) user for this.

Configuration file `/etc/mysql/my.cnf` on the second node (`pxc2`) should look like this:

```
[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 changes how InnoDB autoincrement locks are managed and 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"
```

Second node can be started with the following command:

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

After the server has been started it should receive the state snapshot transfer automatically. Cluster status can now be checked on both nodes. This is the example 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.

MySQL configuration file `/etc/mysql/my.cnf` on the third node (`pxc3`) should look like this:

```
[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 changes how InnoDB autoincrement locks are managed and 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"
```

Third node can now be started with the following command:

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

After the server has been started it should receive the SST same as the second node. Cluster status can now be checked on both nodes. This is the example 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.

5.2.4 Testing the replication

Although the password change from the first node has replicated successfully, this example will show that writing on any node will replicate to the whole cluster. In order to check this, new database will be created on second node and table for that database will be created on the third node.

Creating the new database on the second node:

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

Creating the `example` 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)
```

Inserting records on the first node:

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

Retrieving 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 small example shows that all nodes in the cluster are synchronized and working as intended.

5.3 How to setup 3 node cluster on single box

This example shows how to setup 3-node cluster on the single physical box. Assume you installed *Percona XtraDB Cluster* from binary `.tar.gz` into directory

```
/usr/local/Percona-XtraDB-Cluster-5.5.24-23.6.342.Linux.x86_64
```

To start the cluster with three nodes, three `my.cnf` mysql configuration files should be created with three separate data directories.

For this example we created (see the content of files at the end of document):

- /etc/my.4000.cnf
- /etc/my.5000.cnf
- /etc/my.6000.cnf

and data directories:

- /data/bench/d1
- /data/bench/d2
- /data/bench/d3

In this example local IP address is 192.168.2.21

Then we should be able to start initial node as (from directory `/usr/local/Percona-XtraDB-Cluster-5.6.15-25.3.706.`

```
bin/mysqld_safe --defaults-file=/etc/my.4000.cnf --wsrep-new-cluster
```

Following output will let out know that node was started successfully:

```
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,
```

And you can check used ports:

```
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
```

After first node, we start second and third:

```
bin/mysqld_safe --defaults-file=/etc/my.5000.cnf
bin/mysqld_safe --defaults-file=/etc/my.6000.cnf
```

Successful start will produce 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
```

Cluster size can be checked with the:

```
mysql -h127.0.0.1 -P6000 -e "show global status like 'wsrep_cluster_size';"
+--------------------+-------+
| Variable_name      | Value |
+--------------------+-------+
| wsrep_cluster_size | 3     |
+--------------------+-------+
```

Now you can connect to any node and create database, which will be automatically propagated to other nodes:

```
mysql -h127.0.0.1 -P5000 -e "CREATE DATABASE hello_peter"
```

Configuration files (/etc/my.4000.cnf):

```
/etc/my.4000.cnf

[mysqld]
port = 4000
socket=/tmp/mysql.4000.sock
datadir=/data/bench/d1
basedir=/usr/local/Percona-XtraDB-Cluster-5.6.15-25.3.706.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-5.6.15-25.3.706.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_locks_unsafe_for_binlog=1
innodb_autoinc_lock_mode=2
```

Configuration files (/etc/my.5000.cnf):

```
/etc/my.5000.cnf

[mysqld]
port = 5000
socket=/tmp/mysql.5000.sock
datadir=/data/bench/d2
basedir=/usr/local/Percona-XtraDB-Cluster-5.6.15-25.3.706.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-5.6.15-25.3.706.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_locks_unsafe_for_binlog=1
innodb_autoinc_lock_mode=2
```

Configuration files (/etc/my.6000.cnf):

```
/etc/my.6000.cnf

[mysqld]
port = 6000
socket=/tmp/mysql.6000.sock
datadir=/data/bench/d3
basedir=/usr/local/Percona-XtraDB-Cluster-5.6.15-25.3.706.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-5.6.15-25.3.706.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_locks_unsafe_for_binlog=1
innodb_autoinc_lock_mode=2
```

5.4 How to setup 3 node cluster in EC2 enviroment

This is how to setup 3-node cluster in EC2 enviroment.

Assume you are running *m1.xlarge* instances with OS *Red Hat Enterprise Linux 6.1 64-bit*. Make sure to remove existing PXC-5.5 and PS-5.5/5.6 packages before proceeding.

Install *Percona XtraDB Cluster* from RPM:

1. Install Percona's regular and testing repositories:

   ```
   rpm -Uhv http://repo.percona.com/testing/centos/6/os/noarch/percona-testing-0.0-1.noarch.rpm
   rpm -Uhv http://www.percona.com/downloads/percona-release/percona-release-0.0-1.x86_64.rpm
   ```

2. Install Percona XtraDB Cluster packages:

   ```
   yum install Percona-XtraDB-Cluster-server-56 Percona-XtraDB-Cluster-client-56 Percona-XtraDB-Clu
   ```

3. Create data directories:

   ```
   mkdir -p /mnt/data
   mysql_install_db --datadir=/mnt/data --user=mysql
   ```

4. Stop firewall. Cluster requires couple TCP ports to operate. Easiest way:

   ```
   service iptables stop
   ```

If you want to open only specific ports, you need to open 3306, 4444, 4567, 4568 ports. For example for 4567 port (substitute 192.168.0.1 by your IP):

```
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.

   On the first node (assume IP 10.93.46.58):

   ```
   [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_locks_unsafe_for_binlog=1
   innodb_autoinc_lock_mode=2
   ```

   On the second node (assume IP 10.93.46.59):

   ```
   [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=node2

innodb_locks_unsafe_for_binlog=1
innodb_autoinc_lock_mode=2
```

On the third (and following nodes) configuration is similar, with the following change:

```
wsrep_node_name=node3
```

In this example variable `wsrep_urls` is being used instead of `wsrep_cluster_address`. With this configuration, node will first try to reach a cluster on *10.93.46.58:4567* if there is no cluster node, then it will try on *10.93.46.59:4567* and then *10.93.46.60:4567*. If no nodes are up, it will start a new cluster. Variable `wsrep_urls` goes into the [mysql_safe] section so it's important that the mysql server instance is started with the */bin/mysql_safe* and not *bin/mysqld*.

6. Start the *Percona XtraDB Cluster*

On the first node:

```
[root@node1 ~]# /etc/init.d/mysql bootstrap-pxc
```

You should be able to see in console (or in error-log file):

```
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),
```

On the second (and following nodes):

```
[root@node2 ~]# /etc/init.d/mysql start
```

You should be able to see in console (or in error-log file):

```
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-3e6a
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 sta
2014-01-30 09:52:43 26104 [Note] RSA private key file not found: /var/lib/mysql//private_key.pem. So
2014-01-30 09:52:43 26104 [Note] RSA public key file not found: /var/lib/mysql//public_key.pem. Some
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),
```

```
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 versi
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 stage your cluster is ready!

