MySQL HA/Scalability Guide

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Abstract

This is the MySQL HA/Scalability Guide extract from the MySQL Reference Manual.

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Chapter 1. High Availability and Scalability

When using MySQL you may need to ensure the availability or scalability of your MySQL installation. Availability refers to the ability to cope with, and if necessary recover from, failures on the host, including failures of MySQL, the operating system, or the hardware. Scalability refers to the ability to spread the load of your application queries across multiple MySQL servers. As your application and usage increases, you may need to spread the queries for the application across multiple servers to improve response times.

There are a number of solutions available for solving issues of availability and scalability. The two primary solutions supported by MySQL are MySQL Replication and MySQL Cluster. Further options are available using third-party solutions such as DRBD (Distributed Replicated Block Device) and Heartbeat, and more complex scenarios can be solved through a combination of these technologies. These tools work in different ways:

- *MySQL Replication* enables statements and data from one MySQL server instance to be replicated to another MySQL server instance. Without using more complex setups, data can only be replicated from a single master server to any number of slaves. The replication is asynchronous, so the synchronization does not take place in real time, and there is no guarantee that data from the master will have been replicated to the slaves.
  - **Advantages**
    - MySQL Replication is available on all platforms supported by MySQL, and since it isn't operating system-specific it can operate across different platforms.
    - Replication is asynchronous and can be stopped and restarted at any time, making it suitable for replicating over slower links, partial links and even across geographical boundaries.
    - Data can be replicated from one master to any number of slaves, making replication suitable in environments with heavy reads, but light writes (for example, many web applications), by spreading the load across multiple slaves.
  - **Disadvantages**
    - Data can only be written to the master. In advanced configurations, though, you can set up a multiple-master configuration where the data is replicated around a ring configuration.
    - There is no guarantee that data on master and slaves will be consistent at a given point in time. Because replication is asynchronous there may be a small delay between data being written to the master and it being available on the slaves. This can cause problems in applications where a write to the master must be available for a read on the slaves (for example a web application).
  - **Recommended uses**
    - Scale-out solutions that require a large number of reads but fewer writes (for example, web serving).
    - Logging/data analysis of live data. By replicating live data to a slave you can perform queries on the slave without affecting the operation of the master.
    - Online backup (availability), where you need an active copy of the data available. You need to combine this with other tools, such as custom scripts or Heartbeat. However, because of the asynchronous architecture, the data may be incomplete.
    - Offline backup. You can use replication to keep a copy of the data. By replicating the data to a slave, you take the slave down and get a reliable snapshot of the data (without MySQL running), then restart MySQL and replication to catch up. The master (and any other slaves) can be kept running during this period.

  For information on setting up and configuring replication, see Replication.
- *MySQL Cluster* is a synchronous solution that enables multiple MySQL instances to share database information. Unlike replication, data in a cluster can be read from or written to any node within the cluster, and information will be distributed to the other nodes.
  - **Advantages**
    - Offers multiple read and write nodes for data storage.
    - Provides automatic failover between nodes. Only transaction information for the active node being used is lost in the event of a failure.
    - Data on nodes is instantaneously distributed to the other data nodes.

- **Disadvantages**
  - Available on a limited range of platforms.
  - Nodes within a cluster should be connected via a LAN; geographically separate nodes are not supported. However, you can replicate from one cluster to another using MySQL Replication, although the replication in this case is still asynchronous.
- **Recommended uses**
  - Applications that need very high availability, such as telecoms and banking.
  - Applications that require an equal or higher number of writes compared to reads.

For information on MySQL Cluster, see MySQL Cluster.

- *DRBD (Distributed Replicated Block Device)* is a solution from Linbit supported only on Linux. DRBD creates a virtual block device (which is associated with an underlying physical block device) that can be replicated from the primary server to a secondary server. You create a file system on the virtual block device, and this information is then replicated, at the block level, to the secondary server.

  Because the block device, not the data you are storing on it, is being replicated the validity of the information is more reliable than with data-only replication solutions. DRBD can also ensure data integrity by only returning from a write operation on the primary server when the data has been written to the underlying physical block device on both the primary and secondary servers.

  - **Advantages**
    - Provides high availability and data integrity across two servers in the event of hardware or system failure.
    - Can ensure data integrity by enforcing write consistency on the primary and secondary nodes.
  - **Disadvantages**
    - Only provides a method for duplicating data across the nodes. Secondary nodes cannot use the DRBD device while data is being replicated, and so the MySQL on the secondary node cannot be simultaneously active.
    - Can not be used to scale performance, since you can not redirect reads to the secondary node.
  - **Recommended uses**
    - High availability situations where concurrent access to the data is not required, but instant access to the active data in the event of a system or hardware failure is required.

  For information on configuring DRBD and configuring MySQL for use with a DRBD device, see Chapter 2, *Using MySQL with DRBD*.

- *`memcached`* is a simple, yet highly-scalable key-based cache that stores data and objects wherever dedicated or spare RAM is available for very quick access by applications. You use `memcached` in combination with your application and MySQL to reduce the number of reads from the database.

  When writing your application, you first try to load the data from the `memcached` cache, if the data you are looking for cannot be found, you then load the data from the MySQL database as normal, and populate the cache with the information that you loaded. Because `memcached` can be used to store entire objects that might normally consist of multiple table lookups and aggregations, you can significantly increase the speed of your application because the requirement to load data directly from the database is reduced or even eliminated. Because the cache is entirely in RAM, the response time is very fast, and the information can be distributed among many servers to make the best use of any spare RAM capacity.

  - **Advantages**
    - Very fast, RAM based, cache.
    - Reduces load on the MySQL server, allowing MySQL to concentrate on persistent storage and data writes.
    - Highly distributable and scalable, allowing multiple servers to be part of the cache group.
    - Highly portable - the `memcached` interface is supported by many languages and systems, including Perl, Python, PHP, Ruby, Java and the MySQL server.
  - **Disadvantages**

    - Data is not persistent - you should only use the cache to store information that can otherwise be loaded from a MySQL database.

    - Fault tolerance is implied, rather than explicit. If a `memcached` node fails then your application must be capable of loading the data from MySQL and updating the cache.

  - **Recommended uses**

    - High scalability situations where you have a very high number of reads, particularly of complex data objects that can easily be cached in the final, usable, form directly within the cache.

  For information on installing, configuring and using `memcached`, including using the many APIs available for communicating with `memcached`, see Chapter 4, *Using MySQL with `memcached`*.

- *Heartbeat* is a software solution for Linux. It is not a data replication or synchronization solution, but a solution for monitoring servers and switching active MySQL servers automatically in the event of failure. Heartbeat needs to be combined with MySQL Replication or DRBD to provide automatic failover.

  For more information on configuring Heartbeat for use with MySQL and DRBD, see Chapter 3, *Using Linux HA Heartbeat*.

The information and suitability of the various technologies and different scenarios is summarized in the following table.

Requirements	**MySQL Replication**	**MySQL Replication + Heartbeat**	**MySQL Heartbeat + DRBD**	**MySQL Cluster**	**MySQL + `memcached`**
Availability					
Automated IP failover	No	Yes	Yes	No	No
Automated database failover	No	No	Yes	Yes	No
Typical failover time	User/ script-dependent	Varies	< 30 seconds	< 3 seconds	App dependent
Automatic resynchronization of data	No	No	Yes	Yes	No
Geographic redundancy support	Yes	Yes	Yes, when combined with MySQL Replication	Yes, when combined with MySQL Replication	No
Scalability					
Built-in load balancing	No	No	No	Yes	Yes
Supports Read-intensive applications	Yes	Yes	Yes, when combined with MySQL Replication	Yes	Yes
Supports Write-intensive applications	No	No	Yes	Yes	No
Maximum number of nodes per group	One master, multiple slaves	One master, multiple slaves	One active (primary), one passive (secondary) node	255	Unlimited
Maximum number of slaves	Unlimited (reads only)	Unlimited (reads only)	One (failover only)	Unlimited (reads only)	Unlimited

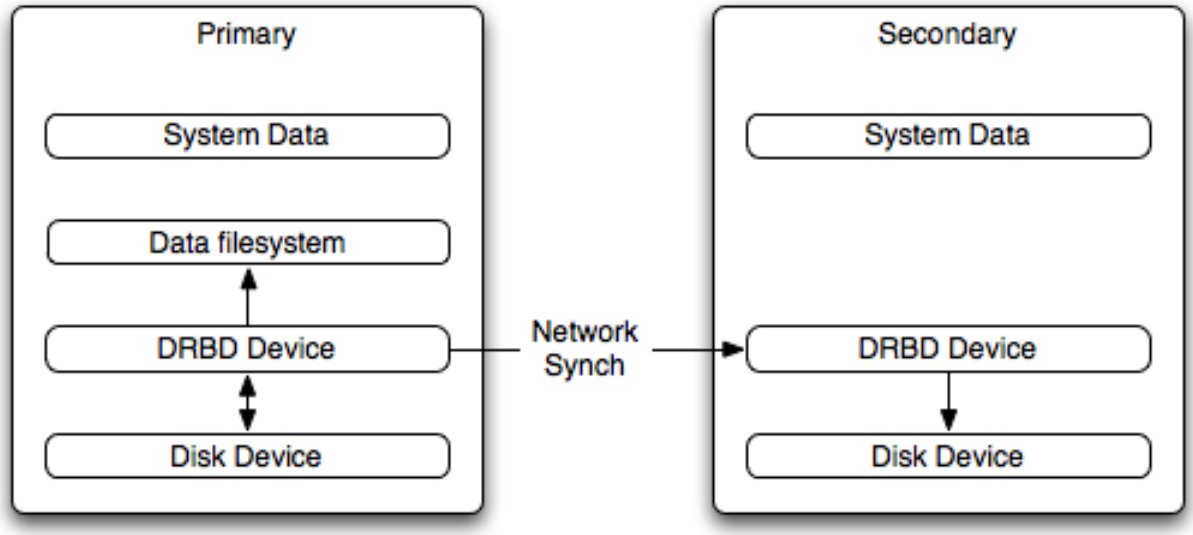
Chapter 2. Using MySQL with DRBD

The Distributed Replicated Block Device (DRBD) is a Linux Kernel module that constitutes a distributed storage system. You can use DRBD to share block devices between Linux servers and, in turn, share file systems and data.

DRBD implements a block device which can be used for storage and which is replicated from a primary server to one or more secondary servers. The distributed block device is handled by the DRBD service. Writes to the DRBD block device are distributed among the servers. Each DRBD service writes the information from the DRBD block device to a local physical block device (hard disk).

On the primary data writes are written both to the underlying physical block device and distributed to the secondary DRBD services. On the secondary, the writes received through DRBD and written to the local physical block device. On both the primary and the secondary, reads from the DRBD block device are handled by the underlying physical block device. The information is shared between the primary DRBD server and the secondary DRBD server synchronously and at a block level, and this means that DRBD can be used in high-availability solutions where you need failover support.

Figure 2.1. DRBD Architecture Overview



When used with MySQL, DRBD can be used to ensure availability in the event of a failure. MySQL is configured to store information on the DRBD block device, with one server acting as the primary and a second machine available to operate as an immediate replacement in the event of a failure.

For automatic failover support you can combine DRBD with the Linux Heartbeat project, which will manage the interfaces on the two servers and automatically configure the secondary (passive) server to replace the primary (active) server in the event of a failure. You can also combine DRBD with MySQL Replication to provide both failover and scalability within your MySQL environment.

For information on how to configure DRBD and MySQL, including Heartbeat support, see Section 2.1, “Configuring the DRBD Environment”.

An FAQ for using DRBD and MySQL is available. See MySQL 5.0 FAQ — MySQL, DRBD, and Heartbeat.

> **Note**
>
> Because DRBD is a Linux Kernel module it is currently not supported on platforms other than Linux.

2.1. Configuring the DRBD Environment

To set up DRBD, MySQL and Heartbeat you need to follow a number of steps that affect the operating system, DRBD and your MySQL installation.

Before starting the installation process, you should be aware of the following information, terms and requirements on using DRBD:

- DRBD is a solution for enabling high-availability, and therefore you need to ensure that the two machines within your DRBD setup are as identically configured as possible so that the secondary machine can act as a direct replacement for the primary machine in the event of system failure.
- DRBD works through two (or more) servers, each called a *node*
- The node that contains the primary data, has read/write access to the data, and in an HA environment is the currently active node is called the *primary*.
- The server to which the data is replicated is referred as *secondary*.
- A collection of nodes that are sharing information are referred to as a *DRBD cluster*.
- For DRBD to operate you must have a block device on which the information can be stored on *each* DRBD node. The *lower level* block device can be a physical disk partition, a partition from a volume group or RAID device or any other block device.

  Typically you use a spare partition on which the physical data will be stored . On the primary node, this disk will hold the raw data that you want replicated. On the secondary nodes, the disk will hold the data replicated to the secondary server by the DRBD service. Ideally, the size of the partition on the two DRBD servers should be identical, but this is not necessary as long as there is enough space to hold the data that you want distributed between the two servers.
- For the distribution of data to work, DRBD is used to create a logical block device that uses the lower level block device for the actual storage of information. To store information on the distributed device, a file system is created on the DRBD logical block device.
- When used with MySQL, once the file system has been created, you move the MySQL data directory (including InnoDB data files and binary logs) to the new file system.
- When you set up the secondary DRBD server, you set up the physical block device and the DRBD logical block device that will store the data. The block device data is then copied from the primary to the secondary server.

The overview for the installation and configuration sequence is as follows:

1. First you need to set up your operating system and environment. This includes setting the correct host name, updating the system and preparing the available packages and software required by DRBD, and configuring a physical block device to be used with the DRBD block device. See Section 2.1.1, “Setting Up Your Operating System for DRBD”.
2. Installing DRBD requires installing or compiling the DRBD source code and then configuring the DRBD service to set up the block devices that will be shared. See Section 2.1.2, “Installing and Configuring DRBD”.
3. Once DRBD has been configured, you must alter the configuration and storage location of the MySQL data. See Section 2.2, “Configuring MySQL for DRBD”.

You may optionally want to configure high availability using the Linux Heartbeat service. See Chapter 3, *Using Linux HA Heartbeat*, for more information.

2.1.1. Setting Up Your Operating System for DRBD

To set your Linux environment for using DRBD there are a number of system configuration steps that you must follow.

- Make sure that the primary and secondary DRBD servers have the correct host name, and that the host names are unique. You can verify this by using the `uname` command:

  ```
  shell> uname -n
  drbd-one
  ```

  If the host name is not set correctly, edit the appropriate file (usually `/etc/sysconfig/network`, `/etc/hostname`, or `/etc/conf.d/hostname`) and set the name correctly.
- Each DRBD node must have a unique IP address. Make sure that the IP address information is set correctly within the network configuration and that the host name and IP address has been set correctly within the `/etc/hosts` file.
- Although you can rely on the DNS or NIS system for host resolving, in the event of a major network failure these services may not be available. If possible, add the IP address and host name of each DRBD node into the /etc/hosts file for each machine. This will ensure that the node information can always be determined even if the DNS/NIS servers are unavailable.
- As a general rule, the faster your network connection the better. Because the block device data is exchanged over the network,

everything that will be written to the local disk on the DRBD primary will also be written to the network for distribution to the DRBD secondary.

For tips on configuring a faster network connection see Section 2.3, “Optimizing Performance and Reliability”.

- You must have a spare disk or disk partition that you can use as the physical storage location for the DRBD data that will be replicated. You do not have to have a complete disk available, a partition on an existing disk is acceptable.

  If the disk is unpartitioned, partition the disk using `fdisk`, `cfdisk` or other partitioning solution. Do not create a file system on the new partition.

  Remember that you must have a physical disk available for the storage of the replicated information on each DRBD node. Ideally the partitions that will be used on each node should be of an identical size, although this is not strictly necessary. Do, however, ensure that the physical partition on the DRBD secondary is at least as big as the partitions on the DRBD primary node.

- If possible, upgrade your system to the latest available Linux kernel for your distribution. Once the kernel has been installed, you must reboot to make the kernel active. To use DRBD you will also need to install the relevant kernel development and header files that are required for building kernel modules. Platform specification information for this is available later in this section.

Before you compile or install DRBD, you must make sure the following tools and files are in place:

- Kernel header files
- Kernel source files
- GCC Compiler
- `glib 2`
- `flex`

Here are some operating system specific tips for setting up your installation:

- **Tips for Red Hat (including CentOS and Fedora)**:

  Use `up2date` or `yum` to update and install the latest kernel and kernel header files:

```
root-shell> up2date kernel-smp-devel kernel-smp
```

  Reboot. If you are going to build DRBD from source, then update your system with the required development packages:

```
root-shell> up2date glib-devel openssl-devel libgcrypt-devel glib2-devel \
pkgconfig ncurses-devel rpm-build rpm-devel redhat-rpm-config gcc \
gcc-c++ bison flex gnutls-devel lm_sensors-devel net-snmp-devel \
python-devel bzip2-devel libselinux-devel perl-DBI
```

  If you are going to use the pre-built DRBD RPMs:

```
root-shell> up2date gnutls lm_sensors net-snmp ncurses libgcrypt glib2 openssl glib
```

- **Tips for Debian, Ubuntu, Kubuntu**:

  Use `apt-get` to install the kernel packages

```
root-shell> apt-get install linux-headers linux-image-server
```

  If you are going to use the pre-built Debian packages for DRBD then you should not need any additional packages.

  If you want to build DRBD from source, you will need to use the following command to install the required components:

```
root-shell> apt-get install devscripts flex bison build-essential \
dpkg-dev kernel-package debconf-utils dpatch debhelper \
libnet1-dev e2fslibs-dev libglib2.0-dev automake1.9 \
libgnutls-dev libtool libltdl3 libltdl3-dev
```

- **Tips for Gentoo**:

  Gentoo is a source based Linux distribution and therefore many of the source files and components that you will need are either already installed or will be installed automatically by `emerge`.

  To install DRBD 0.8.x, you must unmask the `sys-cluster/drbd` build by adding the following line to `/etc/portage/package.keywords`:

```
sys-cluster/drbd ~x86
sys-cluster/drbd-kernel ~x86
```

  If your kernel does not already have the userspace to kernelspace linker enabled, then you will need to rebuild the kernel with this option. The best way to do this is to use `genkernel` with the `--menuconfig` option to select the option and then re-build the kernel. For example, at the command line as `root`:

```
root-shell> genkernel --menuconfig all
```

  Then through the menu options, select DEVICE DRIVERS, CONNECTOR - UNIFIED USERSPACE <-> KERNELSPACE LINKER and finally press 'y' or 'space' to select the CONNECTOR - UNIFIED USERSPACE <-> KERNELSPACE LINKER option. Then exit the menu configuration. The kernel will be rebuilt and installed. If this is a new kernel, make sure you update your bootloader accordingly. Now reboot to enable the new kernel.

2.1.2. Installing and Configuring DRBD

To install DRBD you can choose either the pre-built binary installation packages or you can use the source packages and build from source. If you want to build from source you must have installed the source and development packages.

If you are installing using a binary distribution then you must ensure that the kernel version number of the binary package matches your currently active kernel. You can use `uname` to find out this information:

```
shell> uname -r
2.6.20-gentoo-r6
```

Once DRBD has been built and installed, you need to edit the `/etc/drbd.conf` file and then run a number of commands to build the block device and set up the replication.

Although the steps below are split into those for the primary node and the secondary node, it should be noted that the configuration files for all nodes should be identical, and many of the same steps have to be repeated on each node to enable the DRBD block device.

Building from source:

To download and install from the source code:

1. Download the source code.
2. Unpack the package:

```
shell> tar zxf drbd-8.3.0.tar.gz
```

3. Change to the extracted directory, and then run `make` to build the DRBD driver:

```
shell> cd drbd-8.3.0
shell> make
```

4. Install the kernel driver and commands:

```
shell> make install
```

Binary Installation:

- **SUSE Linux Enterprise Server (SLES)**

  For SUSE, use `yast`:

```
shell> yast -i drbd
```

Alternatively:

```
shell> rug install drbd
```

- **Debian**

  Use `apt-get` to install the modules. You do not need to install any other components.

  ```
  shell> apt-get install drbd8-utils drbd8-module
  ```

- **Debian 3.1 and 4.0**

  You must install the `module-assistant` to build the DRBD kernel module, in addition to the DRBD components.

  ```
  shell> apt-get install drbd0.7-utils drbd0.7-module-source \
    build-essential module-assistant
  shell> module-assistant auto-install drbd0.7
  ```

- **CentOS**

  DRBD can be installed using yum:

  ```
  shell> yum install drbd kmod-drbd
  ```

- **Ubuntu**

  You must enable the universe component for your preferred Ubuntu mirror in `/etc/apt/sources.list`, and then issue these commands:

  ```
  shell> apt-get update
  shell> apt-get install drbd8-utils drbd8-module-source \
    build-essential module-assistant
  shell> module-assistant auto-install drbd8
  ```

- **Gentoo**

  You can now `emerge` DRBD 0.8.x into your Gentoo installation:

  ```
  root-shell> emerge drbd
  ```

  Once `drbd` has been downloaded and installed, you need to decompress and copy the default configuration file from `/usr/share/doc/drbd-8.0.7/drbd.conf.bz2` into `/etc/drbd.conf`.

2.1.3. Setting Up a DRBD Primary Node

To set up a DRBD primary node you need to configure the DRBD service, create the first DRBD block device and then create a file system on the device so that you can store files and data.

The DRBD configuration file `/etc/drbd.conf` defines a number of parameters for your DRBD configuration, including the frequency of updates and block sizes, security information and the definition of the DRBD devices that you want to create.

The key elements to configure are the `on` sections which specify the configuration of each node.

To follow the configuration, the sequence below shows only the changes from the default `drbd.conf` file. Configurations within the file can be both global or tied to specific resource.

1. Set the synchronization rate between the two nodes. This is the rate at which devices are synchronized in the background after a disk failure, device replacement or during the initial setup. You should keep this in check compared to the speed of your network connection. Gigabit Ethernet can support up to 125 MB/second, 100Mbps Ethernet slightly less than a tenth of that (12MBps). If you are using a shared network connection, rather than a dedicated, then you should gauge accordingly.

   To set the synchronization rate, edit the `rate` setting within the `syncer` block:

   ```
   syncer {
       rate 10M;
   }
   ```

You may additionally want to set the `al-extents` parameter. The default for this parameter is 257.

For more detailed information on synchronization, the effects of the synchronization rate and the effects on network performance, see Section 2.3.2, “Optimizing the Synchronization Rate”.

2. Set up some basic authentication. DRBD supports a simple password hash exchange mechanism. This helps to ensure that only those hosts with the same shared secret are able to join the DRBD node group.

```
cram-hmac-alg â##sha1â##;
shared-secret "shared-string";
```

3. Now you must configure the host information. Remember that you must have the node information for the primary and secondary nodes in the `drbd.conf` file on each host. You need to configure the following information for each node:

   - `device` — the path of the logical block device that will be created by DRBD.
   - `disk` — the block device that will be used to store the data.
   - `address` — the IP address and port number of the host that will hold this DRBD device.
   - `meta-disk` — the location where the metadata about the DRBD device will be stored. You can set this to `internal` and DRBD will use the physical block device to store the information, by recording the metadata within the last sections of the disk. The exact size will depend on the size of the logical block device you have created, but it may involve up to 128MB.