7. Connect to database on any node and create database:

```
$ mysql -uroot
> CREATE DATABASE hello_tom;
```

The new database will be propagated to all nodes.

Enjoy!

5.5 Load balancing with HAProxy

This section describes how to configure *HAProxy* to work in front of the cluster.

Here is the simple configuration file example for *HAProxy*

```
# 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 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 load balance between three nodes. In this case it only checks if mysqld listens on port 3306, but it doesn't take into an account 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 checks. This idea was taken from codership-team google groups.

To implement this setup you will need two scripts:

- **clustercheck** (place to /usr/local/bin) and a config for xinetd and
- **mysqlchk** (place to /etc/xinetd.d) on each node.

Both scripts are available in binaries and source distributions of *Percona XtraDB Cluster*.

You'll need to change /etc/services file by adding the following line on each node:

```
mysqlchk        9200/tcp                # mysqlchk
```

The configuration file for *HAProxy* in this case may look like this:

```
# 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
```

5.6 Setting up PXC reference architecture with HAProxy

This tutorial is a step-by-step guide to set up *Percona XtraDB Cluster*, in a virtualized test sandbox. This example uses Amazon EC2 micro instances, but the content here is applicable for any kind of virtualization technology (for example VirtualBox). You will need 4 virtual machines. 3 for *Percona XtraDB Cluster* and 1 for the client, which will

have *HAProxy*. In this how-to CentOS 6 is used as the operating system, the instructions are similar for any Linux distribution.

The client node will have HAProxy installed and it will redirect requests to *Percona XtraDB Cluster* nodes. This approach works well in real-world scenarios too. Running HAProxy on the application servers instead of having them as dedicated entities gives you benefits like no need for an extra network roundtrip, because loadbalancer and scalability of *Percona XtraDB Cluster*'s load balancing layer scales simply with application servers.

We'll use Percona and EPEL repositories for software installation.

After configuring the repositories you'll be able to install software that will be used. First, install *Percona XtraDB Cluster* on the database nodes.

```
# yum -y install Percona-XtraDB-Cluster-server Percona-XtraDB-Cluster-client percona-xtrabackup
```

Install *HAProxy* and *sysbench* on the client node.

```
# yum -y install haproxy sysbench
```

After installing everything, we'll configure *Percona XtraDB Cluster* first. On the first node, `my.cnf` should look something like this on a relatively weak machine.

```
[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_locks_unsafe_for_binlog=1
innodb_autoinc_lock_mode=2
innodb_buffer_pool_size=400M
innodb_log_file_size=64M
```

You can start your first node now. Make sure that you only start second and third nodes when the first node is up and running (it will serve as a donor for *SST*).

This configuration is for the first node. For the second and third node, you need to change `wsrep_cluster_address` (alternatively, you can use `wsrep_urls` in [mysqld_safe] section), which should point to a node in the cluster which is already up, so it will join the cluster. The `server_id` and `wsrep_node_name` variables have to be different on each host, for `wsrep_node_name`, you can use the output of *hostname* command.

Based on that, for the second node, the differences in the configuration should be the following.

```
server_id=2
wsrep_cluster_address=gcomm://10.116.39.76 # replace this with the IP of your first node
wsrep_node_name=ip-10-244-33-92
```

For the third node, the differences look like this.

```
server_id=3
wsrep_cluster_address=gcomm://10.116.39.76 # replace this with the IP of your first node
wsrep_node_name=ip-10-194-10-179
```

For *SST* we use **xtrabackup**. This means at startup time, the new node will connect to an existing node in the cluster and it takes a backup of that node with xtrabackup and copies it to the new node with *netcat*. After a successful *SST*, you should see this 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
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/m
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
       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*'. Selecte
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 24
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),
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 too.

After the SST's is done, you should check if you have a 3 node cluster.

```
mysql> show global status like 'wsrep_cluster_size';
+--------------------+-------+
| Variable_name      | Value |
+--------------------+-------+
| wsrep_cluster_size | 3     |
+--------------------+-------+
1 row in set (0.00 sec)
```

When all nodes are started, you can set up HAProxy on the client. The point of this is that the application will be able to connect to localhost as *MySQL* server, so although we are using *Percona XtraDB Cluster*, the application will see this as a single MySQL server running on localhost.

In order to achieve this, you'll need to configure HAProxy on the client node. There are 2 possible configurations here. First is configuring round robin, which means you will connect and write to all cluster nodes. This can be done, but because of optimistic locking at commit time, rollbacks can happen if you have conflicting writes. In the second configuration, you will configure HAProxy in a way that it writes only to one node, so the application doesn't have to be prepared about unexpected rollbacks. The first configuration is a good choice in most cases, not handling rollbacks is not healthy in a well behaving application anyway.

HAProxy can be configured in the /etc/haproxy/haproxy.cfg and it should look like this.

```
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, and the others are for *Percona XtraDB Cluster*. *MySQL* will be listening on ports 3306 and 3307. If you connect to port 3306, you'll connect to *pxc-onenode*, and you'll be only using one node at a time (to avoid rollbacks because of optimistic locking). If that node goes off-line, you'll start using an other one. However if you connect to port 3307, you'll be using all three nodes for reads and writes too. In this case the *leastconn* load balancing method is used instead of round robin, which means you always connect to the backend with the least connections established. The statistics page is accessible on the client node with a browser pointed to */haproxy/stats*, the stats auth parameter in the configuration has the credentials for that in plain text. You can also use this for monitoring purposes (the CSV version is good for trending and alerting).

Here *MySQL* is checked via HTTP checks. *MySQL* won't serve these requests. As part of *Percona XtraDB Cluster* packages, we distribute the clustercheck utility which has to be set up. After that, HAProxy will be able to use check *MySQL* via HTTP. The clustercheck script is a simple shell script, which accepts HTTP requests, and checks MySQL on incoming request. If the *Percona XtraDB Cluster* node is ok, it will emit a response with HTTP code 200 OK, otherwise, it emits 503. The script examines `wsrep_local_state` variable.

To set it up, create the clustercheck user.

```
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 username or password, you have to modify them in the script too. Let's test.

```
# clustercheck
HTTP/1.1 200 OK

Content-Type: Content-Type: text/plain
```

Node is running.

You can use *xinetd* to daemonize the script. If *xinetd* is not installed yet, you can install it with yum.