   A sample configuration for our primary server might look like this:

```
on drbd-one {
device /dev/drbd0;
disk /dev/hdd1;
address 192.168.0.240:8888;
meta-disk internal;
}
```

   The `on` configuration block should be repeated for the secondary node (and any further) nodes:

```
on drbd-two {
device /dev/drbd0;
disk /dev/hdd1;
address 192.168.0.241:8888;
meta-disk internal;
}
```

   The IP address of each `on` block must match the IP address of the corresponding host. Do not set this value to the IP address of the corresponding primary or secondary in each case.

4. Before starting the primary node, you should create the metadata for the devices:

```
root-shell> drbdadm create-md all
```

5. You are now ready to start DRBD:

```
root-shell> /etc/init.d/drbd start
```

   DRBD should now start and initialize, creating the DRBD devices that you have configured.

6. DRBD creates a standard block device - to make it usable, you must create a file system on the block device just as you would with any standard disk partition. Before you can create the file system, you must mark the new device as the primary device (i.e. where the data will be written and stored), and initialize the device. Because this is a destructive operation, you must specify the command line option to overwrite the raw data:

```
root-shell> drbdadm -- --overwrite-data-of-peer primary all
```

   If you are using a version of DRBD 0.7.x or earlier, then you need to use a different command-line option:

```
root-shell> drbdadm -- --do-what-I-say primary all
```

   Now create a file system using your chosen file system type:

```
root-shell> mkfs.ext3 /dev/drbd0
```

7. You can now mount the file system and if necessary copy files to the mount point:

```
root-shell> mkdir /mnt/drbd
root-shell> mount /dev/drbd0 /mnt/drbd
root-shell> echo "DRBD Device" >/mnt/drbd/samplefile
```

Your primary node is now ready to use. You should now configure your secondary node or nodes.

2.1.4. Setting Up a DRBD Secondary Node

The configuration process for setting up a secondary node is the same as for the primary node, except that you do not have to create the file system on the secondary node device, as this information will automatically be transferred from the primary node.

To set up a secondary node:

1. Copy the `/etc/drbd.conf` file from your primary node to your secondary node. It should already contain all the information and configuration that you need, since you had to specify the secondary node IP address and other information for the primary node configuration.
2. Create the DRBD metadata on the underlying disk device:

```
root-shell> drbdadm create-md all
```

3. Start DRBD:

```
root-shell> /etc/init.d/drbd start
```

Once DRBD has started, it will start the copy the data from the primary node to the secondary node. Even with an empty file system this will take some time, since DRBD is copying the block information from a block device, not simply copying the file system data.

You can monitor the progress of the copy between the primary and secondary nodes by viewing the output of `/proc/drbd`:

```
root-shell> cat /proc/drbd
version: 8.0.4 (api:86/proto:86)
SVN Revision: 2947 build by root@drbd-one, 2007-07-30 16:43:05
 0: cs:SyncSource st:Primary/Secondary ds:UpToDate/Inconsistent C r---
    ns:252284 nr:0 dw:0 dr:257280 al:0 bm:15 lo:0 pe:7 ua:157 ap:0
        [==>.................] sync'ed: 12.3% (1845088/2097152)K
        finish: 0:06:06 speed: 4,972 (4,580) K/sec
        resync: used:1/31 hits:15901 misses:16 starving:0 dirty:0 changed:16
        act_log: used:0/257 hits:0 misses:0 starving:0 dirty:0 changed:0
```

You can monitor the synchronization process by using the `watch` command to run the command at specific intervals:

```
root-shell> watch -n 10 'cat /proc/drbd'
```

2.1.5. Monitoring DRBD Device

Once the primary and secondary machines are configured and synchronized, you can get the status information about your DRBD device by viewing the output from `/proc/drbd`:

```
root-shell> cat /proc/drbd
version: 8.0.4 (api:86/proto:86)
SVN Revision: 2947 build by root@drbd-one, 2007-07-30 16:43:05
 0: cs:Connected st:Primary/Secondary ds:UpToDate/UpToDate C r---
    ns:2175704 nr:0 dw:99192 dr:2076641 al:33 bm:128 lo:0 pe:0 ua:0 ap:0
        resync: used:0/31 hits:134841 misses:135 starving:0 dirty:0 changed:135
        act_log: used:0/257 hits:24765 misses:33 starving:0 dirty:0 changed:33
```

The first line provides the version/revision and build information.

The second line starts the detailed status information for an individual resource. The individual field headings are as follows:

- cs — connection state
- st — node state (local/remote)

- ld — local data consistency
- ds — data consistency
- ns — network send
- nr — network receive
- dw — disk write
- dr — disk read
- pe — pending (waiting for ack)
- ua — unack'd (still need to send ack)
- al — access log write count

In the previous example, the information shown indicates that the nodes are connected, the local node is the primary (because it is listed first), and the local and remote data is up to date with each other. The remainder of the information is statistical data about the device, and the data exchanged that kept the information up to date.

You can also get the status information for DRBD by using the startup script with the `status` option:

```
root-shell> /etc/init.d/drbd status
 * status:  started
 * drbd driver loaded OK; device status: ...
version: 8.3.0 (api:88/proto:86-89)
GIT-hash: 9ba8b93e24d842f0dd3fb1f9b90e8348ddb95829 build by root@gentoo1.vmbear, 2009-03-14 23:00:06
 0: cs:Connected ro:Secondary/Secondary ds:UpToDate/UpToDate C r---
    ns:0 nr:0 dw:0 dr:8385604 al:0 bm:0 lo:0 pe:0 ua:0 ap:0 ep:1 wo:b oos:0
```

The information and statistics are the same.

2.1.6. Managing your DRBD Installation

For administration, the main command is `drbdadm`. There are a number of commands supported by this tool the control the connectivity and status of the DRBD devices.

> **Note**
>
> For convenience, a bash completion script is available. This will provide tab completion for options to `drbdadm`. The file `drbdadm.bash_completion` can be found within the standard DRBD source package within the `scripts` directory. To enable, copy the file to `/etc/bash_completion.d/drbdadm`. You can load it manually by using:
>
> ```
> shell> source /etc/bash_completion.d/drbdadm
> ```

The most common commands are those to set the primary/secondary status of the local device. You can manually set this information for a number of reasons, including when you want to check the physical status of the secondary device (since you cannot mount a DRBD device in primary mode), or when you are temporarily moving the responsibility of keeping the data in check to a different machine (for example, during an upgrade or physical move of the normal primary node). You can set state of all local device to be the primary using this command:

```
root-shell> drbdadm primary all
```

Or switch the local device to be the secondary using:

```
root-shell> drbdadm secondary all
```

To change only a single DRBD resource, specify the resource name instead of `all`.

You can temporarily disconnect the DRBD nodes:

```
root-shell> drbdadm disconnect all
```

Reconnect them using `connect`:

```
root-shell> drbdadm connect all
```

For other commands and help with `drbdadm` see the DRBD documentation.

2.1.7. Additional DRBD Configuration Options

Additional options you may want to configure:

- `protocol` — specifies the level of consistency to be used when information is written to the block device. The option is similar in principle to the `innodb_flush_log_at_trx_commit` option within MySQL. Three levels are supported:
  - `A` — data is considered written when the information reaches the TCP send buffer and the local physical disk. There is no guarantee that the data has been written to the remote server or the remote physical disk.
  - `B` — data is considered written when the data has reached the local disk and the remote node's network buffer. The data has reached the remote server, but there is no guarantee it has reached the remote server's physical disk.
  - `C` — data is considered written when the data has reached the local disk and the remote node's physical disk.

  The preferred and recommended protocol is C, as it is the only protocol which ensures the consistency of the local and remote physical storage.
- `size` — if you do not want to use the entire partition space with your DRBD block device then you can specify the size of the DRBD device to be created. The size specification can include a quantifier. For example, to set the maximum size of the DRBD partition to 1GB you would use:

```
size 1G;
```

With the configuration file suitably configured and ready to use, you now need to populate the lower-level device with the metadata information, and then start the DRBD service.

2.2. Configuring MySQL for DRBD

Once you have configured DRBD and have an active DRBD device and file system, you can configure MySQL to use the chosen device to store the MySQL data.

When performing a new installation of MySQL, you can either select to install MySQL entirely onto the DRBD device, or just configure the data directory to be located on the new file system.

In either case, the files and installation must take place on the primary node, because that is the only DRBD node on which you can mount the DRBD device file system as read/write.

You should store the following files and information on your DRBD device:

- MySQL data files, including the binary log, and InnoDB data files.
- MySQL configuration file (`my.cnf`).

To set up MySQL to use your new DRBD device and file system:

1. If you are migrating an existing MySQL installation, stop MySQL:

   ```
   shell> mysqladmin shutdown
   ```

2. Copy the `my.cnf` onto the DRBD device. If you are not already using a configuration file, copy one of the sample configuration files from the MySQL distribution.

   ```
   root-shell> mkdir /mnt/drbd/mysql
   root-shell> cp /etc/my.cnf /mnt/drbd/mysql
   ```

3. Copy your MySQL data directory to the DRBD device and mounted file system.

   ```
   root-shell> cp -R /var/lib/mysql /drbd/mysql/data
   ```

4. Edit the configuration file to reflect the change of directory by setting the value of the `datadir` option. If you have not already enabled the binary log, also set the value of the `log-bin` option.

```
datadir = /drbd/mysql/data
  log-bin = mysql-bin
```

5. Create a symbolic link from `/etc/my.cnf` to the new configuration file on the DRBD device file system.

```
root-shell> ln -s /drbd/mysql/my.cnf /etc/my.cnf
```

6. Now start MySQL and check that the data that you copied to the DRBD device file system is present.

```
root-shell> /etc/init.d/mysql start
```

Your MySQL data should now be located on the file system running on your DRBD device. The data will be physically stored on the underlying device that you configured for the DRBD device. Meanwhile, the content of your MySQL databases will be copied to the secondary DRBD node.

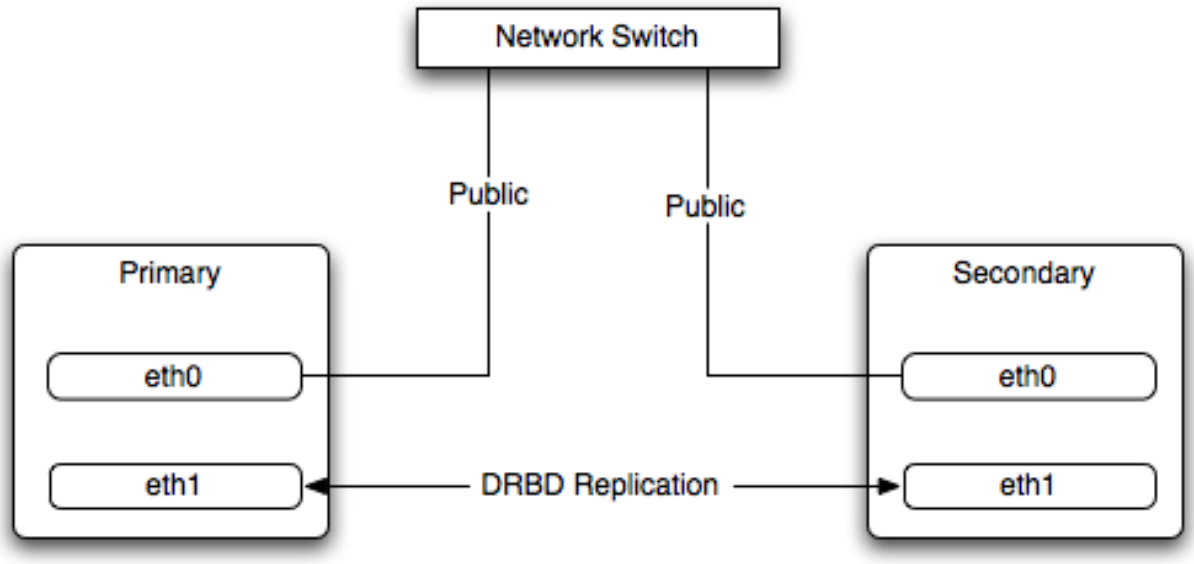
Note that you cannot access the information on your secondary node, as a DRBD device working in secondary mode is not available for use.

2.3. Optimizing Performance and Reliability

Because of the nature of the DRBD system, the critical requirements are for a very fast exchange of the information between the two hosts. To ensure that your DRBD setup is available to switch over in the event of a failure as quickly as possible, you must transfer the information between the two hosts using the fastest method available.

Typically, a dedicated network circuit should be used for exchanging DRBD data between the two hosts. You should then use a separate, additional, network interface for your standard network connection. For an example of this layout, see Figure 2.2, “DRBD Architecture Using Separate Network Interfaces”.

Figure 2.2. DRBD Architecture Using Separate Network Interfaces



The dedicated DRBD network interfaces should be configured to use a non-routed TCP/IP network configuration. For example, you might want to set the primary to use 192.168.0.1 and the secondary 192.168.0.2. These networks and IP addresses should not be part of normal network subnet.

> **Note**
>
> The preferred setup, whenever possible, is to use a direct cable connection (using a crossover cable with Ethernet, for example) between the two machines. This eliminates the risk of loss of connectivity due to switch failures.

2.3.1. Using Bonded Ethernet Network Interfaces

For a set-up where there is a high-throughput of information being written, you may want to use bonded network interfaces. This is where you combine the connectivity of more than one network port, increasing the throughput linearly according to the number of bonded connections.

Bonding also provides an additional benefit in that with multiple network interfaces effectively supporting the same communications channel, a fault within a single network interface in a bonded group does not stop communication. For example, imagine you have a bonded setup with four network interfaces providing a single interface channel between two DRBD servers. If one network interface fails, communication can continue on the other three without interruption, although it will be at a lower speed

To enable bonded connections you must enable bonding within the kernel. You then need to configure the module to specify the bonded devices and then configure each new bonded device just as you would a standard network device:

- To configure the bonded devices, you need to edit the `/etc/modprobe.conf` file (RedHat) or add a file to the `/etc/modprobe.d` directory.. In each case you will define the parameters for the kernel module. First, you need to specify each bonding device:

  ```
  alias bond0 bonding
  ```

  You can then configure additional parameters for the kernel module. Typical parameters are the `mode` option and the `miimon` option.

  The `mode` option specifies how the network interfaces are used. The default setting is 0, which means that each network interface is used in a round-robin fashion (this supports aggregation and fault tolerance). Using setting 1 sets the bonding mode to active-backup. This means that only one network interface is used as a time, but that the link will automatically failover to a new interface if the primary interface fails. This settings only supports fault-tolerance.

  The `miimon` option enables the MII link monitoring. A positive value greater than zero indicates the monitoring frequency in milliseconds for checking each slave network interface that is configured as part of the bonded interface. A typical value is 100.

  You set th options within the module parameter file, and you must set the options for each bonded device individually:

  ```
  options bond0 miimon=100 mode=1
  ```

- Reboot your server to enable the bonded devices.
- Configure the network device parameters. There are two parts to this, you need to setup the bonded device configuration, and then configure the original network interfaces as 'slaves' of the new bonded interface.
  - For RedHat Linux:

    Edit the configuration file for the bonded device. For device `bond0` this would be `/etc/sysconfig/network-scripts/ifcfg-bond0`:

    ```
    DEVICE=bond0
    BOOTPROTO=none
    ONBOOT=yes
    GATEWAY=192.168.0.254
    NETWORK=192.168.0.0
    NETMASK=255.255.255.0
    IPADDR=192.168.0.1
    USERCTL=no
    ```

    Then for each network interface that you want to be part of the bonded device, configure the interface as a slave to the 'master' bond. For example, the configuration of `eth0` in `/etc/sysconfig/network-scripts/ifcfg-eth0` might look like this::

    ```
    DEVICE=eth0
    BOOTPROTO=none
    HWADDR=00:11:22:33:44:55
    ONBOOT=yes
    TYPE=Ethernet
    MASTER=bond0
    SLAVE=yes
    ```

  - For Debian Linux:

    Edit the `/etc/iftab` file and configure the logical name and MAC address for each devices. For example:

    ```
    eth0 mac 00:11:22:33:44:55
    ```

    Now you need to set the configuration of the devices in `/etc/network/interfaces`:

```
auto bond0
    iface bond0 inet static
    address 192.168.0.1
    netmask 255.255.255.0
    network 192.168.0.0
    gateway 192.168.0.254
    up /sbin/ifenslave bond0 eth0
    up /sbin/ifenslave bond0 eth1
```

- For Gentoo:

  Use `emerge` to add the `net-misc/ifenslave` package to your system.

  Edit the `/etc/conf.d/net` file and specify the network interface slaves in a bond, the dependencies and then the configuration for the bond itself. A sample configuration might look like this:

```
slaves_bond0="eth0 eth1 eth2"
config_bond0=( "192.168.0.1 netmask 255.255.255.0"  )
depend_bond0() {
need net.eth0 net.eth1 net.eth2
}
```

  Then make sure that you add the new network interface to list of interfaces configured during boot:

```
root-shell> rc-update add default net.bond0
```

Once the bonded devices are configured you should reboot your systems.

You can monitor the status of a bonded connection using the `/proc` file system:

```
root-shell> cat /proc/net/bonding/bond0
Bonding Mode: fault-tolerance (active-backup)
Primary Slave: None
Currently Active Slave: eth1
MII Status: up
MII Polling Interval (ms): 100
Up Delay (ms): 200
Down Delay (ms): 200
Slave Interface: eth1
MII Status: up
Link Failure Count: 0
Permanent HW addr: 00:11:22:33:44:55
Slave Interface: eth2
MII Status: up
Link Failure Count: 0
Permanent HW addr: 00:11:22:33:44:56
```

2.3.2. Optimizing the Synchronization Rate

The `syncer rate` configuration parameter should be configured with care as the synchronization rate can have a significant effect on the performance of the DRBD setup in the event of a node or disk failure where the information is being synchronized from the Primary to the Secondary node.

In DRBD, there are two distinct ways of data being transferred between peer nodes:

- *Replication* refers to the transfer of modified blocks being transferred from the primary to the secondary node. This happens automatically when the block is modified on the primary node, and the replication process uses whatever bandwidth is available over the replication link. The replication process cannot be throttled, because you want to transfer of the block information to happen as quickly as possible during normal operation.
- *Synchronization* refers to the process of bringing peers back in sync after some sort of outage, due to manual intervention, node failure, disk swap, or the initial setup. Synchronization is limited to the `syncer rate` configured for the DRBD device.

Both replication and synchronization can take place at the same time. For example, the block devices can be being synchronized while they are actively being used by the primary node. Any I/O that updates on the primary node will automatically trigger replication of the modified block. In the event of a failure within an HA environment, it is highly likely that synchronization and replication will take place at the same time.

Unfortunately, if the synchronization rate is set too high, then the synchronization process will use up all the available network bandwidth between the primary and secondary nodes. In turn, the bandwidth available for replication of changed blocks is zero,

which means replication will stall and I/O will block, and ultimately the application will fail or degrade.

To avoid enabling the `syncer rate` to consume the available network bandwidth and prevent the replication of changed blocks you should set the `syncer rate` to less than the maximum network bandwidth.

You should avoid setting the sync rate to more than 30% of the maximum bandwidth available to your device and network bandwidth. For example, if your network bandwidth is based on Gigabit ethernet, you should achieve 110MB/s. Assuming your disk interface is capable of handling data at 110MB/s or more, then the sync rate should be configered as `33M` (33MB/s). If your disk system works at a rate lower than your network interface, use 30% of your disk interface speed.

Depending on the application, you may wish to limit the synchronization rate. For example, on a busy server you may wish to configure a significantly slower synchronization rate to ensure the replication rate is not affected.

The `al-extents` parameter controls the number of 4MB blocks of the underlying disk that can be written to at the same time. Increasing this parameter lowers the frequency of the meta data transactions required to log the changes to the DRBD device, which in turn lowers the number of interruptions in your I/O stream when synchronizing changes. This can lower the latency of changes to the DRBD device. However, if a crash occurs on your primary, then all of the blocks in the activity log (i.e. the number of `al-extents` blocks) will need to be completely resynchronized before replication can continue.

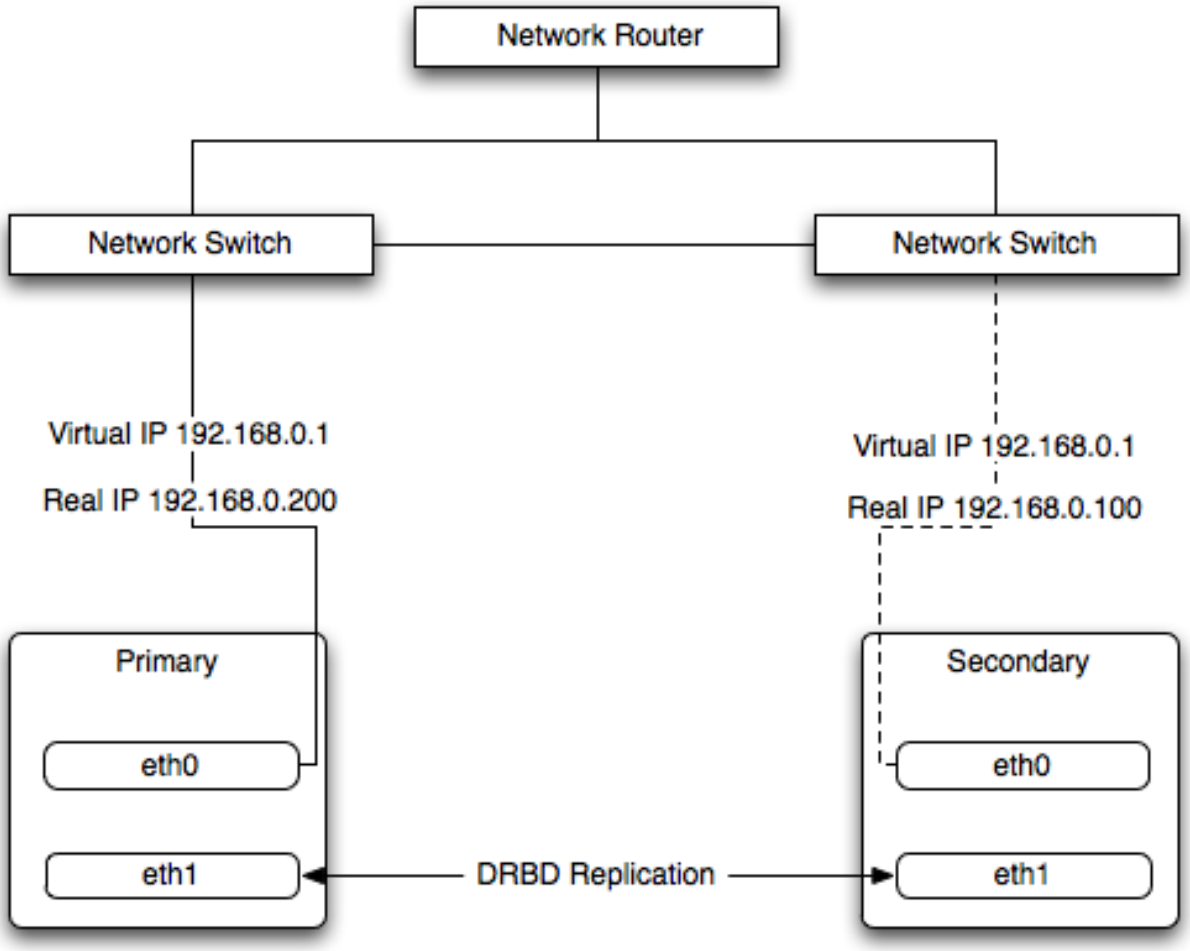
Chapter 3. Using Linux HA Heartbeat

The Heartbeat program provides a basis for verifying the availability of resources on one or more systems within a cluster. In this context a resource includes MySQL, the file systems on which the MySQL data is being stored and, if you are using DRBD, the DRBD device being used for the file system. Heartbeat also manages a virtual IP address, and the virtual IP address should be used for all communication to the MySQL instance.

A cluster within the context of Heartbeat is defined as two computers notionally providing the same service. By definition, each computer in the cluster is physically capable of providing the same services as all the others in the cluster. However, because the cluster is designed for high-availability, only one of the servers is actively providing the service at any one time. Each additional server within the cluster is a “hot-spare” that can be brought into service in the event of a failure of the master, its next connectivity or the connectivity of the network in general.

The basics of Heartbeat are very simple. Within the Heartbeat cluster (see Figure 3.1, “Heartbeat Architecture”, each machine sends a 'heartbeat' signal to the other hosts in the cluster. The other cluster nodes monitor this heartbeat. The heartbeat can be transmitted over many different systems, including shared network devices, dedicated network interfaces and serial connections. Failure to get a heartbeat from a node is treated as failure of the node. Although we do not know the reason for the failure (it could be an OS failure, a hardware failure in the server, or a failure in the network switch), it is safe to assume that if no heartbeat is produced there is a fault.

Figure 3.1. Heartbeat Architecture



In addition to checking the heartbeat from the server, the system can also check the connectivity (using `ping`) to another host on the network, such as the network router. This allows Heartbeat to detect a failure of communication between a server and the router (and therefore failure of the server, since it is no longer capable of providing the necessary service), even if the heartbeat between the servers in the clusters is working fine.

In the event of a failure, the resources on the failed host are disabled, and the resources on one of the replacement hosts is enabled instead. In addition, the Virtual IP address for the cluster is redirected to the new host in place of the failed device.

When used with MySQL and DRBD, the MySQL data is replicated from the master to the slave using the DRBD device, but MySQL is only running on the master. When the master fails, the slave switches the DRBD devices to be primary, the file systems on those devices are mounted, and MySQL is started. The original master (if still available) has its resources disabled, which means shutting down MySQL and unmounting the file systems and switching the DRBD device to secondary.

3.1. Heartbeat Configuration

Heartbeat configuration requires three files located in `/etc/ha.d`. The `ha.cf` contains the main heartbeat configuration, including the list of the nodes and times for identifying failures. `haresources` contains the list of resources to be managed within the cluster. The `authkeys` file contains the security information for the cluster.

The contents of these files should be identical on each host within the Heartbeat cluster. It is important that you keep these files in sync across all the hosts. Any changes in the information on one host should be copied to the all the others.

For these examples n example of the `ha.cf` file is shown below:

```
logfacility local0
keepalive 500ms
deadtime 10
warntime 5
initdead 30
mcast bond0 225.0.0.1 694 2 0
mcast bond1 225.0.0.2 694 1 0
auto_failback off
node drbd1
node drbd2
```

The individual lines in the file can be identified as follows:

- `logfacility` — sets the logging, in this case setting the logging to use `syslog`.
- `keepalive` — defines how frequently the heartbeat signal is sent to the other hosts.
- `deadtime`— the delay in seconds before other hosts in the cluster are considered 'dead' (failed).
- `warntime` — the delay in seconds before a warning is written to the log that a node cannot be contacted.
- `initdead` — the period in seconds to wait during system startup before the other host is considered to be down.
- `mcast` — defines a method for sending a heartbeat signal. In the above example, a multicast network address is being used over a bonded network device. If you have multiple clusters then the multicast address for each cluster should be unique on your network. Other choices for the heartbeat exchange exist, including a serial connection.

  If you are using multiple network interfaces (for example, one interface for your server connectivity and a secondary and/or bonded interface for your DRBD data exchange) then you should use both interfaces for your heartbeat connection. This decreases the chance of a transient failure causing a invalid failure event.
- `auto_failback` — sets whether the original (preferred) server should be enabled again if it becomes available. Switching this to `on` may cause problems if the preferred went offline and then comes back on line again. If the DRBD device has not been synced properly, or if the problem with the original server happens again you may end up with two different datasets on the two servers, or with a continually changing environment where the two servers flip-flop as the preferred server reboots and then starts again.
- `node` — sets the nodes within the Heartbeat cluster group. There should be one `node` for each server.

An optional additional set of information provides the configuration for a ping test that will check the connectivity to another host. You should use this to ensure that you have connectivity on the public interface for your servers, so the ping test should be to a reliable host such as a router or switch. The additional lines specify the destination machine for the `ping`, which should be specified as an IP address, rather than a host name; the command to run when a failure occurs, the authority for the failure and the timeout before an non-response triggers a failure. A sample configure is shown below:

```
ping 10.0.0.1
respawn hacluster /usr/lib64/heartbeat/ipfail
apiauth ipfail gid=haclient uid=hacluster
deadping 5
```

In the above example, the `ipfail` command, which is part of the Heartbeat solution, is called on a failure and 'fakes' a fault on the currently active server. You need to configure the user and group ID under which the command should be executed (using the

`apiauth`). The failure will be triggered after 5 seconds.

> **Note**
>
> The `deadping` value must be less than the `deadtime` value.

The `authkeys` file holds the authorization information for the Heartbeat cluster. The authorization relies on a single unique 'key' that is used to verify the two machines in the Heartbeat cluster. The file is used only to confirm that the two machines are in the same cluster and is used to ensure that the multiple clusters can co-exist within the same network.

3.2. Using Heartbeat with MySQL and DRBD

To use Heartbeat in combination with MySQL you should be using DRBD (see Chapter 2, *Using MySQL with DRBD*) or another solution that allows for sharing of the MySQL database files in event of a system failure. In these examples, DRBD is used as the data sharing solution.

Heartbeat manages the configuration of different resources to manage the switching between two servers in the event of a failure. The resource configuration defines the individual services that should be brought up (or taken down) in the event of a failure.

The `haresources` file within `/etc/ha.d` defines the resources that should be managed, and the individual resource mentioned in this file in turn relates to scripts located within `/etc/ha.d/resource.d`. The resource definition is defined all on one line:

```
drbd1 drbddisk Filesystem::/dev/drbd0::/drbd::ext3 mysql 10.0.0.100
```

The line is notionally split by whitespace. The first entry (`drbd1`) is the name of the preferred host, i.e. the server that is normally responsible for handling the service. The last field is virtual IP address or name that should be used to share the service. This is the IP address that should be used to connect to the MySQL server. It will automatically be allocated to the server that is active when Heartbeat starts.

The remaining fields between these two fields define the resources that should be managed. Each Field should contain the name of the resource (and each name should refer to a script within `/etc/ha.d/resource.d`). In the event of a failure, these resources are started on the backup server by calling the corresponding script (with a single argument, `start`), in order from left to right. If there are additional arguments to the script, you can use a double colon to separate each additional argument.

In the above example, we manage the following resources:

- `drbddisk` — the DRBD resource script, this will switch the DRBD disk on the secondary host into primary mode, making the device read/write.
- `Filesystem` — manages the Filesystem resource. In this case we have supplied additional arguments to specify the DRBD device, mount point and file system type. When executed this should mount the specified file system.
- `mysql` — manages the MySQL instances and starts the MySQL server. You should copy the `mysql.resource` file from the `support-files` directory from any MySQL release into the `/etc/ha.d/resources.d` directory.

  If this file is not available in your distribution, you can use the following as the contents of the `/etc/ha.d/resource.d/mysql.resource` file:

```
#!/bin/bash
#
# This script is inteded to be used as resource script by heartbeat
#
# Mar 2006 by Monty Taylor
#
###
. /etc/ha.d/shellfuncs
case "$1" in
    start)
        res=`/etc/init.d/mysql start`
        ret=$?
        ha_log $res
        exit $ret
        ;;
    stop)
        res=`/etc/init.d/mysql stop`
        ret=$?
        ha_log $res
        exit $ret
        ;;
    status)
        if [ `ps -ef | grep '[m]ysqld'` ] ; then
           echo "running"
        else
           echo "stopped"
        fi
        ;;
    *)
        echo "Usage: mysql {start|stop|status}"
```

```
        exit 1
        ;;
esac
exit 0
```

If you want to be notified of the failure by email, you can add another line to the `haresources` file with the address for warnings and the warning text:

```
MailTo::youremail@address.com::DRBDFailure
```

With the Heartbeat configuration in place, copy the `haresources`, `authkeys` and `ha.cf` files from your primary and secondary servers to make sure that the configuration is identical. Then start the Heartbeat service, either by calling `/etc/init.d/heartbeat start` or by rebooting both primary and secondary servers.

You can test the configuration by running a manual failover, connect to the primary node and run:

```
root-shell> /usr/lib64/heartbeat/hb_standby
```

This will cause the current node to relinquish its resources cleanly to the other node.

3.3. Using Heartbeat with DRBD and dopd

As a further extension to using DRBD and Heartbeat together, you can enable `dopd`. The `dopd` daemon handles the situation where a DRBD node is out of date compared to the master and prevents the slave from being promoted to master in the event of a failure. This stops a situation where you have two machines that have been masters ending up different data on the underlying device.

For example, imagine that you have a two server DRBD setup, master and slave. If the DRBD connectivity between master and slave fails then the slave would be out of the sync with the master. If Heartbeat identifies a connectivity issue for master and then switches over to the slave, the slave DRBD device will be promoted to the primary device, even though the data on the slave and the master is not in synchronization.

In this situation, with `dopd` enabled, the connectivity failure between the master and slave would be identified and the metadata on the slave would be set to `Outdated`. Heartbeat will then refuse to switch over to the slave even if the master failed. In a dual-host solution this would effectively render the cluster out of action, as there is no additional fail over server. In an HA cluster with three or more servers, control would be passed to the slave that has an up to date version of the DRBD device data.

To enable `dopd`, you need to modify the Heartbeat configuration and specify `dopd` as part of the commands executed during the monitoring process. Add the following lines to your `ha.cf` file:

```
respawn hacluster /usr/lib/heartbeat/dopd
apiauth dopd gid=haclient uid=hacluster
```

Make sure you make the same modification on both your primary and secondary nodes.

You will need to reload the Heartbeat configuration:

```
root-shell> /etc/init.d/heartbeat reload
```

You will also need to modify your DRBD configuration by configuration the `outdate-peer` option. You will need to add the configuration line into the `common` section of `/etc/drbd.conf` on both hosts. An example of the full block is shown below:

```
common {
  handlers {
    outdate-peer "/usr/lib/heartbeat/drbd-peer-outdater";
  }
}
```

Finally, set the `fencing` option on your DRBD configured resources:

```
resource my-resource {
  disk {
    fencing    resource-only;
  }
}
```

Now reload your DRBD configuration:

```
root-shell> drbdadmin adjust all
```

You can test the system by unplugging your DRBD link and monitoring the output from `/proc/drbd`.

3.4. Dealing with System Level Errors

Because a kernel panic or oops may indicate potential problem with your server, you should configure your server to remove itself from the cluster in the event of a problem. Typically on a kernel panic your system will automatically trigger a hard reboot. For a kernel oops a reboot may not happen automatically, but the issue that caused that oops may still lead to potential problems.

You can force a reboot by setting the `kernel.panic` and `kernel.panic_on_oops` parameters of the kernel control file `/etc/sysctl.conf`. For example:

```
kernel.panic_on_oops = 1
kernel.panic = 1
```

You can also set these parameters during runtime by using the `sysctl` command. You can either specify the parameters on the command line:

```
shell> sysctl -w kernel.panic=1
```

Or you can edit your `sysctl.conf` file and then reload the configuration information:

```
shell> sysctl -p
```

By setting both these parameters to a positive value (actually the number of seconds to wait before triggering the reboot), the system will reboot. Your second heartbeat node should then detect that the server is down and then switch over to the failover host.

Chapter 4. Using MySQL with memcached

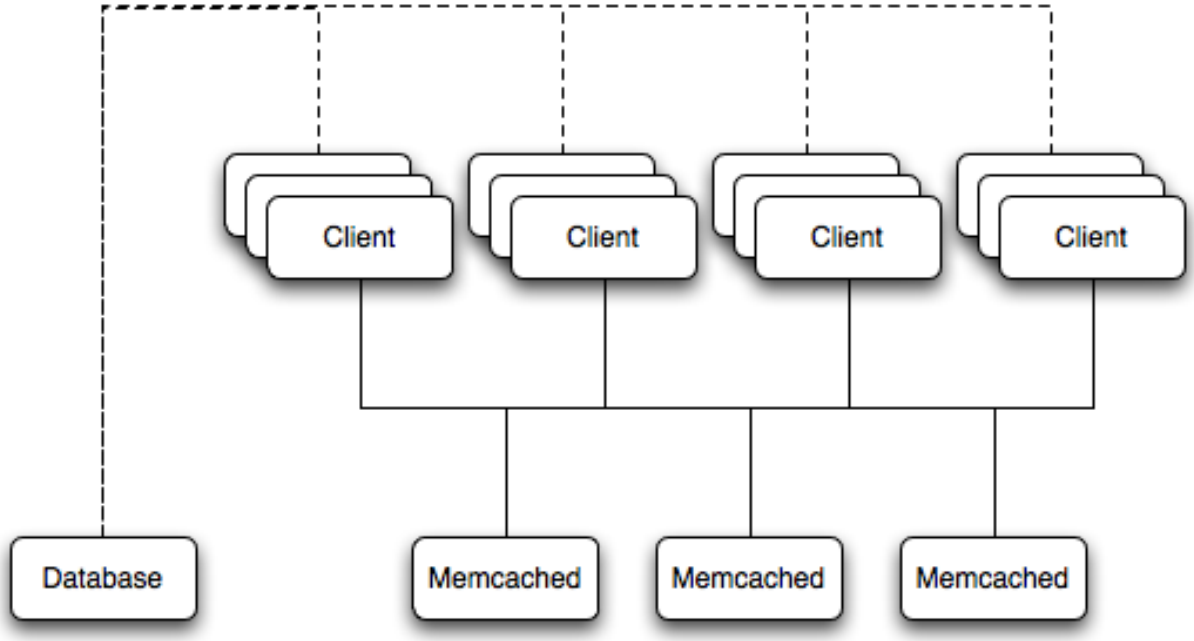
The largest problem with scalability within a typical environment is the speed with which you can access information. For frequently accessed information, using MySQL can be slow because each access of information requires execution of the SQL query and recovery of the information from the database. This also means that queries on tables that are locked or blocking may delay your query and reduce the speed of recovery of information.

memcached is a simple, yet highly-scalable key-based cache that stores data and objects wherever dedicated or spare RAM is available for very quick access by applications. To use, you run memcached on one or more hosts and then use the shared cache to store objects.Because each host's RAM is storing information, the access speed will be much faster than having to load the information from disk. This can provide a significant performance boost in retrieving data versus loading the data natively from a database. Also, because the cache is just a repository for information, you can use the cache to store any data, including complex structures that would normally require a significant amount of effort to create, but in a ready-to-use format, helping to reduce the load on your MySQL servers.

The typical usage environment is to modify your application so that information is read from the cache provided by memcached. If the information isn't in memcached, then the data is loaded from the MySQL database and written into the cache so that future requests for the same object benefit from the cached data.

For a typical deployment layout, see Figure 4.1, “memcached Architecture Overview”.

Figure 4.1. memcached Architecture Overview



In the example structure, any of the clients can contact one of the memcached servers to request a given key. Each client is configured to talk to all of the servers shown in the illustration. Within the client, when the request is made to store the information, the key used to reference the data is hashed and this hash is then used to select one of the memcached servers. The selection of the memcached server takes place on the client before the server is contacted, keeping the process lightweight.

The same algorithm is used again when a client requests the same key. The same key will generate the same hash, and the same memcached server will be selected as the source for the data. Using this method, the cached data is spread among all of the memcached servers, and the cached information is accessible from any client. The result is a distributed, memory-based, cache that can return information, particularly complex data and structures, much faster than natively reading the information from the database.

The data held within a memcached server is never stored on disk (only in RAM, which means there is no persistence of data), and the RAM cache is always populated from the backing store (a MySQL database). If a memcached server fails, the data can always be recovered from the MySQL database, albeit at a slower speed than loading the information from the cache.

4.1. Installing memcached

You can build and install memcached from the source code directly, or you can use an existing operating system package or installation.

Installing memcached from a Binary Distribution

To install memcached on a RedHat, Fedora or CentOS host, use yum:

```
root-shell> yum install memcached
```

To install memcached on a Debian or Ubuntu host, use apt-get:

```
root-shell> apt-get install memcached
```

To install memcached on a Gentoo host, use emerge:

```
root-shell> emerge install memcached
```

To install on OpenSolaris, use the pkg command to install the SUNWmemcached package:

```
root-shell> pkg install SUNWmemcached
```

You may also find memcached in the Coolstack project. For more details, see http://cooltools.sunsource.net/coolstack/.

Building memcached from Source

On other Unix-based platforms, including Solaris, AIX, HP-UX and Mac OS X, and Linux distributions not mentioned already, you will need to install from source. For Linux, make sure you have a 2.6-based kernel, which includes the improved epoll interface. For all platforms, ensure that you have libevent 1.1 or higher installed. You can obtain libevent from libevent web page.

You can obtain the source for memcached from memcached website.

To build memcached, follow these steps:

1. Extract the memcached source package:

   ```
   shell> gunzip -c memcached-1.2.5.tar.gz | tar xf -
   ```

2. Change to the memcached-*1.2.5* directory:

   ```
   shell> cd memcached-1.2.5
   ```

3. Run configure

   ```
   shell> ./configure
   ```

   Some additional options you may want to specify to configure:

   - --prefix

     If you want to specify a different installation directory, use the --prefix option:

     ```
     shell> ./configure --prefix=/opt
     ```

     The default is to use the /usr/local directory.

   - --with-libevent

     If you have installed libevent and configure cannot find the library, use the --with-libevent option to specify the location of the installed library.

   - --enable-64bit

     To build a 64-bit version of memcached (which will allow you to use a single instance with a large RAM allocation), use --enable-64bit.

   - --enable-threads

To enable multi-threading support in memcached, which will improve the response times on servers with a heavy load, use --enable-threads. You must have support for the POSIX threads within your operating system to enable thread support. For more information on the threading support, see Section 4.2.7, "memcached thread Support".

- --enable-dtrace

  memcached includes a range of DTrace threads that can be used to monitor and benchmark a memcached instance. For more information, see Section 4.2.5, "Using memcached and DTrace".

4. Run make to build memcached:

```
shell> make
```

5. Run make install to install memcached:

```
shell> make install
```

4.2. Using memcached

To start using memcached, you must start the memcached service on one or more servers. Running memcached sets up the server, allocates the memory and starts listening for connections from clients.

> **Note**
>
> You do not need to be privileged user (root) to run memcached unless you want to listen on one of the privileged TCP/IP ports (below 1024). You must, however, use a user that has not had their memory limits restricted using setrlimit or similar.

To start the server, run memcached as a non-privileged (i.e. non-root) user:

```
shell> memcached
```

By default, memcached uses the following settings:

- Memory allocation of 64MB
- Listens for connections on all network interfaces, using port 11211
- Supports a maximum of 1024 simultaneous connections

Typically, you would specify the full combination of options that you want when starting memcached, and normally provide a startup script to handle the initialization of memcached. For example, the following line starts memcached with a maximum of 1024MB RAM for the cache, listening on port 11121 on the IP address 192.168.0.110, running has a background daemon:

```
shell> memcached -d -m 1024 -p 11121 -l 192.168.0.110
```

To ensure that memcached is started up on boot you should check the init script and configuration parameters. On OpenSolaris, memcached is controlled by SMF. You can enable it by using:

```
root-shell> svcadm enable memcached
```

memcached supports the following options:

- -u user

  If you start memcached as root, use the -u option to specify the user for executing memcached:

```
shell> memcached -u memcache
```

- -m memory

  Set the amount of memory allocated to memcached for object storage. Default is 64MB.

To increase the amount of memory allocated for the cache, use the `-m` option to specify the amount of RAM to be allocated (in megabytes). The more RAM you allocate, the more data you can store and therefore the more effective your cache will be.

> **Warning**
>
> Do not specify a memory allocation larger than your available RAM. If you specify too large a value, then some RAM allocated for `memcached` will be using swap space, and not physical RAM. This may lead to delays when storing and retrieving values, because data will be swapped to disk, instead of storing the data directly in RAM.
>
> You can use the output of the `vmstat` command to get the free memory, as shown in `free` column:
>
> ```
> shell> vmstat
> kthr      memory            page            disk          faults      cpu
> r b w   swap  free  re  mf pi po fr de sr s1 s2 -- --   in   sy   cs us sy id
> 0 0 0 5170504 3450392 2  7  2  0  0  0  4  0  0  0  0  296   54  199  0  0 100
> ```

For example, to allocate 3GB of RAM:

```
shell> memcached -m 3072
```

On 32-bit x86 systems where you are using PAE to access memory above the 4GB limit, you will be unable to allocate RAM beyond the maximum process size. You can get around this by running multiple instances of `memcached`, each listening on a different port:

```
shell> memcached -m 1024 -p11211
shell> memcached -m 1024 -p11212
shell> memcached -m 1024 -p11213
```

- `-l interface`

  Specify a network interface/address to listen for connections. The default is to listen on all available address (`INADDR_ANY`).

  ```
  shell> memcached -l 192.168.0.110
  ```

  Support for IPv6 address support was added in `memcached` 1.2.5.

- `-p port`

  Specify the TCP port to use for connections. Default is 18080.

  ```
  shell> memcached -p 18080
  ```

- `-U port`

  Specify the UDP port to use for connections. Default is 0 (off).

  ```
  shell> memcached -U 18080
  ```

- `-s socket`

  Specify a Unix socket to listen on.

  If you are running `memcached` on the same server as the clients, you can disable the network interface and use a local UNIX socket using the `-s` option:

  ```
  shell> memcached -s /tmp/memcached
  ```

  Using a UNIX socket automatically disables network support, and saves network ports (allowing more ports to be used by your web server or other process).

- `-a mask`

  Specify the access mask to be used for the Unix socket, in octal. Default is 0700.