```
# yum -y install xinetd
```

The service itself should be 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
}
```

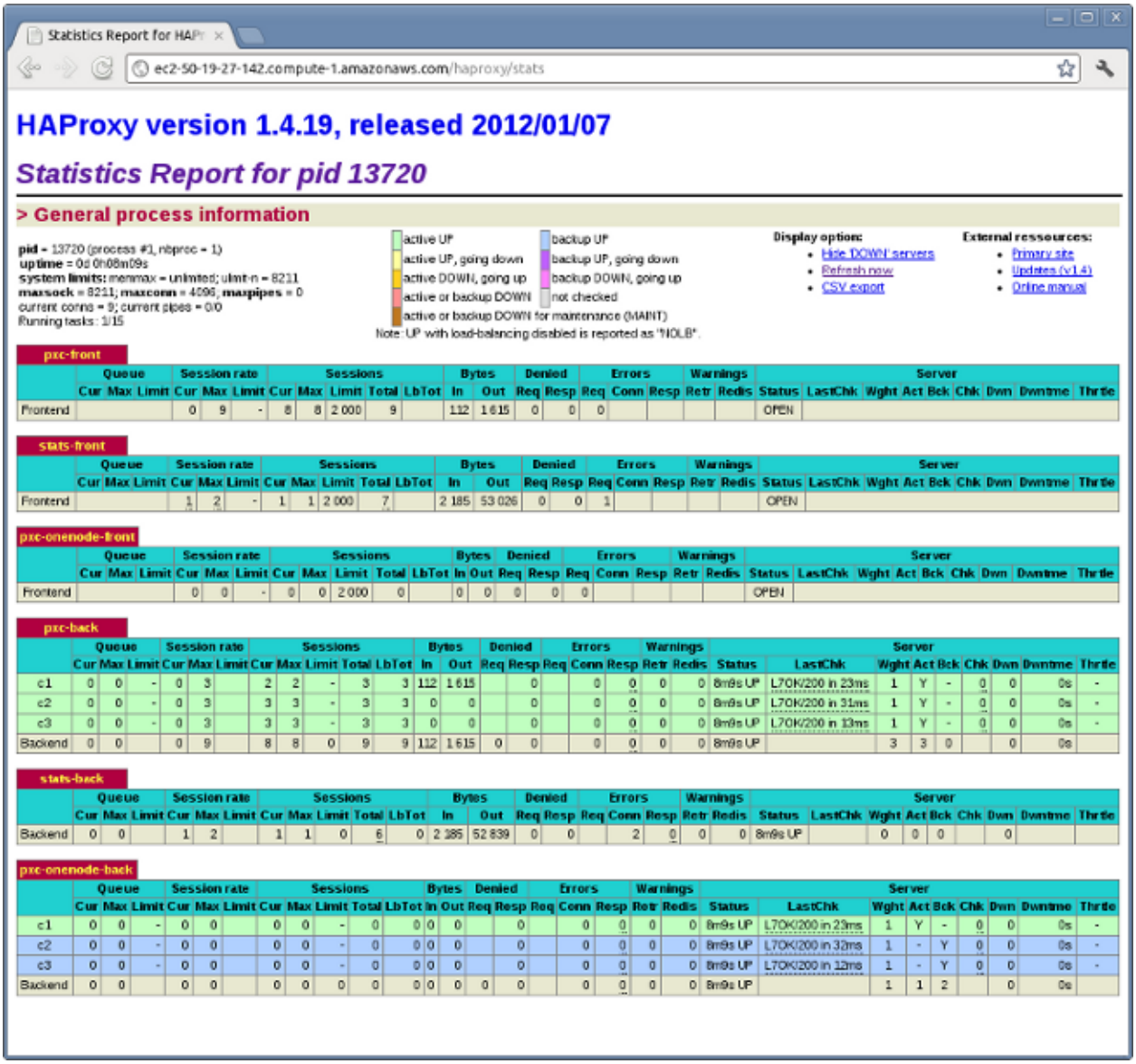
Also, you should add the new service to `/etc/services`.

```
mysqlchk 9200/tcp # mysqlchk
```

Clustercheck will now listen on port 9200 after xinetd restart, and *HAProxy* is ready to check *MySQL* via HTTP.

```
# service xinetd restart
```

If you did everything right so far, the statistics page of *HAProxy* should look like this.



5.6.1 Testing the cluster with sysbench

You can test the cluster using the sysbench (this example uses one from the EPEL repository). First, you need to create a database and a user for it.

```
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)
```

Populate the table with data for the benchmark.

```
# sysbench --test=oltp --db-driver=mysql --mysql-engine-trx=yes --mysql-table-engine=innodb --mysql-
```

You can now run the benchmark against the 3307 port.

```
# sysbench --test=oltp --db-driver=mysql --mysql-engine-trx=yes --mysql-table-engine=innodb --mysql-
```

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	1 615		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	1 615	0	0		0	0	0	0	8m9s UP		3	3	0		0	0s	

This is the status of *pxc-back backend* while the *sysbench* above is running. If you look at Cur column under Session, you can see, that c1 has 2 threads connected, c2 and c3 has 3.

If you run the same benchmark, but against the 3306 backend, *HAProxy* stats will show us that the all the threads are going to hit the c1 server.

```
# sysbench --test=oltp --db-driver=mysql --mysql-engine-trx=yes --mysql-table-engine=innodb --mysql-
```

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	1 615		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	1 615	0	0		0	0	0	0	18m1s UP		1	1	2		0	0s	

This is the status of *pxc-onenode-back* while *sysbench* above is running. Here only c1 has 8 connected threads, 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.

5.7 How to Report Bugs

All bugs can be reported on Launchpad. Please note that error.log files from **all** the nodes need to be submitted.

CHAPTER

SIX

REFERENCE

6.1 *Percona XtraDB Cluster* 5.6 Release notes

6.1.1 *Percona XtraDB Cluster* 5.6.15-25.4

Percona is glad to announce the new release of *Percona XtraDB Cluster* 5.6 on February 20th 2014. Binaries are available from downloads area or from our *software repositories*.

Based on Percona Server 5.6.15-63.0 including all the bug fixes in it, Galera Replicator 3.3 and on Codership wsrep API 5.6.15-25.2 is now the current **General Availability** release. All of *Percona*'s software is open-source and free, all the details of the release can be found in the 5.6.15-25.4 milestone at Launchpad.

Bugs fixed

Percona XtraDB Cluster was reporting `wsrep_cert_deps_distance` to be `1.0` in all cases, which lead to Parallel Applying being disabled for transactions. Bug fixed #1277703.

When binlog was not enabled and there were statements for non *InnoDB* tables, binlog events were created for these statements, but they were never cleaned from transaction cache, which could lead to node crash. Bug fixed #1277986.

Percona XtraDB Cluster didn't check the parameters of `wsrep_provider_options` when starting it up. Bug fixed #1260193.

`clustercheck` script would mark node as down on *Debian* based systems if it was run with default values because it was looking for `my.cnf` in the wrong directory. Bug fixed #1276076.

Deadlock would happen when `NULL` unique key was inserted. Workaround has been implemented to support `NULL` keys, by using the `md5` sum of full row as key value. Bug fixed #1276424.

Variables `innodb-log-group-home-dir` and `innodb-data-home-dir` are now handled by default (ie., there is no need to set them up in `sst_special_dirs`). Bug fixed #1276904.