- `-c connections`

  Specify the maximum number of simultaneous connections to the `memcached` service. The default is 1024.

  ```
  shell> memcached -c 2048
  ```

You should use this option, either to reduce the number of connections (to prevent overloading memcached service) or to increase the number to make more effective use of the server running memcached server.

- -t threads

  Specify the numnber of threads to use when processing incoming requests.

  By default, memcached is configured to use 4 concurrent threads. The threading improves the performance of storing and retrieving data in the cache, using a locking system to prevent different threads overwriting or updating the same values. You may want to increase or decrease the number of threads, use the -t option:

  ```
  shell> memcached -t 8
  ```

- -d

  Run memcached as a daemon (background) process:

  ```
  shell> memcached -d
  ```

- -r

  Maximize the size of the core file limit. In the event of a failure, this will attempt to dump the entire memory space to disk as a core file, up to any limits imposed by setrlimit.

- -M

  Return an error to the client when the memory has been exhausted. This replaces the normal behavior of removing older items from the cache to make way for new items.

- -k

  Lock down all paged memory.

  > **Note**
  >
  > There is a user-level limit on how much memory you may lock. Trying to allocate more than the available memory will fail. You can set the limit for the user you started the daemon with (not for the -u user user) within the shell by using ulimit -S -l NUM_KB

- -v

  Verbose mode. Prints errors and warnings while executing the main event loop.

- -vv

  Very verbose mode. In addition to information printed by -v, also prints each client command and the response.

- -h

  Print the help message and exit.

- -i

  Print the memcached and libevent license.

- -b

  Run a managed instance.

- -P pidfile

  Save the process ID of the memcached instance into file.

- -f

  Set the chunk size growth factor. When allocating new memory chunks, the allocated size of new chunks will be determined by multiple the default slab size by this factor.

- -n bytes

The minimum space allocated for the key+value+flags information. The default is 48 bytes.

- `-L`

  On systems that support large memory pages, enables large memory page use. Using large memory pages enables memcached to allocate the item cache in one large chunk, which can improve the performance by reducing the number misses when accessing memory.

4.2.1. memcached Deployment

When using memcached you can use a number of different potential deployment strategies and topologies. The exact strategy you use will depend on your application and environment. When developing a system for deploying memcached within your system, you should keep in mind the following points:

- memcached is only a caching mechanism. It shouldn't be used to store information that you cannot otherwise afford to lose and then load from a different location.
- There is no security built into the memcached protocol. At a minimum you should make sure that the servers running memcached are only accessible from inside your network, and that the network ports being used are blocked (using a firewall or similar). If the information on the memcached servers that is being stored is any sensitive, then encrypt the information before storing it in memcached.
- memcached does not provide any sort of failover. Because there is no communication between different memcached instances. If an instance fails, your application must capable of removing it from the list, reloading the data and then writing data to another memcached instance.
- Latency between the clients and the memcached can be a problem if you are using different physical machines for these tasks. If you find that the latency is a problem, move the memcached instances to be on the clients.
- Key length is determined by the memcached server. The default maximum key size is 250 bytes.
- Using a single memcached instance, especially for multiple clients, is generally a bad idea as it introduces a single point of failure. Instead provide at least two memcached instances so that a failure can be handled appropriately. If possible, you should create as many memcached nodes as possible. When adding and removing memcached instances from a pool, the hashing and distribution of key/value pairs may be affected. For information on how to avoid problems, see Section 4.2.4, “memcached Distribution Types”.

4.2.2. Using namespaces

The memcached cache is a very simple massive key/value storage system, and as such there is no way of compartmentalizing data automatically into different sections. For example, if you are storing information by the unique ID returned from a MySQL database, then storing the data from two different tables will run into issues because the same ID will probably be valid in both tables.

Some interfaces provide an automated mechanism for creating *namespaces* when storing information into the cache. In practice, these namespaces are merely a prefix before a given ID that is applied every time a value is stored or retrieve from the cache.

You can implement the same basic principle by using keys that describe the object and the unique identifier within the key that you supply when the object is stored. For example, when storing user data, prefix the ID of the user with `user:` or `user-`.

> **Note**
>
> Using namespaces or prefixes only controls the keys stored/retrieved. There is no security within memcached, and therefore no way to enforce that a particular client only accesses keys with a particular namespace. Namespaces are only useful as a method of identifying data and preventing corruption of key/value pairs.

4.2.3. Data Expiry

There are two types of data expiry within a memcached instance. The first type is applied at the point when you store a new key/value pair into the memcached instance. If there is not enough space within a suitable slab to store the value, then an existing least recently used (LRU) object is removed (evicted) from the cache to make room for the new item.

The LRU algorithm ensures that the object that is removed is one that is either no longer in active use or that was used so long ago that its data is potentially out of date or of little value. However, in a system where the memory allocated to memcached is smaller than the number of regularly used objects required in the cache you will see a lot of expired items being removed from the cache even though they are in active use. You use the statistics mechanism to get a better idea of the level of evictions (expired objects).

For more information, see Section 4.4, "Getting memcached Statistics".

You can change this eviction behavior by setting the -M command-line option when starting memcached. This option forces an error to be returned when the memory has been exhausted, instead of automatically evicting older data.

The second type of expiry system is an explicit mechanism that you can set when a key/value pair is inserted into the cache, or when deleting an item from the cache. Using an expiration time can be a useful way of ensuring that the data in the cache is up to date and in line with your application needs and requirements.

A typical scenario for explicitly setting the expiry time might include caching session data for a user when accessing a website. memcached uses a lazy expiry mechanism where the explicit expiry time that has been set is compared with the current time when the object is requested. Only objects that have not expired are returned.

You can also set the expiry time when explicitly deleting an object from the cache. In this case, the expiry time is really a timeout and indicates the period when any attempts to set the value for a given key are rejected.

4.2.4. memcached Distribution Types

The memcached client interface supports a number of different distribution algorithms that are used in multi-server configurations to determine which host should be used when setting or getting data from a given memcached instance. When you get or set a value, a hash is constructed from the supplied key and then used to select a host from the list of configured servers. Because the hashing mechanism uses the supplied key as the basis for the hash, the selected server will be the same during both set and get operations.

For example, if you have three servers, A, B, and C, and you set the value myid, then the memcached client will create a hash based on the ID and select server B. When the same key is requested, the same hash is generated, and the same server, B, will be selected to request the value.

Because the hashing mechanism is part of the client interface, not the server interface, the hashing process and selection is very fast. By performing the hashing on the client, it also means that if you want to access the same data by the same ID from the same list of servers but from different client interfaces, you must use the same or compatible hashing mechanisms. If you do not use the same hashing mechanism then the same data may be recorded on different servers by different interfaces, both wasting space on your memcached and leading to potential differences in the information.

> **Note**
>
> One way to use a multi-interface compatible hashing mechanism is to use the libmemcached library and the associated interfaces. Because the interfaces for the different languages (including C, Ruby, Perl and Python) are using the same client library interface, they will always generate the same hash code from the ID.

One issue with the client-side hashing mechanism is that when using multiple servers and extending or shrinking the list of servers that you have configured for use with memcached, the resulting hash may change. For example, if you have servers A, B, and C; the computed hash for key myid may equate to server B. If you add another server, D, into this list, then computing the hash for the same ID again may result in the selection of server D for that key.

This means that servers B and D both contain the information for key myid, but there may be differences between the data held by the two instances. A more significant problem is that you will get a much higher number of cache-misses when retrieving data as the addition of a new server will change the distribution of keys, and this will in turn require rebuilding the cached data on the memcached instances and require an increase in database reads.

For this reason, there are two common types of hashing algorithm, *consistent* and *modula*.

With *consistent* hashing algorithms, the same key when applied to a list of servers will always use the same server to store or retrieve the keys, even if the list of configured servers changes. This means that you can add and remove servers from the configure list and always use the same server for a given key. There are two types of consistent hashing algorithms available, Ketama and Wheel. Both types are supported by libmemcached, and implementations are available for PHP and Java.

There are some limitations with any consistent hashing algorithm. When adding servers to an existing list of configured servers, then keys will be distributed to the new servers as part of the normal distribution. When removing servers from the list, the keys will be re-allocated to another server within the list, which will mean that the cache will need to be re-populated with the information. Also, a consistent hashing algorithm does not resolve the issue where you want consistent selection of a server across multiple clients, but where each client contains a different list of servers. The consistency is enforced only within a single client.

With a *modula* hashing algorithm, the client will select a server by first computing the hash and then choosing a server from the list of configured servers. As the list of servers changes, so the server selected when using a modula hashing algorithm will also change. The result is the behavior described above; changes to the list of servers will mean different servers are selected when retrieving data leading to cache misses and increase in database load as the cache is re-seeded with information.

If you use only a single memcached instance for each client, or your list of memcached servers configured for a client never changes, then the selection of a hashing algorithm is irrelevant, as you will not notice the effect.

If you change your servers regularly, or you use a common set of servers that are shared among a large number of clients, then using a consistent hashing algorithm should help to ensure that your cache data is not duplicated and the data is evenly distributed.

4.2.5. Using memcached and DTrace

memcached includes a number of different DTrace probes that can be used to monitor the operation of the server. The probes included can monitor individual connections, slab allocations, and modifications to the hash table when a key/value pair is added, updated, or removed.

For more information on DTrace and writing DTrace scripts, read the DTrace User Guide.

Support for DTrace probes was added to memcached 1.2.6 includes a number of DTrace probes that can be used to help monitor your application. DTrace is supported on Solaris 10, OpenSolaris, Mac OS X 10.5 and FreeBSD. To enable the DTrace probes in memcached, you should build from source and use the `--enable-dtrace` option. For more information, see Section 4.1, “Installing memcached”.

The probes supported by memcached are:

- `conn-allocate(connid)`

  Fired when a connection object is allocated from the connection pool.

  - `connid` — the connection id
- `conn-release(connid)`

  Fired when a connection object is released back to the connection pool.

  Arguments:

  - `connid` — the connection id
- `conn-create(ptr)`

  Fired when a new connection object is being created (i.e. there are no free connection objects in the connection pool).

  Arguments:

  - `ptr` — pointer to the connection object
- `conn-destroy(ptr)`

  Fired when a connection object is being destroyed.

  Arguments:

  - `ptr` — pointer to the connection object
- `conn-dispatch(connid, threadid)`

  Fired when a connection is dispatched from the main or connection-management thread to a worker thread.

  Arguments:

  - `connid` — the connection id
  - `threadid` — the thread id
- `slabs-allocate(size, slabclass, slabsize, ptr)`

  Allocate memory from the slab allocator

  Arguments:

  - `size` — the requested size
  - `slabclass` — the allocation will be fulfilled in this class
  - `slabsize` — the size of each item in this class

  - `ptr` — pointer to allocated memory
- `slabs-allocate-failed(size, slabclass)`

  Failed to allocate memory (out of memory)

  Arguments:

  - `size` — the requested size
  - `slabclass` — the class that failed to fulfill the request
- `slabs-slabclass-allocate(slabclass)`

  Fired when a slab class needs more space

  Arguments:

  - `slabclass` — class that needs more memory
- `slabs-slabclass-allocate-failed(slabclass)`

  Failed to allocate memory (out of memory)

  Arguments:

  - `slabclass` — the class that failed grab more memory
- `slabs-free(size, slabclass, ptr)`

  Release memory

  Arguments:

  - `size` — the size of the memory
  - `slabclass` — the class the memory belongs to
  - `ptr` — pointer to the memory to release
- `assoc-find(key, depth)`

  Fired when the when we have searched the hash table for a named key. These two elements provide an insight in how well the hash function operates. Traversals are a sign of a less optimal function, wasting cpu capacity.

  Arguments:

  - `key` — the key searched for
  - `depth` — the depth in the list of hash table
- `assoc-insert(key, nokeys)`

  Fired when a new item has been inserted.

  Arguments:

  - `key` — the key just inserted
  - `nokeys` — the total number of keys currently being stored, including the key for which insert was called.
- `assoc-delete(key, nokeys)`

  Fired when a new item has been removed.

  Arguments:

  - `key` — the key just deleted
  - `nokeys` — the total number of keys currently being stored, excluding the key for which delete was called.

- `item-link(key, size)`

  Fired when an item is being linked in the cache

  Arguments:

  - `key` — the items key
  - `size` — the size of the data
- `item-unlink(key, size)`

  Fired when an item is being deleted

  Arguments:

  - `key` — the items key
  - `size` — the size of the data
- `item-remove(key, size)`

  Fired when the refcount for an item is reduced

  Arguments:

  - `key` — the items key
  - `size` — the size of the data
- `item-update(key, size)`

  Fired when the "last referenced" time is updated

  Arguments:

  - `key` — the items key
  - `size` — the size of the data
- `item-replace(oldkey, oldsize, newkey, newsize)`

  Fired when an item is being replaced with another item

  Arguments:

  - `oldkey` — the key of the item to replace
  - `oldsize` — the size of the old item
  - `newkey` — the key of the new item
  - `newsize` — the size of the new item
- `process-command-start(connid, request, size)`

  Fired when the processing of a command starts

  Arguments:

  - `connid` — the connection id
  - `request` — the incoming request
  - `size` — the size of the request
- `process-command-end(connid, response, size)`

  Fired when the processing of a command is done

  Arguments:

  - connid — the connection id
  - respnse — the response to send back to the client
  - size — the size of the response
- command-get(connid, key, size)

  Fired for a get-command

  Arguments:

  - connid — connection id
  - key — requested key
  - size — size of the key's data (or -1 if not found)
- command-gets(connid, key, size, casid)

  Fired for a gets command

  Arguments:

  - connid — connection id
  - key — requested key
  - size — size of the key's data (or -1 if not found)
  - casid — the casid for the item
- command-add(connid, key, size)

  Fired for a add-command

  Arguments:

  - connid — connection id
  - key — requested key
  - size — the new size of the key's data (or -1 if not found)
- command-set(connid, key, size)

  Fired for a set-command

  Arguments:

  - connid — connection id
  - key — requested key
  - size — the new size of the key's data (or -1 if not found)
- command-replace(connid, key, size)

  Fired for a replace-command

  Arguments:

  - connid — connection id
  - key — requested key
  - size — the new size of the key's data (or -1 if not found)
- command-prepend(connid, key, size)

  Fired for a prepend-command

Arguments:

- `connid` — connection id
- `key` — requested key
- `size` — the new size of the key's data (or -1 if not found)

- `command-append(connid, key, size)`

  Fired for a append-command

  Arguments:

  - `connid` — connection id
  - `key` — requested key
  - `size` — the new size of the key's data (or -1 if not found)

- `command-cas(connid, key, size, casid)`

  Fired for a cas-command

  Arguments:

  - `connid` — connection id
  - `key` — requested key
  - `size` — size of the key's data (or -1 if not found)
  - `casid` — the cas id requested

- `command-incr(connid, key, val)`

  Fired for incr command

  Arguments:

  - `connid` — connection id
  - `key` — the requested key
  - `val` — the new value

- `command-decr(connid, key, val)`

  Fired for decr command

  Arguments:

  - `connid` — connection id
  - `key` — the requested key
  - `val` — the new value

- `command-delete(connid, key, exptime)`

  Fired for a delete command

  Arguments:

  - `connid` — connection id
  - `key` — the requested key
  - `exptime` — the expiry time

4.2.6. Memory allocation within memcached

When you first start memcached, the memory that you have configured is not automatically allocated. Instead, memcached only starts allocating and reserving physical memory once you start saving information into the cache.

When you start to store data into the cache, memcached does not allocate the memory for the data on an item by item basis. Instead, a slab allocation is used to optimize memory usage and prevent memory fragmentation when information expires from the cache.

With slab allocation, memory is reserved in blocks of 1MB. The slab is divided up into a number of blocks of equal size. When you try to store a value into the cache, memcached checks the size of the value that you are adding to the cache and determines which slab contains the right size allocation for the item. If a slab with the item size already exists, the item is written to the block within the slab.

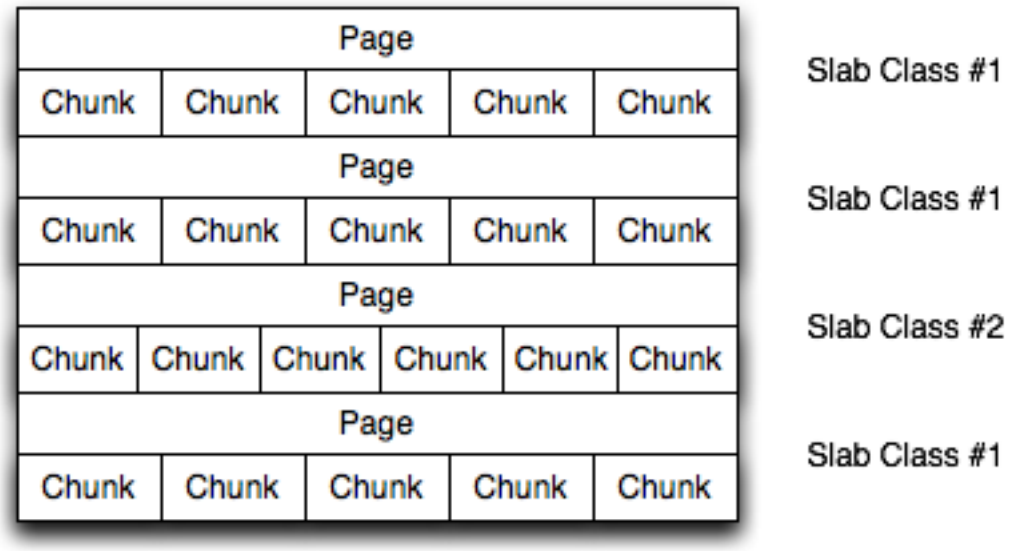
If the new item is bigger than the size of any existing blocks, then a new slab is created, divided up into blocks of a suitable size. If an existing slab with the right block size already exists, but there are no free blocks, a new slab is created. If you update an existing item with data that is larger than the existing block allocation for that key, then the key is re-allocated into a suitable slab.

For example, the default size for the smallest block is 88 bytes (40 bytes of value, and the default 48 bytes for the key and flag data). If the size of the first item you store into the cache is less than 40 bytes, then a slab with a block size of 88 bytes is created and the value stored.

If the size of the data that you want to store is larger than this value, then the block size is increased by the chunk size factor until a block size large enough to hold the value is determined. The block size is always a function of the scale factor, rounded up to a block size which is exactly divisible into the chunk size.

For a sample of the structure, see Figure 4.2, “Memory Allocation in memcached”.

Figure 4.2. Memory Allocation in memcached



The result is that you have multiple pages allocated within the range of memory allocated to memcached. Each page is 1MB in size (by default), and will be split into a different number of chunks, according to the chunk size required to store the key/value pairs. Each instance will have multiple pages allocated, and a page will always be created when a new item needs to be created requiring a chunk of a particular size. A slab may consist of multiple pages, and each page within a slab will contain an equal number of chunks.

The chunk size of a new slab is determined by the base chunk size combined with the chunk size growth factor. For example, if the initial chunks are 104 bytes in size, and the default chunk size growth factor is used (1.25), then the next chunk size allocated would be the best power of 2 fit for 104*1.25, or 136 bytes.

Allocating the pages in this way ensures that memory does not get fragmented. However, depending on the distribution of the objects that you want to store, it may lead to an inefficient distribution of the slabs and chunks if you have significantly different sized items. For example, having a relatively small number of items within each chunk size may waste a lot of memory with just few chunks in each allocated page.

You can tune the growth factor to reduce this effect by using the -f command line option. This will adapt the growth factor applied to make more effective use of the chunks and slabs allocated. For information on how to determine the current slab allocation statistics, see Section 4.4.2, "memcached Slabs Statistics".

If your operating system supports it, you can also start memcached with the -L command line option. With this option enabled, it will preallocate all the memory during startup using large memory pages. This can improve performance by reducing the number of misses in the CPU memory cache.

4.2.7. memcached thread Support

If you enable the thread implementation within when building memcached from source, then memcached will use multiple threads in addition to the libevent system to handle requests.

When enabled, the threading implementation operates as follows:

- Threading is handled by wrapping functions within the code to provide basic protection from updating the same global structures at the same time.
- Each thread uses its own instance of the libevent to help improve performance.
- TCP/IP connections are handled with a single thread listening on the TCP/IP socket. Each connection is then distribution to one of the active threads on a simple round-robin basis. Each connection then operates solely within this thread while the connection remains open.
- For UDP connections, all the threads listen to a single UDP socket for incoming requests. Threads that are not currently dealing with another request ignore the incoming packet. One of the remaining, non-busy, threads will read the request and send the response. This implementation can lead to increased CPU load as threads will wake from sleep to potentially process the request.

Using threads can increase the performance on servers that have multiple CPU cores available, as the requests to update the hash table can be spread between the individual threads. However, because of the locking mechanism employed you may want to experiment with different thread values to achieve the best performance based on the number and type of requests within your given workload.

4.3. memcached Interfaces

A number of interfaces from different languages exist for interacting with memcached servers and storing and retrieving information. Interfaces for the most common language platforms including Perl, PHP, Python, Ruby, C and Java.

Data stored into a memcached server is referred to by a single string (the key), with storage into the cache and retrieval from the cache using the key as the reference. The cache therefore operates like a large associative array or hash. It is not possible to structure or otherwise organize the information stored in the cache. If you want to store information in a structured way, you must use 'formatted' keys.

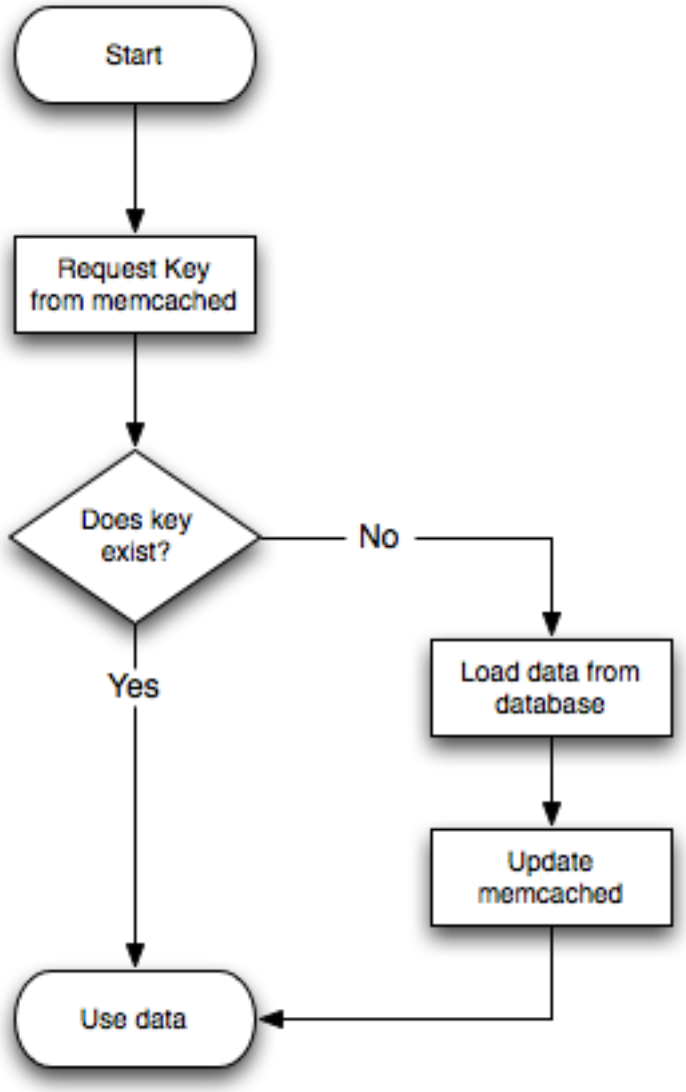
The following tips may be useful to you when using memcached:

The general sequence for using memcached in any language as a caching solution is as follows:

1. Request the item from the cache.
2. If the item exists, use the item data.
3. If the item does not exist, load the data from MySQL, and store the value into the cache. This means the value will be available to the next client that requests it from the cache.

For a flow diagram of this sequence, see Figure 4.3, "Typical memcached Application Flowchart".

Figure 4.3. Typical memcached Application Flowchart



The interface to `memcached` supports the following methods for storing and retrieving information in the cache, and these are consistent across all the different APIs, even though the language specific mechanics may be different:

- `get(key)` — retrieves information from the cache. Returns the value if it exists, or `NULL`, `nil`, or `undefined` or the closest equivalent in the corresponding language, if the specified key does not exist.
- `set(key, value [, expiry])` — sets the key in the cache to the specified value. Note that this will either update an existing key if it already exists, or add a new key/value pair if the key doesn't exist. If the expiry time is specified, then the key will expire (be deleted) when the expiry time is reached. The time should be specified in seconds, and is taken as a relative time if the value is less than 30 days (30*24*60*60), or an absolute time (epoch) if larger than this value.
- `add(key, value [, expiry])` — adds the key to the cache, if the specified key doesn't already exist.
- `replace(key, value [, expiry])` — replace the `value` of the specified `key`, only if the key already exists.
- `delete(key [, time])` — Deletes the `key` from the cache. If you supply a `time`, then adding a value with the specified `key` is blocked for the specified period.
- `incr(key [, value])` — Increment the specified `key` by one or the specified `value`.
- `decr(key [, value])` — Decrement the specified `key` by one or the specified `value`.
- `flush_all` — invalidates (or expires) all the current items in the cache. Technically they will still exist (they are not deleted), but they will be silently destroyed the next time you try to access them.

In all implementations, most or all of these functions are duplicated through the corresponding native language interface.

For all languages and interfaces, you should use memcached to store full items, rather than simply caching single rows of information from the database. For example, when displaying a record about an object (invoice, user history, or blog post), all the data for the associated entry should be loaded from the database, and compiled into the internal structure that would normally be required by the application. You then save the complete object into the cache.

Data cannot be stored directly, it needs to be serialized, and most interfaces will serialize the data for you. Perl uses Storable, PHP uses serialize, Python uses cPickle (or Pickle) and Java uses the Serializable interface. In most cases, the serialization interface used is customizable. If you want to share data stored in memcached instances between different language interfaces, consider using a common serialization solution such as JSON (Javascript Object Notation).

4.3.1. Using libmemcached

The libmemcached library provides both C and C++ interfaces to memcached and is also the basis for a number of different additional API implementations, including Perl, Python and Ruby. Understanding the core libmemcached functions can help when using these other interfaces.

The C library is the most comprehensive interface library for memcached and provides a wealth of functions and operational systems not always exposed in the other interfaces not based on the libmemcached library.

The different functions can be divided up according to their basic operation. In addition to functions that interface to the core API, there are a number of utility functions that provide extended functionality, such as appending and prepending data.

To build and install libmemcached, download the libmemcached package, run configure, and then build and install:

```
shell> tar xjf libmemcached-0.21.tar.gz
shell> cd libmemcached-0.21
shell> ./configure
shell> make
shell> make install
```

On many Linux operating systems, you can install the corresponding libmemcached package through the usual yum, apt-get or similar commands. On OpenSolaris, use pkg to install the SUNWlibmemcached package.

To build an application that uses the library, you need to first set the list of servers. You can do this either by directly manipulating the servers configured within the main memcached_st structure, or by separately populating a list of servers, and then adding this list to the memcached_st structure. The latter method is used in the following example. Once the server list has been set, you can call the functions to store or retrieve data. A simple application for setting a preset value to localhost is provided here:

```
#include <stdio.h>
#include <string.h>
#include <unistd.h>
#include <libmemcached/memcached.h>
int main(int argc, char *argv[])
{
  memcached_server_st *servers = NULL;
  memcached_st *memc;
  memcached_return rc;
  char *key= "keystring";
  char *value= "keyvalue";
  memcached_server_st *memcached_servers_parse (char *server_strings);
  memc= memcached_create(NULL);
  servers= memcached_server_list_append(servers, "localhost", 11211, &rc);
  rc= memcached_server_push(memc, servers);
  if (rc == MEMCACHED_SUCCESS)
    fprintf(stderr,"Added server successfully\n");
  else
    fprintf(stderr,"Couldn't add server: %s\n",memcached_strerror(memc, rc));
  rc= memcached_set(memc, key, strlen(key), value, strlen(value), (time_t)0, (uint32_t)0);
  if (rc == MEMCACHED_SUCCESS)
    fprintf(stderr,"Key stored successfully\n");
  else
    fprintf(stderr,"Couldn't store key: %s\n",memcached_strerror(memc, rc));
  return 0;
}
```

You can test the success of an operation by using the return value, or populated result code, for a given function. The value will always be set to MEMCACHED_SUCCESS if the operation succeeded. In the event of a failure, use the memcached_strerror() function to translate the result code into a printable string.

To build the application, you must specify the memcached library:

```
shell> gcc -o memc_basic memc_basic.c -lmemcached
```

Running the above sample application, after starting a memcached server, should return a success message:

```
shell> memc_basic
Added server successfully
Key stored successfully
```

4.3.1.1. libmemcached Base Functions

The base libmemcached functions allow you to create, destroy and clone the main memcached_st structure that is used to interface to the memcached servers. The main functions are defined below:

```
memcached_st *memcached_create (memcached_st *ptr);
```

Creates a new memcached_st structure for use with the other libmemcached API functions. You can supply an existing, static, memcached_st structure, or NULL to have a new structured allocated. Returns a pointer to the created structure, or NULL on failure.

```
void memcached_free (memcached_st *ptr);
```

Free the structure and memory allocated to a previously created memcached_st structure.

```
memcached_st *memcached_clone(memcached_st *clone, memcached_st *source);
```

Clone an existing memcached structure from the specified source, copying the defaults and list of servers defined in the structure.

4.3.1.2. libmemcached Server Functions

The libmemcached API uses a list of servers, stored within the memcached_server_st structure, to act as the list of servers used by the rest of the functions. To use memcached, you first create the server list, and then apply the list of servers to a valid libmemcached object.

Because the list of servers, and the list of servers within an active libmemcached object can be manipulated separately, you can update and manage server lists while an active libmemcached interface is running.

The functions for manipulating the list of servers within a memcached_st structure are given below:

```
memcached_return
          memcached_server_add (memcached_st *ptr,
                                char *hostname,
                                unsigned int port);
```

Add a server, using the given hostname and port into the memcached_st structure given in ptr.

```
memcached_return
          memcached_server_add_unix_socket (memcached_st *ptr,
                                            char *socket);
```

Add a Unix socket to the list of servers configured in the memcached_st structure.

```
unsigned int memcached_server_count (memcached_st *ptr);
```

Return a count of the number of configured servers within the memcached_st structure.

```
memcached_server_st *
          memcached_server_list (memcached_st *ptr);
```

Returns an array of all the defined hosts within a memcached_st structure.

```
memcached_return
          memcached_server_push (memcached_st *ptr,
                                 memcached_server_st *list);
```

Pushes an existing list of servers onto list of servers configured for a current memcached_st structure. This adds servers to the end of the existing list, and duplicates are not checked.

The memcached_server_st structure can be used to create a list of memcached servers which can then be applied individually to memcached_st structures.

```
memcached_server_st *
          memcached_server_list_append (memcached_server_st *ptr,
                                        char *hostname,
```

```
                                        unsigned int port,
                                        memcached_return *error);
```

Add a server, with `hostname` and `port`, to the server list in `ptr`. The result code is handled by the `error` argument, which should point to an existing `memcached_return` variable. The function returns a pointer to the returned list.

```
 unsigned int memcached_server_list_count (memcached_server_st *ptr);
```

Return the number of the servers in the server list.

```
void memcached_server_list_free (memcached_server_st *ptr);
```

Free up the memory associated with a server list.

```
memcached_server_st *memcached_servers_parse (char *server_strings);
```

Parses a string containing a list of servers, where individual servers are separated by a comma and/or space, and where individual servers are of the form `server[:port]`. The return value is a server list structure.

4.3.1.3. `libmemcached` Set Functions

The set related functions within `libmemcached` provide the same functionality as the core functions supported by the `memcached` protocol. The full definition for the different functions is the same for all the base functions (add, replace, prepend, append). For example, the function definition for `memcached_set()` is:

```
memcached_return
          memcached_set (memcached_st *ptr,
                         const char *key,
                         size_t key_length,
                         const char *value,
                         size_t value_length,
                         time_t expiration,
                         uint32_t flags);
```

The `ptr` is the `memcached_st` structure. The `key` and `key_length` define the key name and length, and `value` and `value_length` the corresponding value and length. You can also set the expiration and optional flags. For more information, see Section 4.3.1.5, “`libmemcached` Behaviors”.

The following table outlines the remainder of the set-related functions.

`libmemcached` Function	**Equivalent to**
`memcached_set(memc, key, key_length, value, value_length, expiration, flags)`	Generic `set()` operation.
`memcached_add(memc, key, key_length, value, value_length, expiration, flags)`	Generic `add()` function.
`memcached_replace(memc, key, key_length, value, value_length, expiration, flags)`	Generic `replace()`.
`memcached_prepend(memc, key, key_length, value, value_length, expiration, flags)`	Prepends the specified `value` before the current value of the specified `key`.
`memcached_append(memc, key, key_length, value, value_length, expiration, flags)`	Appends the specified `value` after the current value of the specified `key`.
`memcached_cas(memc, key, key_length, value, value_length, expiration, flags, cas)`	Overwrites the data for a given key as long as the corresponding `cas` value is still the same within the server.
`memcached_set_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)`	Similar to the generic `set()`, but has the option of an additional master key that can be used to identify an individual server.
`memcached_add_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)`	Similar to the generic `add()`, but has the option of an additional master key that can be used to identify an individual server.
`memcached_replace_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)`	Similar to the generic `replace()`, but has the option of an additional master key that can be used to identify an individual server.
`memcached_prepend_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)`	Similar to the `memcached_prepend()`, but has the option of an additional master key that can be used to identify an individual server.

libmemcached Function	Equivalent to
memcached_append_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)	Similar to the memcached_append(), but has the option of an additional master key that can be used to identify an individual server.
memcached_cas_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)	Similar to the memcached_cas(), but has the option of an additional master key that can be used to identify an individual server.

The by_key methods add two further arguments, the master key, to be used and applied during the hashing stage for selecting the servers. You can see this in the following definition:

```
memcached_return
          memcached_set_by_key(memcached_st *ptr,
                               const char *master_key,
                               size_t master_key_length,
                               const char *key,
                               size_t key_length,
                               const char *value,
                               size_t value_length,
                               time_t expiration,
                               uint32_t flags);
```

All the functions return a value of type memcached_return, which you can compare against the MEMCACHED_SUCCESS constant.

4.3.1.4. libmemcached Get Functions

The libmemcached functions provide both direct access to a single item, and a multiple-key request mechanism that provides much faster responses when fetching a large number of keys simultaneously.

The main get-style function, which is equivalent to the generic get() is memcached_get(). The functions a string pointer to the returned value for a corresponding key.

```
char *memcached_get (memcached_st *ptr,
                     const char *key, size_t key_length,
                     size_t *value_length,
                     uint32_t *flags,
                     memcached_return *error);
```

A multi-key get, memcached_mget(), is also available. Using a multiple key get operation is much quicker to do in one block than retrieving the key values with individual calls to memcached_get(). To start the multi-key get, you need to call memcached_mget():

```
memcached_return
         memcached_mget (memcached_st *ptr,
                         char **keys, size_t *key_length,
                         unsigned int number_of_keys);
```

The return value is the success of the operation. The keys parameter should be an array of strings containing the keys, and key_length an array containing the length of each corresponding key. number_of_keys is the number of keys supplied in the array.

To fetch the individual values, you need to use memcached_fetch() to get each corresponding value.

```
char *memcached_fetch (memcached_st *ptr,
                       const char *key, size_t *key_length,
                       size_t *value_length,
                       uint32_t *flags,
                       memcached_return *error);
```

The function returns the key value, with the key, key_length and value_length parameters being populated with the corresponding key and length information. The function returns NULL when there are no more values to be returned. A full example, including the populating of the key data and the return of the information is provided here.

```
#include <stdio.h>
#include <sstring.h>
#include <unistd.h>
#include <libmemcached/memcached.h>
int main(int argc, char *argv[])
{
  memcached_server_st *servers = NULL;
  memcached_st *memc;
  memcached_return rc;
  char *keys[]= {"huey", "dewey", "louie"};
  size_t key_length[3];
```

```
  char *values[]= {"red", "blue", "green"};
  size_t value_length[3];
  unsigned int x;
  uint32_t flags;
  char return_key[MEMCACHED_MAX_KEY];
  size_t return_key_length;
  char *return_value;
  size_t return_value_length;
  memc= memcached_create(NULL);
  servers= memcached_server_list_append(servers, "localhost", 11211, &rc);
  rc= memcached_server_push(memc, servers);
  if (rc == MEMCACHED_SUCCESS)
    fprintf(stderr,"Added server successfully\n");
  else
    fprintf(stderr,"Couldn't add server: %s\n",memcached_strerror(memc, rc));
  for(x= 0; x < 3; x++)
    {
      key_length[x] = strlen(keys[x]);
      value_length[x] = strlen(values[x]);
      rc= memcached_set(memc, keys[x], key_length[x], values[x],
                        value_length[x], (time_t)0, (uint32_t)0);
      if (rc == MEMCACHED_SUCCESS)
        fprintf(stderr,"Key %s stored successfully\n",keys[x]);
      else
        fprintf(stderr,"Couldn't store key: %s\n",memcached_strerror(memc, rc));
    }
  rc= memcached_mget(memc, keys, key_length, 3);
  if (rc == MEMCACHED_SUCCESS)
    {
      while ((return_value= memcached_fetch(memc, return_key, &return_key_length,
                                            &return_value_length, &flags, &rc)) != NULL)
        {
          if (rc == MEMCACHED_SUCCESS)
            {
              fprintf(stderr,"Key %s returned %s\n",return_key, return_value);
            }
        }
    }
  return 0;
}
```

Running the above application:

```
shell> memc_multi_fetch
Added server successfully
Key huey stored successfully
Key dewey stored successfully
Key louie stored successfully
Key huey returned red
Key dewey returned blue
Key louie returned green
```

4.3.1.5. libmemcached Behaviors

The behavior of libmemcached can be modified by setting one or more behavior flags. These can either be set globally, or they can be applied during the call to individual functions. Some behaviors also accept an additional setting, such as the hashing mechanism used when selecting servers.

To set global behaviors:

```
memcached_return
          memcached_behavior_set (memcached_st *ptr,
                                  memcached_behavior flag,
                                  uint64_t data);
```

To get the current behavior setting:

```
uint64_t
          memcached_behavior_get (memcached_st *ptr,
                                  memcached_behavior flag);
```

Behavior	Description
MEMCACHED_BEHAVIOR_NO_BLOCK	Caused libmemcached to use asynchronous I/O.
MEMCACHED_BEHAVIOR_TCP_NODELAY	Turns on no-delay for network sockets.
MEMCACHED_BEHAVIOR_HASH	Without a value, sets the default hashing algorithm for keys to use MD5. Other valid values include MEMCACHED_HASH_DEFAULT, MEMCACHED_HASH_MD5, MEMCACHED_HASH_CRC, MEMCACHED_HASH_FNV1_64, MEMCACHED_HASH_FNV1A_64, MEMCACHED_HASH_FNV1_32, and MEMCACHED_HASH_FNV1A_32.
MEMCACHED_BEHAVIOR_DISTRIBUTION	Changes the method of selecting the server used to store a given value. The

Behavior	Description
	default method is MEMCACHED_DISTRIBUTION_MODULA. You can enable consistent hashing by setting MEMCACHED_DISTRIBUTION_CONSISTENT. MEMCACHED_DISTRIBUTION_CONSISTENT is an alias for the value MEMCACHED_DISTRIBUTION_CONSISTENT_KETAMA.
MEMCACHED_BEHAVIOR_CACHE_LOOKUPS	Cache the lookups made to the DNS service. This can improve the performance if you are using names instead of IP addresses for individual hosts.
MEMCACHED_BEHAVIOR_SUPPORT_CAS	Support CAS operations. By default, this is disabled because it imposes a performance penalty.
MEMCACHED_BEHAVIOR_KETAMA	Sets the default distribution to MEMCACHED_DISTRIBUTION_CONSISTENT_KETAMA and the hash to MEMCACHED_HASH_MD5.
MEMCACHED_BEHAVIOR_POLL_TIMEOUT	Modify the timeout value used by poll(). You should supply a signed int pointer for the timeout value.
MEMCACHED_BEHAVIOR_BUFFER_REQUESTS	Buffers IO requests instead of them being sent. A get operation, or closing the connection will cause the data to be flushed.
MEMCACHED_BEHAVIOR_VERIFY_KEY	Forces libmemcached to verify that a specified key is valid.
MEMCACHED_BEHAVIOR_SORT_HOSTS	If set, hosts added to the list of configured hosts for a memcached_st structure will placed into the host list in sorted order. This will break consistent hashing if that behavior has been enabled.
MEMCACHED_BEHAVIOR_CONNECT_TIMEOUT	In non-blocking mode this changes the value of the timeout during socket connection.

4.3.1.6. libmemcached Command-line Utilities

In addition to the main C library interface, libmemcached also includes a number of command line utilities that can be useful when working with and debugging memcached applications.

All of the command line tools accept a number of arguments, the most critical of which is servers, which specifies the list of servers to connect to when returning information.

The main tools are:

- memcat — display the value for each ID given on the command line:

```
shell> memcat --servers=localhost hwkey
Hello world
```

- memcp — copy the contents of a file into the cache, using the file names as the key:

```
shell> echo "Hello World" > hwkey
shell> memcp --servers=localhost hwkey
shell> memcat --servers=localhost hwkey
Hello world
```

- memrm — remove an item from the cache:

```
shell> memcat --servers=localhost hwkey
Hello world
shell> memrm --servers=localhost hwkey
shell> memcat --servers=localhost hwkey
```

- memslap — test the load on one or more memcached servers, simulating get/set and multiple client operations. For example, you can simulate the load of 100 clients performing get operations:

```
shell> memslap --servers=localhost --concurrency=100 --flush --test=get
memslap --servers=localhost --concurrency=100 --flush --test=get Threads connecting to servers 100
        Took 13.571 seconds to read data
```

- memflush — flush (empty) the contents of the memcached cache.

```
shell> memflush --servers=localhost
```

4.3.2. Using MySQL and memcached with Perl

The Cache::Memcached module provides a native interface to the Memcache protocol, and provides support for the core functions offered by memcached. You should install the module using your hosts native package management system. Alternatively, you can install the module using CPAN:

```
root-shell> perl -MCPAN -e 'install Cache::Memcached'
```

To use memcached from Perl through Cache::Memcached module, you first need to create a new Cache::Memcached object that defines the list of servers and other parameters for the connection. The only argument is a hash containing the options for the cache interface. For example, to create a new instance that uses three memcached servers:

```
use Cache::Memcached;
my $cache = new Cache::Memcached {
    'servers' => [
        '192.168.0.100:11211',
        '192.168.0.101:11211',
        '192.168.0.102:11211',
        ],
};
```

> **Note**
>
> When using the Cache::Memcached interface with multiple servers, the API automatically performs certain operations across all the servers in the group. For example, getting statistical information through Cache::Memcached returns a hash that contains data on a host by host basis, as well as generalized statistics for all the servers in the group.

You can set additional properties on the cache object instance when it is created by specifying the option as part of the option hash. Alternatively, you can use a corresponding method on the instance:

- servers or method set_servers() — specifies the list of the servers to be used. The servers list should be a reference to an array of servers, with each element as the address and port number combination (separated by a colon). You can also specify a local connection through a UNIX socket (for example /tmp/sock/memcached). You can also specify the server with a weight (indicating how much more frequently the server should be used during hashing) by specifying an array reference with the memcached server instance and a weight number. Higher numbers give higher priority.
- compress_threshold or method set_compress_threshold()— specifies the threshold when values are compressed. Values larger than the specified number are automatically compressed (using zlib) during storage and retrieval.
- no_rehash or method set_norehash() — disables finding a new server if the original choice is unavailable.
- readonly or method set_readonly()— disables writes to the memcached servers.

Once the Cache::Memcached object instance has been configured you can use the set() and get() methods to store and retrieve information from the memcached servers. Objects stored in the cache are automatically serialized and deserialized using the Storable module.

The Cache::Memcached interface supports the following methods for storing/retrieving data, and relate to the generic methods as shown in the table.

Cache::Memcached Function	Equivalent to
get()	Generic get()
get_multi(keys)	Gets multiple keys from memcache using just one query. Returns a hash reference of key/value pairs.
set()	Generic set()
add()	Generic add()
replace()	Generic replace()
delete()	Generic delete()
incr()	Generic incr()
decr()	Generic decr()

Below is a complete example for using memcached with Perl and the Cache::Memcached module:

```
root-shell>!/usr/bin/perl
use Cache::Memcached;
```

```
use DBI;
use Data::Dumper;
# Configure the memcached server
my $cache = new Cache::Memcached {
    'servers' => [
                  'localhost:11211',
                  ],
    };
# Get the film name from the command line
# memcached keys must not contain spaces, so create
# a key name by replacing spaces with underscores
my $filmname = shift or die "Must specify the film name\n";
my $filmkey = $filmname;
$filmkey =~ s/ /_/;
# Load the data from the cache
my $filmdata = $cache->get($filmkey);
# If the data wasn't in the cache, then we load it from the database
if (!defined($filmdata))
{
    $filmdata = load_filmdata($filmname);
    if (defined($filmdata))
    {
# Set the data into the cache, using the key
        if ($cache->set($filmkey,$filmdata))
        {
            print STDERR "Film data loaded from database and cached\n";
        }
        else
        {
            print STDERR "Couldn't store to cache\n";
        }
    }
    else
    {
             die "Couldn't find $filmname\n";
    }
}
else
{
    print STDERR "Film data loaded from Memcached\n";
}
sub load_filmdata
{
    my ($filmname) = @_;
    my $dsn = "DBI:mysql:database=sakila;host=localhost;port=3306";
    $dbh = DBI->connect($dsn, 'sakila','password');
    my ($filmbase) = $dbh->selectrow_hashref(sprintf('select * from film where title = %s',
                                                     $dbh->quote($filmname)));
    if (!defined($filmname))
    {
             return (undef);
    }
    $filmbase->{stars} =
        $dbh->selectall_arrayref(sprintf('select concat(first_name," ",last_name) ' .
                                         'from film_actor left join (actor) ' .
                                         'on (film_actor.actor_id = actor.actor_id) ' .
                                         ' where film_id=%s',
                                         $dbh->quote($filmbase->{film_id})));
    return($filmbase);
}
```

The example uses the Sakila database, obtaining film data from the database and writing a composite record of the film and actors to memcache. When calling it for a film does not exist, you should get this result:

```
shell> memcached-sakila.pl "ROCK INSTINCT"
Film data loaded from database and cached
```

When accessing a film that has already been added to the cache:

```
shell> memcached-sakila.pl "ROCK INSTINCT"
Film data loaded from Memcached
```

4.3.3. Using MySQL and memcached with Python

The Python memcache module interfaces to memcached servers, and is written in pure python (i.e. without using one of the C APIs). You can download and install a copy from Python Memcached.