Build bugs fixed: #1279844, #1277928.

We did our best to eliminate bugs and problems during the testing release, but this is a software, so bugs are expected. If you encounter them, please report them to our bug tracking system.

6.1.2 *Percona XtraDB Cluster* 5.6.15-25.3

Percona is glad to announce the first General Availability release of *Percona XtraDB Cluster* 5.6 on January 30th 2014. Binaries are available from downloads area or from our *software repositories*.

Based on Percona Server 5.6.15-63.0 including all the bug fixes in it, Galera Replicator 3.3 and on Codership wsrep API 5.6.15-25.2 is now the first **General Availability** release. All of *Percona*'s software is open-source and free, all the details of the release can be found in the 5.6.15-25.3 milestone at Launchpad.

New Features

New meta packages are now available in order to make the *Percona XtraDB Cluster installation* easier.

Debian/*Ubuntu* debug packages are now available for Galera and `garbd`.

xtrabackup-v2 SST now supports the GTID replication.

Bugs fixed

Node would get stuck and required restart if `DDL` was performed after `FLUSH TABLES WITH READ LOCK`. Bug fixed #1265656.

Galera provider pause has been fixed to avoid potential deadlock with replicating threads.

Default value for `binlog_format` is now `ROW`. This is done so that *Percona XtraDB Cluster* is not started with wrong defaults leading to non-deterministic outcomes like crash. Bug fixed #1243228.

During the installation of `percona-xtradb-cluster-garbd-3.x` package, *Debian* tries to start it, but as the configuration is not set, it would fail to start and leave the installation in `iF` state. Bug fixed #1262171.

Runtime checks have been added for dynamic variables which are Galera incompatible. Bug fixed #1262188.

During the upgrade process, parallel applying could hit an unresolvable conflict when events were replicated from *Percona XtraDB Cluster* 5.5 to *Percona XtraDB Cluster* 5.6. Bug fixed #1267494.

xtrabackup-v2 is now used as default *SST* method in `wsrep_sst_method`. Bug fixed #1268837.

`FLUSH TABLES WITH READ LOCK` behavior on the same connection was changed to conform to *MySQL* behavior. Bug fixed #1269085.

Read-only detection has been added in clustercheck, which can be helpful during major upgrades (this is used by `xinetd` for HAProxy etc.) Bug fixed #1269469.

Binary log directory is now being cleanup as part of the *XtraBackup SST*. Bug fixed #1273368.

First connection would hang after changing the `wsrep_cluster_address` variable. Bug fixed #1022250.

When `gmcast.listen_addr` was set manually it did not allow nodes own address in gcomm address list. Bug fixed #1099478.

GCache file allocation could fail if file size was a multiple of page size. Bug fixed #1259952.

Group remerge after partitioning event has been fixed. Bug fixed #1232747.

Fixed the OpenSSL linking exceptions. Bug fixed #1259063.

Fixed multiple build bugs: #1262716, #1269063, #1269351, #1272723, #1272732, and #1261996.

Other bugs fixed: #1273101, #1272961, #1271264, and #1253055.

We did our best to eliminate bugs and problems during the testing release, but this is a software, so bugs are expected. If you encounter them, please report them to our bug tracking system.

6.1.3 *Percona XtraDB Cluster* 5.6.15-25.2

Percona is glad to announce the first Release Candidate release of *Percona XtraDB Cluster* 5.6 on December 18th 2013. Binaries are available from downloads area or from our *software repositories*.

Based on Percona Server 5.6.15-63.0 including all the bug fixes in it, Galera Replicator 3.2 and on Codership wsrep API 5.6.15-25.2 is now the first **RELEASE CANDIDATE** release. All of *Percona*'s software is open-source and free, all the details of the release can be found in the 5.6.15-25.2 milestone at Launchpad.

This release contains all of the features and bug fixes in Percona XtraDB Cluster 5.5.34-25.9, plus the following:

New Features

Percona XtraDB Cluster now supports stream compression/decompression with new xtrabackup-sst `compressor/decompressor` options.

New `wsrep_reject_queries` has been implemented that can be used to reject queries for that node. This can be useful if someone wants to manually run maintenance on the node like `mysqldump` without need to change the settings on the load balancer.

XtraBackup SST now supports `innodb_data_home_dir` and `innodb_log_group_home_dir` in the configuration file with `sst_special_dirs` option.

New `wsrep_local_cached_downto` status variable has been introduced. This variable shows the lowest sequence number in `gcache`. This information can be helpful with determining IST and/or SST.

`Garbd` init script and configuration files have been packaged for *CentOS* and *Debian*, in addition, in *Debian* garbd is packaged separately in `percona-xtradb-cluster-garbd-3.x` package.

Bugs fixed

When `grastate.dat` file was not getting zeroed appropriately it would lead to RBR error during the IST. Bug fixed #1180791.

`init stop` script on *CentOS* didn't wait for the server to be fully stopped. This would cause unsuccessful server restart because the `start` action would fail because the daemon would still be running. Bug fixed #1254153.

`DELETE FROM` statement (without `WHERE` clause) would crash slaves if master did not have binlogging enabled. Bug fixed #1254179.

Missing protection for brute force threads against `innodb lock wait time out` would cause applier to fail with lock wait timeout exceeded on `rsync` SST donor. Bug fixed #1255501.

Recent optimizations in 3.x branch introduced a regression in base filename construction which could lead big transactions fail with: `WSREP: Failed to open file '...'`. Bug fixed #1255964.

Joiner node would not initialize storage engines if `rsync` was used for SST and the first view was non-primary. Bug fixed #1257341.

Table level lock conflict resolving was releasing the wrong lock. Bug fixed #1257678.

Resolved the `perl` dependencies needed for *Percona XtraDB Cluster* 5.6. Bug fixed #1258563.

Obsolete dependencies have been removed from *Percona XtraDB Cluster*. Bug fixed #1259256.

`CREATE TABLE AS SELECT` process would remain hanging in case it was run in parallel with the DDL statement on the selected table. Bug fixed #1164893.

Naming of the *Galera* packages have been fixed to avoid the confusion, ie. `Percona-XtraDB-Cluster-galera-56` is `Percona-XtraDB-Cluster-galera-3` now. Bug fixed #1253923.

Fixed rsync SST for compatibility with `rsync` version 3.1.0. Bug fixed #1261673.

Other bugs fixed: #1261138, #1254633.

Note: On *CentOS* 5/6, those who may have installed `percona-xtrabackup-20` with *Percona XtraDB Cluster* 5.6 due to bug #1226185, the upgrade may fail, the dependency issue has been fixed since then, hence replace `percona-xtrabackup-20` with `percona-xtrabackup` before upgrade.

We did our best to eliminate bugs and problems during the testing release, but this is a software, so bugs are expected. If you encounter them, please report them to our bug tracking system.