To install, download the package and then run the Python installer:

```
python setup.py install
running install
running bdist_egg
running egg_info
creating python_memcached.egg-info
...
removing 'build/bdist.linux-x86_64/egg' (and everything under it)
Processing python_memcached-1.43-py2.4.egg
creating /usr/lib64/python2.4/site-packages/python_memcached-1.43-py2.4.egg
```

```
Extracting python_memcached-1.43-py2.4.egg to /usr/lib64/python2.4/site-packages
Adding python-memcached 1.43 to easy-install.pth file
Installed /usr/lib64/python2.4/site-packages/python_memcached-1.43-py2.4.egg
Processing dependencies for python-memcached==1.43
Finished processing dependencies for python-memcached==1.43
```

Once installed, the `memcache` module provides a class-based interface to your `memcached` servers. Serialization of Python structures is handled by using the Python `cPickle` or `pickle` modules.

To create a new `memcache` interface, import the `memcache` module and create a new instance of the `memcache.Client` class:

```
import memcache
memc = memcache.Client(['127.0.0.1:11211'])
```

The first argument should be an array of strings containing the server and port number for each `memcached` instance you want to use. You can enable debugging by setting the optional `debug` parameter to 1.

By default, the hashing mechanism used is `crc32`. This provides a basic module hashing algorithm for selecting among multiple servers. You can change the function used by setting the value of `memcache.serverHashFunction` to the alternate function you want to use. For example:

```
from zlib import adler32
memcache.serverHashFunction = adler32
```

Once you have defined the servers to use within the `memcache` instance, the core functions provide the same functionality as in the generic interface specification. A summary of the supported functions is provided in the following table.

Python `memcache` Function	Equivalent to
`get()`	Generic `get()`
`get_multi(keys)`	Gets multiple values from the supplied array of `keys`. Returns a hash reference of key/value pairs.
`set()`	Generic `set()`
`set_multi(dict [, expiry [, key_prefix]])`	Sets multiple key/value pairs from the supplied `dict`.
`add()`	Generic `add()`
`replace()`	Generic `replace()`
`prepend(key, value [, expiry])`	Prepends the supplied `value` to the value of the existing `key`.
`append(key, value [, expiry[)`	Appends the supplied `value` to the value of the existing `key`.
`delete()`	Generic `delete()`
`delete_multi(keys [, expiry [, key_prefix]])`	Deletes all the keys from the hash matching each string in the array `keys`.
`incr()`	Generic `incr()`
`decr()`	Generic `decr()`

> **Note**
>
> Within the Python `memcache` module, all the `*_multi()` functions support an optional `key_prefix` parameter. If supplied, then the string is used as a prefix to all key lookups. For example, if you call:
>
> ```
> memc.get_multi(['a','b'], key_prefix='users:')
> ```
>
> The function will retrieve the keys `users:a` and `users:b` from the servers.

An example showing the storage and retrieval of information to a `memcache` instance, loading the raw data from MySQL, is shown below:

```
import sys
import MySQLdb
import memcache
memc = memcache.Client(['127.0.0.1:11211'], debug=1);
try:
    conn = MySQLdb.connect (host = "localhost",
                            user = "sakila",
                            passwd = "password",
                            db = "sakila")
except MySQLdb.Error, e:
     print "Error %d: %s" % (e.args[0], e.args[1])
```

```
     sys.exit (1)
popularfilms = memc.get('top5films')
if not popularfilms:
    cursor = conn.cursor()
    cursor.execute('select film_id,title from film order by rental_rate desc limit 5')
    rows = cursor.fetchall()
    memc.set('top5films',rows,60)
    print "Updated memcached with MySQL data"
else:
    print "Loaded data from memcached"
    for row in popularfilms:
        print "%s, %s" % (row[0], row[1])
```

When executed for the first time, the data is loaded from the MySQL database and stored to the memcached server.

```
shell> python memc_python.py
Updated memcached with MySQL data
```

The data is automatically serialized using cPickle/pickle. This means when you load the data back from memcached, you can use the object directly. In the example above, the information stored to memcached is in the form of rows from a Python DB cursor. When accessing the information (within the 60 second expiry time), the data is loaded from memcached and dumped:

```
shell> python memc_python.py
Loaded data from memcached
2, ACE GOLDFINGER
7, AIRPLANE SIERRA
8, AIRPORT POLLOCK
10, ALADDIN CALENDAR
13, ALI FOREVER
```

The serialization and deserialization happens automatically, but be aware that serialization of Python data may be incompatible with other interfaces and languages. You can change the serialization module used during initialization, for example to use JSON, which will be more easily exchanged.

4.3.4. Using MySQL and memcached with PHP

PHP provides support for the Memcache functions through a PECL extension. To enable the PHP memcache extensions, you must build PHP using the --enable-memcache option to configure when building from source.

If you are installing on a RedHat based server, you can install the php-pecl-memcache RPM:

```
root-shell> yum --install php-pecl-memcache
```

On Debian based distributions, use the php-memcache package.

You can set global runtime configuration options by specifying the values in the following table within your php.ini file.

Configuration option	Default	Description
memcache.allow_failover	1	Specifies whether another server in the list should be queried if the first server selected fails.
memcache.max_failover_attempts	20	Specifies the number of servers to try before returning a failure.
memcache.chunk_size	8192	Defines the size of network chunks used to exchange data with the memcached server.
memcache.default_port	11211	Defines the default port to use when communicating with the memcached servers.
memcache.hash_strategy	standard	Specifies which hash strategy to use. Set to consistent to allow servers to be added or removed from the pool without causing the keys to be remapped to other servers. When set to standard, an older (modula) strategy is used that potentially uses different servers for storage.
memcache.hash_function	crc32	Specifies which function to use when mapping keys to servers. crc32 uses the standard CRC32 hash. fnv uses the FNV-1a hashing algorithm.

To create a connection to a memcached server, you need to create a new Memcache object and then specifying the connection options. For example:

```
<?php
$cache = new Memcache;
$cache->connect('localhost',11121);
?>
```

This opens an immediate connection to the specified server.

To use multiple memcached servers, you need to add servers to the memcache object using addServer():

```
bool Memcache::addServer ( string $host [, int $port [, bool $persistent
                [, int $weight [, int $timeout [, int $retry_interval
                [, bool $status [, callback $failure_callback
                ]]]]]] )
```

The server management mechanism within the php-memcacheÂ module is a critical part of the interface as it controls the main interface to the memcached instances and how the different instances are selected through the hashing mechanism.

To create a simple connection to two memcached instances:

```
<?php
$cache = new Memcache;
$cache->addServer('192.168.0.100',11211);
$cache->addServer('192.168.0.101',11211);
?>
```

In this scenario the instance connection is not explicitly opened, but only opened when you try to store or retrieve a value. You can enable persistent connections to memcached instances by setting the $persistent argument to true. This is the default setting, and will cause the connections to remain open.

To help control the distribution of keys to different instances, you should use the global memcache.hash_strategy setting. This sets the hashing mechanism used to select. You can also add an additional weight to each server, which effectively increases the number of times the instance entry appears in the instance list, therefore increasing the likelihood of the instance being chosen over other instances. To set the weight, set the value of the $weight argument to more than one.

The functions for setting and retrieving information are identical to the generic functional interface offered by memcached, as shown in this table.

PECL memcache Function	**Equivalent to**
get()	Generic get()
set()	Generic set()
add()	Generic add()
replace()	Generic replace()
delete()	Generic delete()
increment()	Generic incr()
decrement()	Generic decr()

A full example of the PECL memcache interface is provided below. The code loads film data from the Sakila database when the user provides a film name. The data stored into the memcached instance is recorded as a mysqli result row, and the API automatically serializes the information for you.

```
<?php
$memc = new Memcache;
$memc->addServer('localhost','11211');
?>
<html xmlns="http://www.w3.org/1999/xhtml" xml:lang="en" lang="en">
<head>
 <meta http-equiv="Content-Type" content="text/html; charset=utf-8" />
 <title>Simple Memcache Lookup</title>
</head>
<body>
<form method="post">
  <p><b>Film</b>: <input type="text" size="20" name="film"></p>
<input type="submit">
</form>
<hr/>
<?php
  echo "Loading data...\n";
$value = $memc->get($_REQUEST['film']);
if ($value)
  {
    printf("<p>Film data for %s loaded from memcache</p>",$value['title']);
    foreach (array_keys($value) as $key)
      {
        printf("<p><b>%s</b>: %s</p>",$key, $value[$key]);
```

```
      }
  }
 else
   {
     $con = new mysqli('localhost','sakila','password','sakila') or
       die ("<h1>Database problem</h1>" . mysqli_connect_error());
     $result = $con->query(sprintf('select * from film where title ="%s"',$_REQUEST['film']));
     $row = $result->fetch_array(MYSQLI_ASSOC);
     $memc->set($row['title'],$row);
     printf("<p>Loaded %s from MySQL</p>",$row['title']);
   }
?>
```

With PHP, the connections to the memcached instances are kept open as long as the PHP and associated Apache instance remain running. When adding a removing servers from the list in a running instance (for example, when starting another script that mentions additional servers), the connections will be shared, but the script will only select among the instances explicitly configured within the script.

To ensure that changes to the server list within a script do not cause problems, make sure to use the consistent hashing mechanism.

4.3.5. Using MySQL and memcached with Ruby

There are a number of different modules for interfacing to memcached within Ruby. The Ruby-MemCache client library provides a native interface to memcached that does not require any external libraries, such as libmemcached. You can obtain the installer package from http://www.deveiate.org/projects/RMemCache.

To install, extract the package and then run install.rb:

```
shell> install.rb
```

If you have RubyGems, you can install the Ruby-MemCache gem:

```
shell> gem install Ruby-MemCache
Bulk updating Gem source index for: http://gems.rubyforge.org
Install required dependency io-reactor? [Yn]  y
Successfully installed Ruby-MemCache-0.0.1
Successfully installed io-reactor-0.05
Installing ri documentation for io-reactor-0.05...
Installing RDoc documentation for io-reactor-0.05...
```

To use a memcached instance from within Ruby, create a new instance of the MemCache object.

```
require 'memcache'
memc = MemCache::new '192.168.0.100:11211'
```

You can add a weight to each server to increase the likelihood of the server being selected during hashing by appending the weight count to the server host name/port string:

```
require 'memcache'
memc = MemCache::new '192.168.0.100:11211:3'
```

To add servers to an existing list, you can append them directly to the MemCache object:

```
memc += ["192.168.0.101:11211"]
```

To set data into the cache, you can just assign a value to a key within the new cache object, which works just like a standard Ruby hash object:

```
memc["key"] = "value"
```

Or to retrieve the value:

```
print memc["key"]
```

For more explicit actions, you can use the method interface, which mimics the main memcached API functions, as summarized in the following table.

Ruby MemCache Method	Equivalent to
get()	Generic get()
get_hash(keys)	Get the values of multiple keys, returning the information as a hash of the keys and their values.

Ruby MemCache Method	Equivalent to
set()	Generic set()
set_many(pairs)	Set the values of the keys and values in the hash pairs.
add()	Generic add()
replace()	Generic replace()
delete()	Generic delete()
incr()	Generic incr()
decr()	Generic decr()

4.3.6. Using MySQL and memcached with Java

The com.danga.MemCached class within Java provides a native interface to memcached instances. You can obtain the client from http://whalin.com/memcached/. The Java class uses hashes that are compatible with libmemcached, so you can mix and match Java and libmemcached applications accessing the same memcached instances. The serialization between Java and other interfaces will not be compatible. If this is a problem, use JSON or a similar nonbinary serialization format.

On most systems you can download the package and use the jar directly. On OpenSolaris, use pkg to install the SUNWmemcached-java package.

To use the com.danga.MemCached interface, you create a MemCachedClient instance and then configure the list of servers by configuring the SockIOPool. Through the pool specification you set up the server list, weighting, and the connection parameters to optimized the connections between your client and the memcached instances that you configure.

Generally you can configure the memcached interface once within a single class and then use this interface throughout the rest of your application.

For example, to create a basic interface, first configure the MemCachedClient and base SockIOPool settings:

```
public class MyClass {
    protected static MemCachedClient mcc = new MemCachedClient();
    static {

        String[] servers =
            {
                "localhost:11211",
            };

        Integer[] weights = { 1 };

        SockIOPool pool = SockIOPool.getInstance();

        pool.setServers( servers );
        pool.setWeights( weights );
```

In the above sample, the list of servers is configured by creating an array of the memcached instances that you want to use. You can then configure individual weights for each server.

The remainder of the properties for the connection are optional, but you can set the connection numbers (initial connections, minimum connections, maximum connections, and the idle timeout) by setting the pool parameters:

```
pool.setInitConn( 5 );
pool.setMinConn( 5 );
pool.setMaxConn( 250 );
pool.setMaxIdle( 1000 * 60 * 60 * 6
```

Once the parameters have been configured, initialize the connection pool:

```
pool.initialize();
```

The pool, and the connection to your memcached instances should now be ready to use.

To set the hashing algorithm used to select the server used when storing a given key you can use pool.setHashingAlg():

```
pool.setHashingAlg( SockIOPool.NEW_COMPAT_HASH );
```

Valid values ares NEW_COMPAT_HASH, OLD_COMPAT_HASH and NATIVE_HASH are also basic modula hashing algorithms. For a consistent hashing algorithm, use CONSISTENT_HASH. These constants are equivalent to the corresponding hash settings within libmemcached.

Java com.danga.MemCached Method	Equivalent to
get()	Generic get()
getMulti(keys)	Get the values of multiple keys, returning the information as Hash map using java.lang.String for the keys and java.lang.Object for the corresponding values.
set()	Generic set()
add()	Generic add()
replace()	Generic replace()
delete()	Generic delete()
incr()	Generic incr()
decr()	Generic decr()

4.3.7. Using the MySQL memcached UDFs

The memcached MySQL User Defined Functions (UDFs) enable you to set and retrieve objects from within MySQL 5.0 or greater.

To install the MySQL memcached UDFs, download the UDF package from http://tangent.org/586/Memcached_Functions_for_MySQL.html. You will need to unpack the package and run configure to configure the build process. When running configure, use the --with-mysql option and specify the location of the mysql_config command. Note that you must be running :

```
shell> tar zxf memcached_functions_mysql-0.5.tar.gz
shell> cd memcached_functions_mysql-0.5
shell> ./configure --with-mysql-config=/usr/local/mysql/bin/mysql_config
```

Now build and install the functions:

```
shell> make
shell> make install
```

You may want to copy the MySQL memcached UDFs into your MySQL plugins directory:

```
shell> cp /usr/local/lib/libmemcached_functions_mysql* /usr/local/mysql/lib/mysql/plugins/
```

Once installed, you must initialize the function within MySQL using CREATE and specifying the return value and library. For example, to add the memc_get() function:

```
mysql> CREATE FUNCTION memc_get RETURNS STRING SONAME "libmemcached_functions_mysql.so";
```

You must repeat this process for each function that you want to provide access to within MySQL. Once you have created the association, the information will be retained, even over restarts of the MySQL server. You can simplify the process by using the SQL script provided in the memcached UDFs package:

```
shell> mysql <sql/install_functions.sql
```

Alternatively, if you have Perl installed, then you can use the supplied Perl script, which will check for the existence of each function and create the function/library association if it has not already been defined:

```
shell> utils/install.pl --silent
```

The --silent option installs everything automatically. Without this option, the script will ask whether you want to install each of the available functions.

The interface remains consistent with the other APIs and interfaces. To set up a list of servers, use the memc_servers_set() function, which accepts a single string containing and comma-separated list of servers:

```
mysql> SELECT memc_servers_set('192.168.0.1:11211,192.168.0.2:11211');
```

> **Note**
>
> The list of servers used by the memcached UDFs is not persistent over restarts of the MySQL server. If the MySQL server fails, then you must re-set the list of memcached servers.

To set a value, use memc_set:

```
mysql> SELECT memc_set('myid', 'myvalue');
```

To retrieve a stored value:

```
mysql> SELECT memc_get('myid');
```

The list of functions supported by the UDFs, in relation to the standard protocol functions, is shown in the following table.

MySQL memcached UDF Function	Equivalent to
memc_get()	Generic get()
memc_get_by_key(master_key, key, value)	Like the generic get(), but uses the supplied master key to select the server to use.
memc_set()	Generic set()
memc_set_by_key(master_key, key, value)	Like the generic set(), but uses the supplied master key to select the server to use.
memc_add()	Generic add()
memc_add_by_key(master_key, key, value)	Like the generic add(), but uses the supplied master key to select the server to use.
memc_replace()	Generic replace()
memc_replace_by_key(master_key, key, value)	Like the generic replace(), but uses the supplied master key to select the server to use.
memc_prepend(key, value)	Prepend the specified value to the current value of the specified key.
memc_prepend_by_key(master_key, key, value)	Prepend the specified value to the current value of the specified key, but uses the supplied master key to select the server to use.
memc_append(key, value)	Append the specified value to the current value of the specified key.
memc_append_by_key(master_key, key, value)	Append the specified value to the current value of the specified key, but uses the supplied master key to select the server to use.
memc_delete()	Generic delete()
memc_delete_by_key(master_key, key, value)	Like the generic delete(), but uses the supplied master key to select the server to use.
memc_increment()	Generic incr()
memc_decrement()	Generic decr()

The respective *_by_key() functions are useful when you want to store a specific value into a specific memcached server, possibly based on a differently calculated or constructed key.

The memcached UDFs include some additional functions:

- memc_server_count()

  Returns a count of the number of servers in the list of registered servers.

- memc_servers_set_behavior(behavior_type, value), memc_set_behavior(behavior_type, value)

  Set behaviors for the list of servers. These behaviors are identical to those provided by the libmemcached library. For more information on libmemcached behaviors, see Section 4.3.1, “Using libmemcached”.

  You can use the behavior name as the behavior_type:

  ```
  mysql> SELECT memc_servers_behavior_set("MEMCACHED_BEHAVIOR_KETAMA",1);
  ```

- memc_servers_behavior_get(behavior_type), memc_get_behavior(behavior_type, value)

Returns the value for a given behavior.

- `memc_list_behaviors()`

  Returns a list of the known behaviors.

- `memc_list_hash_types()`

  Returns a list of the supported key-hashing algorithms.

- `memc_list_distribution_types()`

  Returns a list of the supported distribution types to be used when selecting a server to use when storing a particular key.

- `memc_libmemcached_version()`

  Returns the version of the `libmemcached` library.

- `memc_stats()`

  Returns the general statistics information from the server.

4.3.8. `memcached` Protocol

Communicating with a `memcached` server can be achieved through either the TCP or UDP protocols. When using the TCP protocol you can use a simple text based interface for the exchange of information.

4.3.8.1. Using the TCP text protocol

When communicating with `memcached` you can connect to the server using the port configured for the server. You can open a connection with the server without requiring authorization or login. As soon as you have connected, you can start to send commands to the server. When you have finished, you can terminate the connection without sending any specific disconnection command. Clients are encouraged to keep their connections open to decrease latency and improve performance.

Data is sent to the `memcached` server in two forms:

- Text lines, which are used to send commands to the server, and receive responses from the server.
- Unstructured data, which is used to receive or send the value information for a given key. Data is returned to the client in exactly the format it was provided.

Both text lines (commands and responses) and unstructured data are always terminated with the string `\r\n`. Because the data being stored may contain this sequence, the length of the data (returned by the client before the unstructured data is transmitted should be used to determine the end of the data.

Commands to the server are structured according to their operation:

- **Storage commands**: `set`, `add`, `replace`, `append`, `prepend`, `cas`

  Storage commands to the server take the form:

  ```
  command key [flags] [exptime] length [noreply]
  ```

  Or when using compare and swap (cas):

  ```
  cas key [flags] [exptime] length [casunique] [noreply]
  ```

  Where:

  - `command` — the command name.
    - `set` — Store value against key
    - `add` — Store this value against key if the key does not already exist

  - `replace` — Store this value against key if the key already exists
  - `append` — Append the supplied value to the end of the value for the specified key. The `flags` and `exptime` arguments should not be used.
  - `prepend` — Append value currently in the cache to the end of the supplied value for the specified key. The `flags` and `exptime` arguments should not be used.
  - `cas` — Set the specified key to the supplied value, only if the supplied `casunique` matches. This is effectively the equivalent of change the information if nobody has updated it since I last fetched it.
- `key` — the key. All data is stored using a the specific key. The key cannot contain control characters or whitespace, and can be up to 250 characters in size.
- `flags` — the flags for the operation (as an integer). Flags in `memcached` are transparent. The `memcached` server ignores the contents of the flags. They can be used by the client to indicate any type of information. In `memcached` 1.2.0 and lower the value is a 16-bit integer value. In `memcached` 1.2.1 and higher the value is a 32-bit integer.
- `exptime` — the expiry time, or zero for no expiry.
- `length` — the length of the supplied value block in bytes, excluding the terminating `\r\n` characters.
- `casunique` — is a unique 64-bit value of an existing entry. This will be used to compare against the existing value. You should use the value returned by the `gets` command when issuing `cas` updates.
- `noreply` — tells the server not to reply to the command.

For example, to store the value `abcdef` into the key `xyzkey`, you would use:

```
set xyzkey 0 0 6\r\nabcdef\r\n
```

The return value from the server will be one line, specifying the status or error information. For more information, see Table 4.2, “`memcached` Protocol Responses”.

- **Retrieval commands**: `get`, `gets`

  Retrieval commands take the form:

  ```
  get key1 [key2 .... keyn]
  gets key1 [key2 ... keyn]
  ```

  You can supply multiple keys to the commands, with each requested key separated by whitespace.

  The server will respond with an information line of the form:

  ```
  VALUE key flags bytes [casunique]
  ```

  Where:

  - `key` — the key name.
  - `flags` — the value of the flag integer supplied to the `memcached` server when the value was stored.
  - `bytes` — the size (excluding the terminating `\r\n` character sequence) of the stored value.
  - `casunique` — the unique 64-bit integer that identifies the item.