6.1.4 *Percona XtraDB Cluster* 5.6.14-25.1

Percona is glad to announce the first Beta release of *Percona XtraDB Cluster* 5.6 on November 21st, 2013. Binaries are available from downloads area or from our *software repositories*.

Based on Percona Server 5.6.14-62.0 including all the bug fixes in it, Galera Replicator 3.1 and on Codership wsrep API 5.6.14-25.1 is now the first **BETA** release. All of *Percona*'s software is open-source and free, all the details of the release can be found in the 5.6.14-25.1 milestone at Launchpad.

This release contains all of the features and bug fixes in Percona XtraDB Cluster 5.5.34-23.7.6, plus the following:

New Features

Percona XtraDB Cluster is now using Galera Replicator 3.1 and wsrep API 5.6.14-25.1.

Percona XtraDB Cluster has implemented a number of XtraDB performance improvements for I/O-bound high-concurrency workloads.

Percona XtraDB Cluster has implemented a number of performance improvements for Page cleaner thread tuning.

`ALL_O_DIRECT` method for innodb_flush_method has been ported from 5.5 version.

Statement Timeout feature has been ported from the Twitter branch.

Percona XtraDB Cluster has extended the `SELECT INTO ... OUTFILE` and `SELECT INTO DUMPFILE` to add the support for `UNIX` sockets and named pipes.

Percona XtraDB Cluster has implemented more efficient log block checksums with new innodb_log_checksum_algorithm variable.

Percona XtraDB Cluster now supports Per-query variable statements.

Limited support for Query Cache has been implemented. Query cache cannot still be fully enabled during the startup. To enable query cache, `mysqld` should be started with `query_cache_type=1` and `query_cache_size=0` and then query_cache_size should be changed to desired value during runtime.

`RPM` packages are now made relocatable which means they now support installation to custom prefixes.

Features from Galera

Following are salient features of Galera 3:

- new writeset format optimized for performance and reduced memory usage.
- 128-bit writeset checksums, checked every time before writeset is applied, so that corruption cannot sneak in neither on disk, nor in transfer.
- hardware accelerated CRC32-C algorithm for network packets (and ability to turn it off completely). Parameter: socket.checksum.
- improved handling of preordered (read: master-slave replication) events, that preserves original event ID and offers better throughput.
- ability to divide cluster into segments with minimized communication between them to minimize network traffic over WAN. Parameter: gmcast.segment.

Bugs fixed

Some wsrep variables (`wsrep_provider`, `wsrep_provider_options`, `wsrep_cluster_address`...) could be "doubly" allocated which caused memory leaks. Bug fixed #1072839.

If `SELECT FOR UPDATE...` query was aborted due to multi-master conflict, the client wouldn't get back the deadlock error. From client perspective the transaction would be successful. Bug fixed #1187739.

Temporary tables are not replicated, but any DDL on those tables were, which would generates error messages on other nodes. Bugs fixed #1194156, #1084702, #1212247.

When setting the `gcache.size` to a larger value than the default 128M, the mysql service command did not allow enough time for the file to be preallocated. Bug fixed #1207500.

When installing first `Percona-XtraDB-Cluster-client` and then `Percona-XtraDB-Cluster-server` on two single statements or a single statement with both packages , yum would install `percona-xtrabackup-20` instead `percona-xtrabackup` package as dependency of `Percona-XtraDB-Cluster-server`. Bug fixed #1226185.

Different mutex implementation in the 5.6 could lead to server assertion error. Bug fixed #1233383.

Enabling `wsrep_log_conflicts` variable could cause issues with `lock_mutex`. Bug fixed #1234382.

Server could freeze with mixed DML/DDL load because TOI brute force aborts were not properly propagated. Bug fixed #1239571.

`CREATE TABLE AS SELECT` would fail with explicit temporary tables, when binlogging was enabled and `autocommit` was set to `0`. Bug fixed #1240098.

Transaction cleanup function did not get called for autocommit statements after rollback, it would stay in `LOCAL_COMMIT` even after rollback finished which caused problems when the next transaction started. Bug fixed #1240567.

`DDL` statements like `CREATE TEMPORARY TABLE LIKE` would be replicated and applied in all cluster nodes. This caused temporary table definitions to pile up in slave threads. Bug fixed #1246257.

`CREATE TABLE AS SELECT` was not replicated, if the select result set was empty. Bug fixed #1246921.

Write set flags defined in wsrep API are now exposed to application side appliers too. Bug fixed #1247402.

Local brute force aborts are counted accurately. Bug fixed #1247971.

Certain combinations of transaction rollbacks could leave stale transactional `MDL` locks. Bug fixed #1247978.

After turning `UNIV_SYNC_DEBUG` on, node that was started from clean state would crash immediately at startup. Bug fixed #1248908.

Server built with `UNIV_SYNC_DEBUG` would assert if SQL load has `DELETE` statements on tables with foreign key constraints with `ON DELETE CASCADE` option. Bug fixed #1248921.

Xtrabackup SST dependencies have been added as Optional/Recommended/Suggested dependencies. Bug fixed #1250326.

Other bugs fixed: bug fixed #1020457, bug fixed #1250865, bug fixed #1249753, bug fixed #1248396, bug fixed #1247980, bug fixed #1238278, bug fixed #1234421, bug fixed #1228341, bug fixed #1228333, bug fixed #1225236, bug fixed #1221354, bug fixed #1217138, bug fixed #1206648, bug fixed #1200647, bug fixed #1180792, bug fixed #1163283, bug fixed #1234229, bugs fixed #1250805, bug fixed #1233301, and bug fixed #1210509.

We did our best to eliminate bugs and problems during the testing release, but this is a software, so bugs are expected. If you encounter them, please report them to our bug tracking system.

6.2 Index of wsrep status variables

variable `wsrep_local_state_uuid`

This variable contains *UUID* state stored on the node.

variable `wsrep_protocol_version`

Version of the wsrep protocol used.

variable `wsrep_last_committed`

Sequence number of the last committed transaction.

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.

variable `wsrep_repl_keys`

variable `wsrep_repl_keys_bytes`

variable `wsrep_repl_data_bytes`

variable `wsrep_repl_other_bytes`

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_local_commits`

Number of writesets commited on the node.

variable `wsrep_local_cert_failures`

Number of writesets that failed the certification test.

variable `wsrep_local_replays`

Number of transaction replays due to “asymmetric lock granularity”.

variable wsrep_local_send_queue

Current length of the send queue. Show 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_recv_queue

Current length of the receive queue. Show 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're received. This could be sign that node is overloaded and it will cause the replication throttling.

variable wsrep_local_cached_downto

This variable shows the lowest sequence number in gcache. This information can be helpful with determining IST and/or SST. If the value is 18446744073709551615, then it means there are no writesets in cached in gcache (usual for a single node).

variable wsrep_flow_control_paused_ns

variable wsrep_flow_control_paused

Time since the last status query that replication was paused due to flow control.

variable wsrep_flow_control_sent

Number of `FC_PAUSE` events sent since the last status query.

variable wsrep_flow_control_recv

Number of `FC_PAUSE` events sent and received since the last status query.

variable wsrep_cert_deps_distance

Average distance between highest and lowest sequence number that can be possibly applied in parallel.