  The information line will immediately be followed by the value data block. For example:

  ```
  get xyzkey\r\n
  VALUE xyzkey 0 6\r\n
  abcdef\r\n
  ```

  If you have requested multiple keys, an information line and data block will be returned for each key found. If a requested key does not exist in the cache, no information is returned.

- **Delete commands**: `delete`

  Deletion commands take the form:

```
delete key [time] [noreply]
```

Where:

- key — the key name.
- time — the time in seconds (or a specific Unix time) for which the client wishes the server to refuse add or replace commands on this key. All add, replace, get, and gets commands will fail during this period. set operations will succeed. After this period, the key will be deleted permanently and all commands will be accepted.

  If not supplied, the value is assumed to be zero (delete immediately).
- noreply — tells the server not to reply to the command.

Responses to the command will either be DELETED to indicate that the key was successfully removed, or NOT_FOUND to indicate that the specified key could not be found.

- **Increment/Decrement**: incr, decr

  The increment and decrement commands change the value of a key within the server without performing a separate get/set sequence. The operations assume that the currently stored value is a 64-bit integer. If the stored value is not a 64-bit integer, then the value is assumed to be zero before the increment or decrement operation is applied.

  Increment and decrement commands take the form:

  ```
  incr key value [noreply]
  decr key value [noreply]
  ```

  Where:

  - key — the key name.
  - value — an integer to be used as the increment or decrement value.
  - noreply — tells the server not to reply to the command.

  The response will be:

  - NOT_FOUND — the specified key could not be located.
  - value — the new value of the specified key.

  Values are assumed to be unsigned. For decr operations the value will never be decremented below 0. For incr operations, the value will be wrap around the 64-bit maximum.

- **Statistics commands**: stats

  The stats command provides detailed statistical information about the current status of the memcached instance and the data it is storing.

  Statistics commands take the form:

  ```
  STAT [name] [value]
  ```

  Where:

  - name — is the optional name of the statistics to return. If not specified, the general statistics are returned.
  - value — a specific value to be used when performing certain statistics operations.

  The return value is a list of statistics data, formatted as follows:

  ```
  STAT name value
  ```

  The statistics are terminated with a single line, END.

  For more information, see Section 4.4, “Getting memcached Statistics”.

For reference, a list of the different commands supported and their formats is provided below.

Table 4.1. memcached Command Reference

Command	Command Formats
set	set key flags exptime length, set key flags exptime length noreply
add	add key flags exptime length, add key flags exptime length noreply
replace	replace key flags exptime length, replace key flags exptime length noreply
append	append key length, append key length noreply
prepend	prepend key length, prepend key length noreply
cas	cas key flags exptime length casunique, cas key flags exptime length casunique noreply
get	get key1 [key2 ... keyn]
gets	
delete	delete key, delete key noreply, delete key expiry, delete key expory noreply
incr	incr key, incr key noreply, incr key value, incr key value noreply
decr	decr key, decr key noreply, decr key value, decr key value noreply
stat	stat, stat name, stat name value

When sending a command to the server, the response from the server will be one of the settings in the following table. All response values from the server are terminated by \r\n:

Table 4.2. memcached Protocol Responses

String	Description
STORED	Value has successfully been stored.
NOT_STORED	The value was not stored, but not because of an error. For commands where you are adding a or updating a value if it exists (such as add and replace), or where the item has already been set to be deleted.
EXISTS	When using a cas command, the item you are trying to store already exists and has been modified since you last checked it.
NOT_FOUND	The item you are trying to store, update or delete does not exist or has already been deleted.
ERROR	You submitted a non-existent command name.
CLIENT_ERROR error-string	There was an error in the input line, the detail is contained in errorstring.
SERVER_ERROR error-string	There was an error in the server that prevents it from returning the information. In extreme conditions, the server may disconnect the client after this error occurs.
VALUE keys flags length	The requested key has been found, and the stored key, flags and data block will be returned, of the specified length.
DELETED	The requested key was deleted from the server.
STAT name value	A line of statistics data.
END	The end of the statistics data.

4.4. Getting memcached Statistics

The memcached system has a built in statistics system that collects information about the data being stored into the cache, cache hit ratios, and detailed information on the memory usage and distribution of information through the slab allocation used to store individual items. Statistics are provided at both a basic level that provide the core statistics, and more specific statistics for specific areas of the memcached server.

This information can prove be very useful to ensure that you are getting the correct level of cache and memory usage, and that your slab allocation and configuration properties are set at an optimal level.

The stats interface is available through the standard memcached protocol, so the reports can be accessed by using telnet to connect to the memcached. Alternatively, most of the language API interfaces provide a function for obtaining the statistics from the server.

For example, to get the basic stats using telnet:

```
shell> telnet localhost 11211
Trying ::1...
Connected to localhost.
Escape character is '^]'.
stats
STAT pid 23599
STAT uptime 675
STAT time 1211439587
STAT version 1.2.5
STAT pointer_size 32
STAT rusage_user 1.404992
STAT rusage_system 4.694685
STAT curr_items 32
STAT total_items 56361
STAT bytes 2642
STAT curr_connections 53
STAT total_connections 438
STAT connection_structures 55
STAT cmd_get 113482
STAT cmd_set 80519
STAT get_hits 78926
STAT get_misses 34556
STAT evictions 0
STAT bytes_read 6379783
STAT bytes_written 4860179
STAT limit_maxbytes 67108864
STAT threads 1
END
```

When using Perl and the Cache::Memcached module, the stats() function returns information about all the servers currently configured in the connection object, and total statistics for all the memcached servers as a whole.

For example, the following Perl script will obtain the stats and dump the hash reference that is returned:

```
use Cache::Memcached;
use Data::Dumper;
my $memc = new Cache::Memcached;
$memc->set_servers(\@ARGV);
print Dumper($memc->stats());
```

When executed on the same memcached as used in the Telnet example above we get a hash reference with the host by host and total statistics:

```
$VAR1 = {
    'hosts' => {
           'localhost:11211' => {
                      'misc' => {
                            'bytes' => '2421',
                            'curr_connections' => '3',
                            'connection_structures' => '56',
                            'pointer_size' => '32',
                            'time' => '1211440166',
                            'total_items' => '410956',
                            'cmd_set' => '588167',
                            'bytes_written' => '35715151',
                            'evictions' => '0',
                            'curr_items' => '31',
                            'pid' => '23599',
                            'limit_maxbytes' => '67108864',
                            'uptime' => '1254',
                            'rusage_user' => '9.857805',
                            'cmd_get' => '838451',
                            'rusage_system' => '34.096988',
                            'version' => '1.2.5',
                            'get_hits' => '581511',
                            'bytes_read' => '46665716',
                            'threads' => '1',
                            'total_connections' => '3104',
                            'get_misses' => '256940'
                          },
                      'sizes' => {
                             '128' => '16',
                             '64' => '15'
                           }
                    }
         },
    'self' => {},
    'total' => {
           'cmd_get' => 838451,
           'bytes' => 2421,
           'get_hits' => 581511,
           'connection_structures' => 56,
           'bytes_read' => 46665716,
```

```
          'total_items' => 410956,
          'total_connections' => 3104,
          'cmd_set' => 588167,
          'bytes_written' => 35715151,
          'curr_items' => 31,
          'get_misses' => 256940
        }
      };
```

The statistics are divided up into a number of distinct sections, and then can be requested by adding the type to the `stats` command. Each statistics output is covered in more detail in the following sections.

- General statistics, see Section 4.4.1, "`memcached` General Statistics".
- Slab statistics (`slabs`), see Section 4.4.2, "`memcached` Slabs Statistics".
- Item statistics (`items`), see Section 4.4.3, "`memcached` Item Statistics".
- Size statistics (`sizes`), see Section 4.4.4, "`memcached` Size Statistics".

4.4.1. `memcached` General Statistics

The output of the general statistics provides an overview of the performance and use of the `memcached` instance. The statistics returned by the command and their meaning is shown in the following table.

The following terms are used to define the value type for each statistics value:

- `32u` — 32-bit unsigned integer
- `64u` — 64-bit unsigned integer
- `32u32u` — Two 32-bit unsigned integers separated by a colon
- `String` — Character string

Statistic	Description	
pid	32u	Process id of the `memcached` instance.
uptime	32u	Uptime (in seconds) for this `memcached` instance.
time	32u	Current time (as epoch).
version	string	Version string of this instance.
pointer_size	string	Size of pointers for this host specified in bits (32 or 64).
rusage_user	32u:32u	Total user time for this instance (seconds:microseconds).
rusage_system	32u:32u	Total system time for this instance (seconds:microseconds).
curr_items	32u	Current number of items stored by this instance.
total_items	32u	Total number of items stored during the life of this instance.
bytes	64u	Current number of bytes used by this server to store items.
curr_connections	32u	Current number of open connections.
total_connections	32u	Total number of connections opened since the server started running.
connection_structures	32u	Number of connection structures allocated by the server.
cmd_get	64u	Total number of retrieval requests (`get` operations).
cmd_set	64u	Total number of storage requests (`set` operations).
get_hits	64u	Number of keys that have been requested and found present.
get_misses	64u	Number of items that have been requested and not found.
evictions	64u	Number of valid items removed from cache to free memory for new items.
bytes_read	64u	Total number of bytes read by this server from network.
bytes_written	64u	Total number of bytes sent by this server to network.
limit_maxbytes	32u	Number of bytes this server is allowed to use for storage.
threads	32u	Number of worker threads requested.

The most useful statistics from those given here are the number of cache hits, misses, and evictions.

A large number of `get_misses` may just be an indication that the cache is still being populated with information. The number should, over time, decrease in comparison to the number of cache `get_hits`. If, however, you have a large number of cache misses compared to cache hits after an extended period of execution, it may be an indication that the size of the cache is too small and you either need to increase the total memory size, or increase the number of the `memcached` instances to improve the hit ratio.

A large number of `evictions` from the cache, particularly in comparison to the number of items stored is a sign that your cache is too small to hold the amount of information that you regularly want to keep cached. Instead of items being retained in the cache, items are being evicted to make way for new items keeping the turnover of items in the cache high, reducing the efficiency of the cache.

4.4.2. `memcached` Slabs Statistics

To get the `slabs` statistics, use the `stats slabs` command, or the API equivalent.

The slab statistics provide you with information about the slabs that have created and allocated for storing information within the cache. You get information both on each individual slab-class and total statistics for the whole slab.

```
STAT 1:chunk_size 104
STAT 1:chunks_per_page 10082
STAT 1:total_pages 1
STAT 1:total_chunks 10082
STAT 1:used_chunks 10081
STAT 1:free_chunks 1
STAT 1:free_chunks_end 10079
STAT 9:chunk_size 696
STAT 9:chunks_per_page 1506
STAT 9:total_pages 63
STAT 9:total_chunks 94878
STAT 9:used_chunks 94878
STAT 9:free_chunks 0
STAT 9:free_chunks_end 0
STAT active_slabs 2
STAT total_malloced 67083616
END
```

Individual stats for each slab class are prefixed with the slab ID. A unique ID is given to each allocated slab from the smallest size up to the largest. The prefix number indicates the slab class number in relation to the calculated chunk from the specified growth factor. Hence in the example, 1 is the first chunk size and 9 is the 9th chunk allocated size.

The different parameters returned for each chunk size and the totals are shown in the following table.

Statistic	Description
chunk_size	Space allocated to each chunk within this slab class.
chunks_per_page	Number of chunks within a single page for this slab class.
total_pages	Number of pages allocated to this slab class.
total_chunks	Number of chunks allocated to the slab class.
used_chunks	Number of chunks allocated to an item..
free_chunks	Number of chunks not yet allocated to items.
free_chunks_end	Number of free chunks at the end of the last allocated page.
active_slabs	Total number of slab classes allocated.
total_malloced	Total amount of memory allocated to slab pages.

The key values in the slab statistics are the `chunk_size`, and the corresponding `total_chunks` and `used_chunks` parameters. These given an indication of the size usage of the chunks within the system. Remember that one key/value pair will be placed into a chunk of a suitable size.

From these stats you can get an idea of your size and chunk allocation and distribution. If you are storing many items with a number of largely different sizes, then you may want to adjust the chunk size growth factor to increase in larger steps to prevent chunk and memory wastage. A good indication of a bad growth factor is a high number of different slab classes, but with relatively few chunks actually in use within each slab. Increasing the growth factor will create fewer slab classes and therefore make better use of the allocated pages.

4.4.3. `memcached` Item Statistics

To get the `items` statistics, use the `stats items` command, or the API equivalent.

The items statistics give information about the individual items allocated within a given slab class.

```
STAT items:2:number 1
STAT items:2:age 452
STAT items:2:evicted 0
STAT items:2:outofmemory 0
STAT items:27:number 1
STAT items:27:age 452
STAT items:27:evicted 0
STAT items:27:outofmemory 0
```

The prefix number against each statistics relates to the corresponding chunk size, as returned by the stats slabs statistics. The result is a display of the number of items stored within each chunk within each slab size, and specific statistics about their age, eviction counts, and out of memory counts. A summary of the statistics is given in the following table.

Statistic	Description
number	The number of items currently stored in this slab class.
age	The age of the oldest item within the slab class, in seconds.
evicted	The number of items evicted to make way for new entries.
outofmemory	The number of items for this slab class that have triggered an out of memory error (only value when the -M command line option is in effect).

Item level statistics can be used to determine how many items are stored within a given slab and their freshness and recycle rate. You can use this to help identify whether there are certain slab classes that are triggering a much larger number of evictions that others.

4.4.4. memcached Size Statistics

To get size statistics, use the stats sizes command, or the API equivalent.

The size statistics provide information about the sizes and number of items of each size within the cache. The information is returned as two columns, the first column is the size of the item (rounded up to the nearest 32 byte boundary), and the second column is the count of the number of items of that size within the cache:

```
96 35
128 38
160 807
192 804
224 410
256 222
288 83
320 39
352 53
384 33
416 64
448 51
480 30
512 54
544 39
576 10065
```

> **Caution**
>
> Running this statistic will lock up your cache as each item is read from the cache and its size calculated. On a large cache, this may take some time and prevent any set or get operations until the process completes.

The item size statistics are useful only to determine the sizes of the objects you are storing. Since the actual memory allocation is relevant only in terms of the chunk size and page size, the information will only be useful during a careful debugging or diagnostic session.

4.5. memcached FAQ

Questions

- 4.5.4: How expensive is it to establish a memcache connection? Should those connections be pooled?
- 4.5.5: How will the data will be handled when the memcached server is down?
- 4.5.6: Can memcached be run on a Windows environment?
- 4.5.7: What is the max size of an object you can store in memcache and is that configurable?
- 4.5.8: Is it true memcached will be much more effective with db-read-intensive applications than with db-write-intensive applications?
- 4.5.9: What are best practices for testing an implementation, to ensure that it is an improvement over the MySQL query cache, and to measure the impact of memcached configuration changes? And would you recommend keeping the configuration very simple to start?
- 4.5.10: Can MySQL actually trigger/store the changed data to memcached?
- 4.5.11: So the responsibility lies with the application to populate and get records from the database as opposed to being a transparent cache layer for the db?
- 4.5.12: memcached is fast - is there any overhead in not using persistent connections? If persistent is always recommended, what are the downsides (e.g. locking up?)
- 4.5.13: Is compression available?
- 4.5.14: File socket support for memcached from the localhost use to the local memcached server?
- 4.5.15: What are the advantages of using UDFs when the get/sets are manageable from within the client code rather than the db?
- 4.5.16: Is memcached typically a better solution for improving speed than MySQL Cluster and\or MySQL Proxy?
- 4.5.17: What speed trade offs is there between memcached vs MySQL Query Cache? Where you check memcached, and get data from MySQL and put it in memcached or just make a query and results are put into MySQL Query Cache.
- 4.5.18: Does the -L flag automatically sense how much memory is being used by other memcached?
- 4.5.19: Is the data inside of memcached secure?
- 4.5.20: Can we implement different types of memcached as different nodes in the same server - so can there be deterministic and non deterministic in the same server?
- 4.5.21: How easy is it to introduce memcached to an existing enterprise application instead of inclusion at project design?
- 4.5.22: Can memcached work with ASPX?
- 4.5.23: If I have an object larger then a MB, do I have to manually split it or can I configure memcached to handle larger objects?
- 4.5.24: How does memcached compare to nCache?
- 4.5.25: Doing a direct telnet to the memcached port, is that just for that one machine, or does it magically apply across all nodes?
- 4.5.26: Is memcached more effective for video and audio as opposed to textual read/writes
- 4.5.27: We are caching XML by serialising using saveXML(), because PHP cannot serialise DOM objects; Some of the XML is variable and is modified per-request. Do you recommend caching then using XPath, or is it better to rebuild the DOM from separate node-groups?
- 4.5.28: Do the memcache UDFs work under 5.1?
- 4.5.29: How are auto-increment columns in the MySQL database coordinated across multiple instances of memcached?
- 4.5.30: If you log a complex class (with methods that do calculation etc) will the get from Memcache re-create the class on the way out?

Questions and Answers

4.5.1: How does an event such as a crash of one of the memcached servers handled by the memcached client?

There is no automatic handling of this. If your client fails to get a response from a server then it should fall back to loading the data from the MySQL database.

The client APIs all provide the ability to add and remove memcached instances on the fly. If within your application you notice that memcached server is no longer responding, your can remove the server from the list of servers, and keys will automatically be redistributed to another memcached server in the list. If retaining the cache content on all your servers is important, make sure you use an API that supports a consistent hashing algorithm. For more information, see Section 4.2.4, "memcached Distribution Types".

4.5.2: Are there any, or are there any plans to introduce, a framework to hide the interaction of memcached from the application, i.e., within hibernate?

There are lots of projects working with memcached. There is a Google Code implementation of Hibernate and memcached working together. See http://code.google.com/p/hibernate-memcached/.

4.5.3: What's a recommended hardware config for a memcached server? Linux or Windows?

memcached is only available on Unix/Linux, so using a Windows machine is not an option. Outside of this, memcached has a very low processing overhead. All that is required is spare physical RAM capacity. The point is not that you should necessarily deploy a dedicated memcached server. If you have web, application, or database servers that have spare RAM capacity, then use them with memcached.

If you want to build and deploy a dedicated memcached servers, then you use a relatively low-power CPU, lots of RAM and one or more Gigabit Ethernet interfaces.

4.5.4: How expensive is it to establish a memcache connection? Should those connections be pooled?

Opening the connection is relatively inexpensive, because there is no security, authentication or other handshake taking place before you can start sending requests and getting results. Most APIs support a persistent connection to a memcached instance to reduce the latency. Connection pooling would depend on the API you are using, but if you are communicating directly over TCP/IP, then connection pooling would provide some small performance benefit.

4.5.5: How will the data will be handled when the memcached server is down?

The behavior is entirely application dependent. Most applications will fall back to loading the data from the database (just as if they were updating the memcached) information. If you are using multiple memcached servers, you may also want to remove a server from the list to prevent the missing server affecting performance. This is because the client will still attempt to communicate the memcached that corresponds to the key you are trying to load.

4.5.6: Can memcached be run on a Windows environment?

No. Currently memcached is available only on the Unix/Linux platform. There is an unofficial port available, see http://www.codeplex.com/memcachedproviders.

4.5.7: What is the max size of an object you can store in memcache and is that configurable?

The default maximum object size is 1MB. If you want to increase this size, you have to re-compile memcached. You can modify the value of the POWER_BLOCK within the slabs.c file within the source.

4.5.8: Is it true memcached will be much more effective with db-read-intensive applications than with db-write-intensive applications?

Yes. memcached plays no role in database writes, it is a method of caching data already read from the database in RAM.

4.5.9: What are best practices for testing an implementation, to ensure that it is an improvement over the MySQL query cache, and to measure the impact of memcached configuration changes? And would you recommend keeping the configuration very simple to start?

The best way to test the performance is to start up a memcached instance. First, modify your application so that it stores the data just before the data is about to be used or displayed into memcached.Since the APIs handle the serialization of the data, it should just be a one line modification to your code. Then, modify the start of the process that would normally load that information from MySQL with the code that requests the data from memcached. If the data cannot be loaded from memcached, default to the MySQL process.

All of the changes required will probably amount to just a few lines of code. To get the best benefit, make sure you cache entire objects (for example, all the components of a web page, blog post, discussion thread, etc.), rather than using memcached as a simple cache of individuals rows of MySQL tables. You should see performance benefits almost immediately.

Keeping the configuration very simple at the start, or even over the long term, is very easy with memcached. Once you have the basic structure up and running, the only addition you may want to make is to add more servers into the list of servers used by your clients. You don't need to manage the memcached servers, and there is no complex configuration, just add more servers to the list

and let the client API and the memcached servers make the decisions.

4.5.10: Can MySQL actually trigger/store the changed data to memcached?

Yes. You can use the MySQL UDFs for memcached and either write statements that directly set the values in the memcached server, or use triggers or stored procedures to do it for you. For more information, see Section 4.3.7, "Using the MySQL memcached UDFs"

4.5.11: So the responsibility lies with the application to populate and get records from the database as opposed to being a transparent cache layer for the db?

Yes. You load the data from the database and write it into the cache provided by memcached. Using memcached as a simple database row cache, however, is probably inefficient. The best way to use memcached is to load all of the information from the database relating to a particular object, and then cache the entire object. For example, in a blogging environment, you might load the blog, associated comments, categories and so on, and then cache all of the information relating to that blog post. The reading of the data from the database will require multiple SQL statements and probably multiple rows of data to complete, which is time consuming. Loading the entire blog post and the associated information from memcached is just one operation and doesn't involve using the disk or parsing the SQL statement.

4.5.12: memcached is fast - is there any overhead in not using persistent connections? If persistent is always recommended, what are the downsides (e.g. locking up?)

If you don't use persistent connections when communicating with memcached then there will be a small increase in the latency of opening the connection each time. The effect is comparable to use non-persistent connections with MySQL.

In general, the chance of locking or other issues with persistent connections is minimal, because there is very little locking within memcached. If there is a problem then eventually your request will timeout and return no result so your application will need to load from MySQL again.

4.5.13: Is compression available?

Yes. Most of the client APIs support some sort of compression, and some even allow you to specify the threshold at which a value is deemed appropriate for compression during storage.

4.5.14: File socket support for memcached from the localhost use to the local memcached server?

You can use the -s option to memcached to specify the location of a file socket. This automatically disables network support.

4.5.15: What are the advantages of using UDFs when the get/sets are manageable from within the client code rather than the db?

Sometimes you want to be able to be able to update the information within memcached based on a generic database activity, rather than relying on your client code. For example, you may want to update status or counter information in memcached through the use of a trigger or stored procedure. For some situations and applications the existing use of a stored procedure for some operations means that updating the value in memcached from the database is easier than separately loading and communicating that data to the client just so the client can talk to memcached.

In other situations, when you are using a number of different clients and different APIs, you don't want to have to write (and maintain) the code required to update memcached in all the environments. Instead, you do this from within the database and the client never gets involved.

4.5.16: Is memcached typically a better solution for improving speed than MySQL Cluster and\or MySQL Proxy?