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 was writeset with higher sequence number applied before the one with lower sequence number.

variable wsrep_apply_window

Average distance between highest and lowest concurrently applied sequence number.

variable wsrep_commit_oooe

This variable shows how often a transaction has been applied out of order.

variable wsrep_commit_oool

This variable currently isn't being used.

variable wsrep_commit_window

Average distance between highest and lowest concurrently committed sequence number.

variable wsrep_local_state

This variable shows internal Galera state number. Possible values are:

- 1 - Joining (requesting/receiving State Transfer) - 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_comment`

Description of the `wsrep_local_state` variable.

variable `wsrep_cert_index_size`

variable `wsrep_causal_reads_`

Shows the number of writesets processed while the variable `wsrep_causal_reads` was set to `ON`.

variable `wsrep_incoming_addresses`

Shows the comma-separated list of incoming node addresses in the cluster.

variable `wsrep_cluster_conf_id`

Number of cluster membership changes happened.

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_connected`

variable `wsrep_local_bf_aborts`

Number of local transactions that were aborted by slave transactions while being executed.

variable `wsrep_local_index`

Node index in the cluster

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 the queries will fail with `ERROR 1047 (08S01) Unknown Command` error (unless `wsrep_on` variable is set to `0`)

6.3 Index of wsrep system variables

variable `wsrep_OSU_method`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value TOI

This variable can be used to select schema upgrade method. Available values are:

- TOI - Total Order Isolation - When this method is selected `DDL` is processed in the same order with regards to other transactions in each cluster node. This guarantees data consistency. In case of `DDL` statements cluster will have parts of 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 high availability, but it could be fine for quick changes that happen almost instantly (like fast index changes). When `DDL` is processed under total order isolation (TOI) the `DDL` statement will be replicated up front to the cluster. i.e. cluster will assign global transaction ID for the `DDL` statement before the `DDL` processing begins. Then every node in the cluster has the responsibility to execute the `DDL` in the given slot in the sequence of incoming transactions, and this `DDL` execution has to happen with high priority.
- RSU - Rolling Schema Upgrade - When this 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 the `DDL` statement is processed 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 the replication breaks the SST will be triggered when the node tries to join again but the change will be undone.

variable `wsrep_auto_increment_control`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value ON

This variable manages the `auto_increment_increment` and `auto_increment_offset` variables automatically depending on the size of the cluster. This helps prevent `auto_increment` replication conflicts across the cluster by giving each node it's own range of `auto_increment` values. This may not be desirable depending on application's use and assumptions of auto-increments. It can be turned off in Master/Slave clusters.

variable `wsrep_causal_reads`

Command Line Yes

Config File Yes

Scope Global, Local

Dynamic Yes

Default Value OFF

In some cases master may apply event faster than a slave, which can cause master and slave being out-of-sync for a brief moment. When this variable is set to `ON` slave will wait till that event is applied before doing any other queries. Enabling this variable will also result in larger latencies.

variable `wsrep_certify_nonPK`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value ON

When this variable is enabled, primary keys will be generated automatically for the rows that the rows don't have them. Using tables without primary keys is not recommended.

variable `wsrep_cluster_address`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

This minimally needs to be any single other cluster node's address that 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. This takes the form of:

```
gcomm://<node:ip>,<node:ip>,<node:ip>
```

If an empty `gcomm://` is provided, this tells the node to bootstrap it self (i.e., form a new cluster). This is not recommended for production after the cluster has been bootstrapped initially.

variable `wsrep_cluster_name`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value my_wsrep_cluster

This is the name of the cluster and should be identical on all nodes belonging to the same cluster.

variable `wsrep_convert_LOCK_to_trx`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value OFF

This variable is used to convert `LOCK/UNLOCK TABLES` statements to `BEGIN/COMMIT`. Although this can help some older applications to work with multi-master setup it can also result in having huge writesets.

variable `wsrep_data_home_dir`

Command Line No

Config File Yes

Scope Global

Dynamic No

Default Value mysql *datadir*

This variable can be used to set up the directory where wsrep provider will store its files (like `grastate.dat`).

variable `wsrep_dbug_option`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

This variable is used to send the `DBUG` option to the wsrep provider.

variable `wsrep_debug`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value OFF

When this variable is set to `ON`, debug messages will also be logged to the error_log. This can be used when trying to diagnose the problem or when submitting a bug.

variable `wsrep_desync`

Command Line No

Config File Yes

Scope Global

Dynamic Yes

Default Value OFF

When this variable is set to `ON`, the node is desynced from the cluster. Toggling this back will require a IST or a SST depending on how long it was desynced. This is similar to desync which occurs during RSU TOI. This can also be done with `/*! WSREP_DESYNC */` query comment.

variable `wsrep_drupal_282555_workaround`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value OFF

This variable was introduced as workaround for Drupal/MySQL bug #282555. In some cases duplicate key error would occur when inserting the `default` value in into the `auto_increment` field.

variable `wsrep_forced_binlog_format`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value NONE

This variable defines a binlog format that will be always be effective regardless of session binlog format setting. Supported optio

- ROW
- STATEMENT
- MIXED
- NONE - This option resets the forced state of the binlog format

variable `wsrep_load_data_splitting`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value ON

This variable controls whether `LOAD DATA` transaction splitting is wanted or not.

variable `wsrep_log_conflicts`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value OFF

This variable is used to control whether sole cluster conflicts should be logged. When enabled details of conflicting *InnoDB* lock will be logged.

variable `wsrep_max_ws_rows`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value 131072 (128K)

This variable is used to control maximum number of rows each writeset can contain. Anything bigger than this will be rejected.

variable `wsrep_max_ws_size`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value 1073741824 (1G)

This variable is used to control maximum writeset size (in bytes). Anything bigger than this will be rejected.

variable `wsrep_mysql_replication_bundle`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 0 (no grouping)

Range 0-1000

This variable controls how many replication events will be grouped together. Replication events are grouped in SQL slave thread by skipping events which may cause commit. This way the wsrep node acting in *MySQL* slave role and all other wsrep nodes in provider replication group, will see same (huge) transactions. This implementation is still experimental. This may help with the bottleneck of having only one *MySQL* slave facing commit time delay of synchronous provider.

variable `wsrep_node_address`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Format <ip address>[:port]

Default Value Usually set up as primary network interface (eth0)

This variable is used to specify the network address of the node. In some cases when there are multiple NICs available, state transfer might not work if the default NIC is on different network. Setting this variable explicitly to the correct value will makes SST and IST work correctly out of the box. Even in the multi-network setups, IST/SST can be configured to use other interfaces/addresses.

variable `wsrep_node_incoming_address`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value <`wsrep_node_address`>:3306

This is the address at which the node accepts client connections. This is information is used for status variable `wsrep_incoming_addresses` which shows all the active cluster nodes.

variable `wsrep_node_name`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

This variable is used to set up the unique node name.

variable `wsrep_notify_cmd`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

This variable is used to set the notification command that server will execute every time cluster membership or local node status changes.

variable `wsrep_on`

Command Line No

Config File No

Scope Local, Global

Dynamic Yes

Default Value ON

This variable is used to enable/disable wsrep replication. When set to `OFF` server will stop replication and behave like standalone *MySQL* server.

variable `wsrep_preordered`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value OFF

When enabled this option will use new, transparent handling of preordered replication events (like replication from traditional master).

variable `wsrep_provider`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value None

This variable should contain the path to the Galera library (like `/usr/lib64/libgalera_smm.so`).

variable `wsrep_provider_options`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

This variable contains settings currently used by Galera library.

variable `wsrep_recover`

Command Line No

Config File Yes

Scope Global

Dynamic No

Default Value OFF

Location mysqld_safe

When server is started with this variable it will parse Global Transaction ID from log, and if the GTID is found, assign it as initial position for actual server start. This option is used to recover GTID.

variable `wsrep_reject_queries`

Command Line No

Config File Yes

Scope Global

Dynamic Yes

Default Value NONE

This variable can be used to reject queries for that node. This can be useful if someone wants to manually run maintenance on the node like mysqldump without need to change the settings on the load balancer. Following values are supported:

- `NONE` - default - nothing is rejected.
- `ALL` - all queries are rejected with 'Error 1047: Unknown command'.
- `ALL_KILL` - all queries are rejected and existing client connections are also killed without waiting.

Note, that this doesn't affect galera replication in any way, only the applications which connect to database are affected. If you are looking for desyncing a node then `wsrep_desync` is the right option for that.

variable `wsrep_replicate_myisam`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value OFF

This variable controls if *MyISAM* will be replicated or not. *MyISAM* replication is still experimental and that is one of the reasons why this variable is set to `OFF` by default.

variable `wsrep_retry_autocommit`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 1

This variable sets the number of times autocommitted transactions will be tried 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 the client's knowledge with the hopes that it will pass the next time. This can be useful to help an application using autocommit to avoid the deadlock errors that can be triggered by replication conflicts. If this variable is set to `0` transaction won't be retried and if it is set to `1` it will be retried once.

variable `wsrep_slave_threads`

Command Line Yes

Config File Yes

Scope Global

Dynamic No

Default Value 1

This variable controls the number of threads that can apply replication transactions in parallel. Galera supports true parallel replication, replication that applies transactions in parallel only when it is safe to do so. The default value can be increased for better throughput. If any replication consistency problems are encountered, it's recommended to set this back to `1` to see if that resolves the issue.

variable `wsrep_sst_auth`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Format <username>:<password>

This variable should contain the authentication information needed for State Snapshot Transfer. Required information depends on the method selected in the `wsrep_sst_method`. More information about required authentication can be found in the *State Snapshot Transfer* documentation. This variable will appear masked in the logs and in the `SHOW VARIABLES` query.

variable `wsrep_sst_donor`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

This variable contains the name (`wsrep_node_name`) of the preferred donor for the SST. If no node is selected as a preferred donor it will be chosen from one of the available nodes automatically.

variable `wsrep_sst_donor_rejects_queries`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value OFF

When this variable is enabled SST donor node will not accept incoming queries, instead it will reject queries with `UNKNOWN COMMAND` error code. This can be used to signal load-balancer that the node isn't available.

variable `wsrep_sst_method`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value xtrabackup-v2

Recommended xtrabackup-v2

This variable sets up the method for taking the State Snapshot Transfer (SST). Available options are:

- xtrabackup - uses Percona XtraBackup to perform the SST, this method requires `wsrep_sst_auth` to be set up with <user>:<password> which *XtraBackup* will use on donor. Privileges and permissions needed for running *XtraBackup* can be found here.
- xtrabackup-v2 - This is same as xtrabackup SST except that it uses newer protocol, hence is not compatible. This is the **recommended** option for PXC 5.5.34 and above. For more details, please check *Xtrabackup SST Configuration* and *Percona XtraDB Cluster Errata*. This is also the default SST method. For SST with older nodes (< 5.5.34), use xtrabackup as the SST method.
- rsync - uses `rsync` to perform the SST, this method doesn't use the `wsrep_sst_auth`
- mysqldump - uses `mysqldump` to perform the SST, this method requires `wsrep_sst_auth` to be set up with <user>:<password>, where user has root privileges on the server.
- custom_script_name - Galera supports Scriptable State Snapshot Transfer. This enables users to create their own custom script for performing an SST.
- skip - this option can be used to skip the SST, it can be used when initially starting the cluster and manually restore the same data to all nodes. It shouldn't be used as permanent setting because it could lead to data inconsistency across the nodes.

Note:

Note the following:

- mysqldump SST is not recommended unless it is required for specific reasons. Also, it is not compatible with `bind_address = 127.0.0.1 or localhost` and will cause startup to fail if set so.
- Xtrabackup-v2 SST is currently recommended if you have innodb-log-group_home-dir/innodb-data-home-dir in your cnf. Refer to `sst-special-dirs` for more.
- Only xtrabackup-v2 and rsync provide gtid_mode async-slave support during SST.

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variable `wsrep_sst_receive_address`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

Default Value AUTO

This variable is used to configure address on which the node expects the SST.

variable `wsrep_start_position`

Command Line Yes

Config File Yes

Scope Global

Dynamic Yes

This variable contains the `UUID:seqno` value. By setting all the nodes to have the same value for this option cluster can be set up without the state transfer.

6.4 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.

```
$ 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
/*!40019 SET @@session.max_insert_delayed_threads=0*/;
/*!50003 SET @OLD_COMPLETION_TYPE=@@COMPLETION_TYPE,COMPLETION_TYPE=0*/;
DELIMITER /*!*/;
# at 4
#120715  9:45:56 server id 1  end_log_pos 107     Start: binlog v 4, server v 5.5.25-debug-l
# Warning: this binlog is either in use or was not closed properly.
ROLLBACK/*!*/;
BINLOG '
NHUCUA8BAAAAZwAAAGsAAAABAAQANS41LjI1LWRlYnVnLWxvZwAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAA0dQJQEzgNAAgAEgAEBAQEEgAAVAAEGggAAAAICAgCAA==
'/*!*/;
# at 107
#130226 11:48:50 server id 1  end_log_pos 83      Query   thread_id=3     exec_time=0     er
use `test`/*!*/;
SET TIMESTAMP=1361875730/*!*/;
SET @@session.pseudo_thread_id=3/*!*/;
SET @@session.foreign_key_checks=1, @@session.sql_auto_is_null=0, @@session.unique_checks=1,
SET @@session.sql_mode=1437073440/*!*/;
SET @@session.auto_increment_increment=3, @@session.auto_increment_offset=2/*!*/;
/*!\C utf8 *//*!*/;
SET @@session.character_set_client=33,@@session.collation_connection=33,@@session.collation_
SET @@session.lc_time_names=0/*!*/;
SET @@session.collation_database=DEFAULT/*!*/;
drop table test
/*!*/;
DELIMITER ;
# End of log file
ROLLBACK /* added by mysqlbinlog */;
/*!50003 SET COMPLETION_TYPE=@OLD_COMPLETION_TYPE*/;
```

  This information can be used for checking the *MySQL* error log for the corresponding error message.

```
130226 11:48:50 [ERROR] Slave SQL: Error 'Unknown table 'test'' on query. Default database:
130226 11:48:50 [Warning] WSREP: RBR event 1 Query apply warning: 1, 3
130226 11:48:50 [Warning] WSREP: Ignoring error for TO isolated action: source: dd40ad88-7ff
```

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.

  Example of this file looks like this:

  ```
  # GALERA saved state
  version: 2.1
  uuid:    1917033b-7081-11e2-0800-707f5d3b106b
  seqno:   -1
  cert_index:
  ```

6.5 Frequently Asked Questions

6.5.1 Q: How do you solve locking issues like auto increment?

A: For auto-increment particular, Cluster changes auto_increment_offset for each new node. In the single node workload, locking handled by usual way how *InnoDB* handles locks. In case of write load on several nodes, Cluster uses optimistic locking and application may receive lock error in the response on COMMIT query.

6.5.2 Q: What if one of the nodes crashes and innodb recovery roll back some transactions?

A: When the node crashes, after the restart it will copy whole dataset from another node (if there were changes to data since crash).

6.5.3 Q: How can I check the Galera node health?

A: Your check should be simply:

```
SELECT * FROM someinnodbtable WHERE id=1;
```

3 different results 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)

6.5.4 Q: How does XtraDB Cluster handle big transaction?

A: XtraDB Cluster populates write set in memory before replication and this sets one limit for how large transactions make sense. There are wsrep variables for max row count and max size of of write set to make sure that server is not running out of memory.

6.5.5 Q: Is there a chance to have different table structure on the nodes?

What I mean is like having 4 nodes, 4 tables like sessions_a, sessions_b, sessions_c and sessions_d and have each only on one of the nodes?

A: Not at the moment for InnoDB tables. But it will work for MEMORY tables.

6.5.6 Q: What if a node fail and/or what if there is a network issue between them?

A: Then Quorum mechanism in XtraDB Cluster will decide what nodes can accept traffic and will shutdown nodes that not belong to quorum. Later when the failure is fixed, the nodes will need to copy data from working cluster.

6.5.7 Q: How would it handle split brain?

A: It would not handle it. The *split brain* is hard stop, XtraDB Cluster can't resolve it. That's why the minimal recommendation is to have 3 nodes. However there is possibility to allow a node to handle the traffic, option is:

```
wsrep_provider_options="pc.ignore_sb = yes"
```

6.5.8 Q: Is it possible to set up cluster without state transfer

A: It is possible in two ways:

1. By default Galera reads starting position from a text file <datadir>/grastate.dat. Just make this file identical on all nodes, and there will be no state transfer upon start.
2. With `wsrep_start_position` variable - start the nodes with the same *UUID:seqno* value and there you are.

6.5.9 Q: I have a two nodes setup. When node1 fails, node2 does not accept commands, why?

A: This is expected behavior, to prevent *split brain*. See previous question.

6.5.10 Q: What tcp ports are used by Percona XtraDB Cluster?

A: You may need to open up to 4 ports if you are using firewall.

1. Regular MySQL port, default 3306.
2. Port for group communication, default 4567. It can be changed by the option:

   ```
   wsrep_provider_options ="gmcast.listen_addr=tcp://0.0.0.0:4010; "
   ```

3. Port for State Transfer, default 4444. It can be changed by the option:

   ```
   wsrep_sst_receive_address=10.11.12.205:5555
   ```

4. Port for Incremental State Transfer, default port for group communication + 1 (4568). It can be changed by the option:

   ```
   wsrep_provider_options = "ist.recv_addr=10.11.12.206:7777; "
   ```

6.5.11 Q: Is there "async" mode for Cluster or only "sync" commits are supported?

A: There is no "async" mode, all commits are synchronous on all nodes. Or, to be fully correct, the commits are "virtually" synchronous. Which means that transaction should pass "certification" on nodes, not physical commit. "Certification" means a guarantee that transaction does not have conflicts with another transactions on corresponding node.

6.5.12 Q: Does it work with regular MySQL replication?

A: Yes. On the node you are going to use as master, you should enable log-bin and log-slave-update options.

6.5.13 Q: Init script (/etc/init.d/mysql) does not start

A: Try to disable SELinux. Quick way is:

```
echo 0 > /selinux/enforce
```

6.5.14 Q: I'm getting "nc: invalid option – 'd'" in the sst.err log file

A: This is Debian/Ubuntu specific error, Percona-XtraDB-Cluster uses netcat-openbsd package. This dependency has been fixed in recent releases. Future releases of PXC will be compatible with any netcat (bug #959970).

6.6 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*, *.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 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.

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`, 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.

innodb_file_per_table InnoDB option to use separate .ibd files for each table.

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).

.ibd On a multiple tablespace setup (*innodb_file_per_table* enabled), *MySQL* will store each newly created table on a file with a `.ibd` extension.

.MYD Each *MyISAM* table has `.MYD` (MYData) file which contains the data on it.

.MYI Each *MyISAM* table has `.MYI` (MYIndex) file which contains the table's indexes.

.MRG Each table using the **MERGE** storage engine, besides of a *.frm* file, will have *.MRG* file containing the names of the *MyISAM* tables associated with it.

.TRG File containing the triggers associated to a table, e.g. `mytable.TRG`. With the *.TRN* file, they represent all the trigger definitions.

.TRN File containing the triggers' Names associated to a table, e.g. `mytable.TRN`. With the *.TRG* file, they represent all the trigger definitions.

.ARM Each table with the **Archive Storage Engine** has `.ARM` file which contains the metadata of it.

.ARZ Each table with the **Archive Storage Engine** has `.ARZ` file which contains the data of it.

.CSM Each table with the **CSV Storage Engine** has `.CSM` file which contains the metadata of it.

.CSV Each table with the **CSV Storage** engine has `.CSV` file which contains the data of it (which is a standard Comma Separated Value file).

.opt *MySQL* stores options of a database (like charset) in a file with a `.opt` extension in the database directory.

- *genindex*
- *search*

INDEX

Symbols

C

D

E

G

H

I

J

L

M

N

P

Q

R

S

T

U

W

X