Both MySQL Cluster and MySQL Proxy still require access to the underlying database to retrieve the information. This implies both a parsing overhead for the statement and, often, disk based access to retrieve the data you have selected.

The advantage of memcached is that you can store entire objects or groups of information that may require multiple SQL statements to obtain. Restoring the result of 20 SQL statements formatted into a structure that your application can use directly without requiring any additional processing is always going to be faster than building that structure by loading the rows from a database.

4.5.17: What speed trade offs is there between memcached vs MySQL Query Cache? Where you check memcached, and get data from MySQL and put it in memcached or just make a query and results are put into MySQL Query Cache.

In general, the time difference between getting data from the MySQL Query Cache and getting the exact same data from memcached is very small.

However, the benefit of memcached is that you can store any information, including the formatted and processed results of many queries into a single memcached key. Even if all the queries that you executed could be retrieved from the Query Cache without having to go to disk, you would still be running multiple queries (with network and other overhead) compared to just one for the memcached equivalent. If your application uses objects, or does any kind of processing on the information, with memcached you can store the post-processed version, so the data you load is immediately available to be used. With data loaded from the Query Cache, you would still have to do that processing.

In addition to these considerations, keep in mind that keeping data in the MySQL Query Cache is difficult as you have no control over the queries that are stored. This means that a slightly unusual query can temporarily clear a frequently used (and normally cached) query, reducing the effectiveness of your Query Cache. With memcached you can specify which objects are stored, when they are stored, and when they should be deleted giving you much more control over the information stored in the cache.

4.5.18: Does the -L flag automatically sense how much memory is being used by other memcached?

No. There is no communication or sharing of information between memcached instances.

4.5.19: Is the data inside of memcached secure?

No, there is no security required to access or update the information within a memcached instance, which means that anybody with access to the machine has the ability to read, view and potentially update the information. If you want to keep the data secure, you can encrypt and decrypt the information before storing it. If you want to restrict the users capable of connecting to the server, your only choice is to either disable network access, or use IPTables or similar to restrict access to the memcached ports to a select set of hosts.

4.5.20: Can we implement different types of memcached as different nodes in the same server - so can there be deterministic and non deterministic in the same server?

Yes. You can run multiple instances of memcached on a single server, and in your client configuration you choose the list of servers you want to use.

4.5.21: How easy is it to introduce memcached to an existing enterprise application instead of inclusion at project design?

In general, it is very easy. In many languages and environments the changes to the application will be just a few lines, first to attempt to read from the cache when loading data and then fall back to the old method, and to update the cache with information once the data has been read.

memcached is designed to be deployed very easily, and you shouldn't require significant architectural changes to your application to use memcached.

4.5.22: Can memcached work with ASPX?

There are ports and interfaces for many languages and environments. ASPX relies on an underlying language such as C# or VisualBasic, and if you are using ASP.NET then there is a C# memcached library. For more information, see .

4.5.23: If I have an object larger then a MB, do I have to manually split it or can I configure memcached to handle larger objects?

You would have to manually split it. memcached is very simple, you give it a key and some data, it tries to cache it in RAM. If you try to store more than the default maximum size, the value is just truncated for speed reasons.

4.5.24: How does memcached compare to nCache?

The main benefit of memcached is that is very easy to deploy and works with a wide range of languages and environments, including .NET, Java, Perl, Python, PHP, even MySQL. memcached is also very lightweight in terms of systems and requirements, and you can easily add as many or as few memcached servers as you need without changing the individual configuration. memcached does require additional modifications to the application to take advantage of functionality such as multiple memcached servers.

4.5.25: Doing a direct telnet to the memcached port, is that just for that one machine, or does it magically apply across all nodes?

Just one. There is no communication between different instances of memcached, even if each instance is running on the same machine.

4.5.26: Is memcached more effective for video and audio as opposed to textual read/writes

memcached doesn't care what information you are storing. To memcached, any value you store is just a stream of data. Remember, though, that the maximum size of an object you can store in memcached without modifying the source code is 1MB, so it's usability with audio and video content is probably significantly reduced. Also remember that memcached is a solution for caching information for reading. It shouldn't be used for writes, except when updating the information in the cache.

4.5.27: We are caching XML by serialising using saveXML(), because PHP cannot serialise DOM objects; Some of the XML is variable and is modified per-request. Do you recommend caching then using XPath, or is it better to rebuild the DOM from separate node-groups?

You would need to test your application using the different methods to determine this information. You may find that the default serialization within PHP may allow you to store DOM objects directly into the cache.

4.5.28: Do the memcache UDFs work under 5.1?

Yes.

4.5.29: How are auto-increment columns in the MySQL database coordinated across multiple instances of memcached?

They aren't. There is no relationship between MySQL and memcached unless your application (or, if you are using the MySQL UDFs for memcached, your database definition) creates one.

If you are storing information based on an auto-increment key into multiple instances of memcached then the information will only be stored on one of the memcached instances anyway. The client uses the key value to determine which memcached instance to store the information, it doesn't store the same information across all the instances, as that would be a waste of cache memory.

4.5.30: If you log a complex class (with methods that do calculation etc) will the get from Memcache re-create the class on the way out?

In general, yes. If the serialization method within the API/language that you are using supports it, then methods and other information will be stored and retrieved.

Chapter 5. MySQL and Virtualization

Using virtualization can be an effective way of better utilizing the hardware of your machine when using MySQL, or to provide improved security or isolation of different instances of MySQL on the same machine. In some circumstances, virtualization may be a suitable solution for scaling out your database environment by enabling you to easily deploy additional instances of a pre-configured MySQL server and application environment to new virtualization hosts.

With any virtualization solution there is often a tradeoff between the flexibility and ease of deployment and performance, or between the potential performance advantage and complexities of effectively configuring multiple instances of MySQL to reside within a single physical host.

Different issues are experienced according to the virtualization environment you are using. Virtualization generally falls into one of the following categories:

- **Native virtualization**, including products like VMware Workstation, Parallels Desktop/Parallels Workstation, Microsoft Virtual PC and VirtualBox, all work by acting as an application that runs within an existing operating system environment. Recent versions can take advantage of the virtualization extensions in the Intel and AMD CPUs to help improve performance.

  The application-based solutions have a number of advantages, including the ability to prioritize CPU usage (including multiple CPUs) and easily run multiple virtualized environments simultaneously.

  With these solutions, you also have the ability to easily create a virtualized environment that can be packaged and shared among different virtualization hosts. For example, you can create a MySQL environment and configuration that can be deployed multiple times to help extend an existing scalability or HA environment.

  The major disadvantage of this type of virtualization environment is the effect of the host on the performance of the virtualization instances. Disk storage is typically provided by using one or more files on the host OS which are then emulated to provide physical disks within the virtual instance. Other resources on the host are similarly shared, including CPU, network interfaces and additional devices (USB). It is also difficult to directly share lower-level components, such as PCI devices and that the ability to take advantage of RAID storage solutions.

- **Paravirtualization (Hypervisor)**, including Xen, Solaris xVM (based on Xen), VMware ESX Server, Windows Server 2008 Hyper-V, and Solaris Logical Domains (LDOM), work by running a specialized version of the host operating system. The host OS then allows slightly modified versions of different operating systems to run within the virtualized environment.

  With paravirtualization, the level of performance and the control over the underlying hardware used to support the virtualized environments is higher than native virtualization solutions. For example, using paravirtualization you can dedicate individual CPU cores, RAM, disk drives and even PCI devices to be accessible to individual and specific virtual instances.

  For example, within a paravirtualized environment you could dedicate a physical disk drive or subsystem to a particular virtual environment and gain a performance benefit over a typical file-based solution virtual disk.

- **Operating system-level virtualization**, including BSD jails, and Solaris Containers/Zones, offer methods for isolating different instances of an operating system environment while sharing the same hardware environment. Unlike the other virtualization solutions, operating system level virtualization is not normally used to run other operating systems, but instead to provide a level of security isolation and resource control within the core operating environment.

  The isolation of these different instances is the key advantage of this type of virtualization. Each virtualized instance sees its environment as if it were completely different system. The solution can be an effective method to provide isolated computing resources for different departments or users, or to provide unique instances for testing and development.

The main reasons for using virtualization, particularly with a database or an application stack that includes a database component, include:

- **Security** — separate instances of different operating systems running within a single host but with effective isolation from each other. When used with MySQL, you can provide an increased level of security between different instances of each server.

- **Consolidation** — merging a number of individual systems with a relatively small load onto a single, larger, server. This can help reduce footprint and energy costs, or make more efficient use of a larger machine. Performance is the main issue with this solution as the load of many MySQL databases running in individual virtual instances on a single machine can be considerable.

- **Development/QA/Testing** — by creating different instances of different environments and operating systems you can test your MySQL-based application in different environments.

- **Scalability** — although using virtualization imposes a performance hit, many virtualization solutions allow you to create a packaged version of an environment, including MySQL and the other application components. By distributing the virtualization environment package to new hosts you can often very quickly scale out by adding new hosts and deploying the virtualized en-

vironment.

The remainder of this chapter looks at common issues with using MySQL in a virtualized environment and tips for using MySQL within different virtualization tools.

For advice on common issues and problems, including performance and configuration issues, when using virtualized instances, see Section 5.1, “Common Issues with Virtualization”.

5.1. Common Issues with Virtualization

There are many issues related to using MySQL within a virtualized environment that are common across the different virtualization types. Most are directly related to the performance or security of the environment in which you are deploying the MySQL server compared to the host on which you are running the virtualization solution.

Before deciding to use virtualization as a solution for your database, you should ensure that the expected load for the server and the expected performance when run in a virtualized environment meet your needs and requirements.

To help you determine the issues and some of the potential solutions, use the following sections:

- For general performance issues, problems and the probable causes, see Section 5.1.1, “Virtualization Performance Issues”.
- Disk and storage concerns directly affect database storage because most database access is limited by the I/O bandwidth. For some examples and issues, see Section 5.1.2, “Virtualization Storage Issues”.
- Issues related to network configuration and performance may need more careful planning, especially if you are using network-specific technologies such as MySQL replication. For further examples and details, see Section 5.1.3, “Virtualization Networking Issues”.

5.1.1. Virtualization Performance Issues

Often the biggest consideration is the performance of a virtualized environment once hosted. In most cases, the virtualized environment involves some level of emulation of one or more of the hardware interfaces (CPU, network or disk) of the host environment. The effect is to reduce the effective performance of the virtualized environment compared to running an application natively on the host.

Some core resourcing issues to be aware of include:

- Using virtualization does not reduce the amount of CPU required to support a particular application or environment. If your application stack requires 2GB of RAM on an individual machine, the same RAM requirement will apply within your virtualized environment. The additional overhead of the virtualization layer and host operating system or environment often mean that you will need 2.5GB or 3GB of RAM to run the same application within the virtualized environment.

  You should configure your virtualization environment with the correct RAM allocation according to your applications needs, and not to maximize the number of virtualized environments that you can execute within the virtualization host.

- Virtualization of the CPU resources is more complex. If your MySQL database and application stack do not have a high CPU load, then consolidating multiple environments onto a single host is often more efficient. You should keep in mind that at peak times your application and database CPU requirement may need to grow beyond your default allocation.

  With some virtualization environments (Xen, Solaris Containers, Solaris LDOMs) you can dedicate CPU or core to a virtual instance. You should use this functionality to improve performance for database or application loads that have a high constant CPU requirement as the performance benefit will outweigh the flexibility of dynamic allocation of the CPU resources.

- Contention of resources within the host should be taken into account. In a system with high CPU loads, even when dedicating RAM and CPU resources, the I/O channels and interfaces to storage and networking resources may exceed the capacity of the host. Solutions such as Xen and Solaris LDOMs dedicate specific resources to individual virtual instances, but this will not eliminate the effects of the overall load on the host.

- If your database application is time sensitive, including logging and real-time database applications, or you are using MySQL Cluster, then the effects of virtualization may severely reduce the performance of your application. Because of the way the virtualized instances are executed and shared between CPUs and the effects of load on other resources, the response times for your database or application may be much higher than normal. This is especially true if you are running a large number of virtualized instances on a single host.

- Be aware of the limitation of using a single host to run multiple virtualized instances. In the event of a machine or component failure, the problem will affect more than just one database instance. For example, a failure in a storage device could bring

down all your virtualized instances. Using a RAID solution that supports fault tolerance (RAID levels 1,3,4,5 or 6) will help protect you from the effects of this.

5.1.2. Virtualization Storage Issues

Due to the random I/O nature of any database solution, running MySQL within a virtualized environment places a heavy load on the storage solution you are using. To help keep the performance of your virtualized solution at the highest level, you should use the following notes to help configure your systems.

- Some virtualization solutions allow you to use a physical disk directly within your virtual host as if it were a local disk. You should use this whenever possible to ensure that disk contention issues do not affect the performance of your virtual environment.

  When running multiple virtual machines, you should use an individual disk for each virtual instance. Using a single disk and multiple partitions, with each partition dedicated to a virtual host, will lead to the same contention issues.

- If you are using standard file-based storage for your virtualized disks:

  - File-based storage is subject to fragmentation on the host disk. To prevent fragmentation, create a fixed-size disk (that is, one where the entire space for the disk file is preallocated) instead of a dynamic disk that will grow with usage. Also be prepared to defragment the disk hosting the files at regular intervals to reduce the fragmentation.

  - Use separate disk files for the operating system and database disks, and try to avoid partitioning a disk file as this increases the contention within the file.

  - Use a high-performance disk solution, such as RAID or SAN, to store the disk files for your virtualized environments. This will improve the performance of what is essentially a large single file on a physical device.

  - When running a number of different virtualized environments within a single host, do not use the same physical host drive for multiple virtual disks. Instead, spread the virtual disks among multiple physical disks. Even when using a RAID device, be aware that each virtual host is equivalent to increasing the load linearly on the host RAID device.

5.1.3. Virtualization Networking Issues

When running multiple virtual machines on a host, you should be aware of the networking implications of each virtualized instance. If your host machine has only one network card, then you will be sharing the networking throughput for all of your machines through only one card, and this may severely limit the performance of your virtual environments.

If possible, you should use multiple network cards to support your virtualized instances. Depending on the expected load of each instance, you should dedicate or spread the allocation of the virtual network devices across these physical devices to ensure that you do not reach saturation.

If you are using packaged virtual machines as the basis for deployment of your MySQL database solution, you should make sure that the network interfaces are correctly reconfigured. Some solutions duplicate the hardware MAC address which will cause problems when you start up additional instances of the same virtualized environment.

5.2. Using MySQL within an Amazon EC2 Instance

The Amazon Elastic Compute Cloud (EC2) service provides virtual servers that you can build and deploy to run a variety of different applications and services, including MySQL. The EC2 service is based around the Xen framework, supporting x86, Linux based, platforms with individual instances of a virtual machine referred to as an Amazon Machine Image (AMI). You have complete (root) access to the AMI instance that you create, allowing you to configure and install your AMI in any way you choose.

To use EC2, you create an AMI based on the configuration and applications that you want to use and upload the AMI to the Amazon Simple Storage Service (S3). From the S3 resource, you can deploy one or more copies of the AMI to run as an instance within the EC2 environment. The EC2 environment provides management and control of the instance and contextual information about the instance while it is running.

Because you can create and control the AMI, the configuration, and the applications, you can deploy and create any environment you choose. This includes a basic MySQL server in addition to more extensive replication, HA and scalability scenarios that enable you to take advantage of the EC2 environment, and the ability to deploy additional instances as the demand for your MySQL services and applications grow.

To aid the deployment and distribution of work, three different Amazon EC2 instances are available, small (identified as `m1.small`), large (`m1.large`) and extra large (`m1.xlarge`). The different types provide different levels of computing power measured in EC2 computer units (ECU). A summary of the different instance configurations is shown here.

	Small	Large	Extra Large
Platform	32-bit	64-bit	64-bit
CPU cores	1	2	4
ECUs	1	4	8
RAM	1.7GB	7.5GB	15GB
Storage	150GB	840GB	1680GB
I/O Performance	Medium	High	High

The typical model for deploying and using MySQL within the EC2 environment is to create a basic AMI that you can use to hold your database data and application. Once the basic environment for your database and application has been created you can then choose to deploy the AMI to a suitable instance. Here the flexibility of having an AMI that can be re-deployed from the small to the large or extra large EC2 instance makes it easy to upgrade the hardware environment without rebuilding your application or database stack.

To get started with MySQL on EC2, including information on how to set up and install MySQL within an EC2 installation and how to port and migrate your data to the running instance, see Section 5.2.1, “Setting Up MySQL on an EC2 AMI”.

For tips and advice on how to create a scalable EC2 environment using MySQL, including guides on setting up replication, see Section 5.2.3, “Deploying a MySQL Database Using EC2”.

5.2.1. Setting Up MySQL on an EC2 AMI

There are many different ways of setting up an EC2 AMI with MySQL, including using any of the pre-configured AMIs supplied by Amazon.

The default *Getting Started* AMI provided by Amazon uses Fedora Core 4, and you can install MySQL by using `yum`:

```
shell> yum install mysql
```

This will install both the MySQL server and the Perl DBD::mysql driver for the Perl DBI API.

Alternatively, you can use one of the AMIs that include MySQL within the standard installation.

Finally, you can also install a standard version of MySQL downloaded from the MySQL website. The installation process and instructions are identical to any other installation of MySQL on Linux. See Installing and Upgrading MySQL.

The standard configuration for MySQL places the data files in the default location, `/var/lib/mysql`. The default data directory on an EC2 instance is `/mnt` (although on the large and extra large instance you can alter this configuration). You must edit `/etc/my.cnf` to set the `datadir` option to point to the larger storage area.

> **Important**
>
> The first time you use the main storage location within an EC2 instance it needs to be initialized. The initialization process starts automatically the first time you write to the device. You can start using the device right away, but the write performance of the new device is significantly lower on the initial writes until the initialization process has finished.
>
> To avoid this problem when setting up a new instance, you should start the initialization process before populating your MySQL database. One way to do this is to use `dd` to write to the file system:
>
> ```
> root-shell> dd if=/dev/zero of=initialize bs=1024M count=50
> ```
>
> The preceding will create a 50GB on the file system and start the initialization process. You should delete the file once the process has finished.
>
> The initialization process can be time-consuming. On the small instance, initialization will take between two and three hours. For the large and extra large drives, the initialization will be 10 or 20 hours, respectively.

In addition to configuring the correct storage location for your MySQL data files, you should also consider setting the following other settings in your instance before you save the instance configuration for deployment:

- Set the MySQL server ID so that when you use it for replication the ID information is set correctly.
- Enabling binary logging so that replication can be initialized without starting and stopping the server.

- Set the caching and memory parameters for your storage engines. There are no limitations or restrictions on what storage engines you use in your EC2 environment. Choose a configuration, possibly using one of the standard configurations provided with MySQL appropriate for the instance on which you expect to deploy. The large and extra large instances have RAM that can be dedicated to caching. Be aware that if you choose to install `memcached` on the servers as part of your application stack you must ensure there is enough memory for both MySQL and `memcached`.

Once you have configured your AMI with MySQL and the rest of your application stack, you should save the AMI so that you can deploy and reuse the instance.

Once you have your application stack configured in an AMI, populating your MySQL database with data should be performed by creating a dump of your database using `mysqldump`, transferring the dump to the EC2 instance, and then reloading the information into the EC2 instance database.

Before using your instance with your application in a production situation you should be aware of the limitations of the EC2 instance environment. See Section 5.2.2, “EC2 Instance Limitations”. To begin using your MySQL AMI, you should consult the notes on deployment. See Section 5.2.3, “Deploying a MySQL Database Using EC2”.

5.2.2. EC2 Instance Limitations

There are some limitations of the EC2 instances that you should be aware of before deploying your applications. Although these shouldn't affect your ability to deploy within the Amazon EC2 environment, they may alter the way you setup and configure your environment to support your application.

- Data stored within instances is not persistent. If you create an instance and populate the instance with data, then the data will only remain in place while the machine is running. The data will survive a reboot. If you shut down the instance, any data it contained will be lost.

  To ensure that you do not lose information, take regular backups using `mysqldump`. If the data being stored is critical, consider using replication to keep a “live” backup of your data in the event of a failure. When creating a backup, write the data to the Amazon S3 service to avoid the transfer charges applied when copying data offsite.

- EC2 instances are not persistent. If the hardware on which an instance is running fails, then the instance will be shut down. This can lead to loss of data or service.

- If you want to use replication with your EC2 instances to a non-EC2 environment, be aware of the transfer costs to and from the EC2 service. Data transfer between different EC2 instances is free, so using replication within the EC2 environment does not incur additional charges.

- Certain HA features are either not directly supported, or have limiting factors or problems that may reduce their utility. For example, using DRBD or MySQL Cluster may not work. The default storage configuration is also not redundant. You can use software-based RAID to improve redundancy, but this implies a further performance hit.

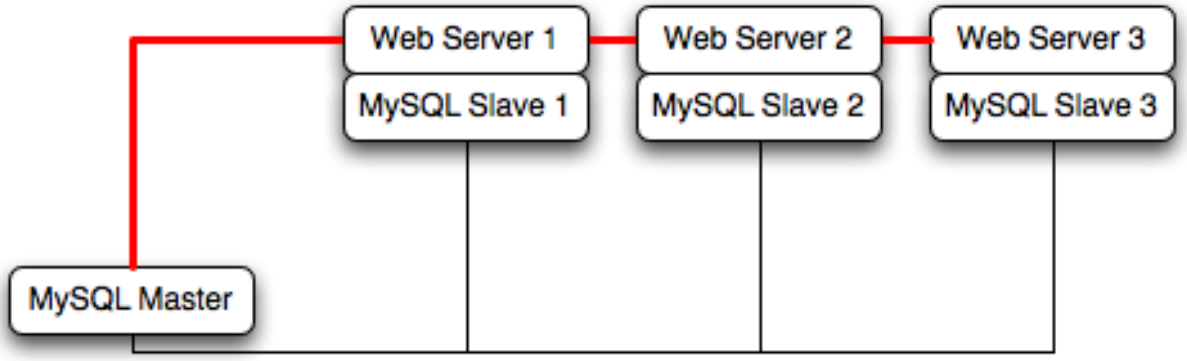
5.2.3. Deploying a MySQL Database Using EC2

Because you cannot guarantee the uptime and availability of your EC2 instances, when deploying MySQL within the EC2 environment you should use an approach that enables you to easily distribute work among your EC2 instances. There are a number of ways of doing this. Using sharding techniques, where you split the application across multiple servers dedicating specific blocks of your dataset and users to different servers is an effective way of doing this. As a general rule, it is easier to create more EC2 instances to support more users than to upgrade the instance to a larger machine.

The EC2 architecture means that you should treat the EC2 instances as temporary, cache-based solutions, rather than as a long-term, high availability solution. In addition to using multiple machines, you should also take advantage of other services, such as `memcached` to provide additional caching for your application to help reduce the load on the MySQL server so that it can concentrate on writes. On the large and extra large instances within EC2, the RAM available can be used to provide a large memory cache for data.

Most types of scale out topology that you would use with your own hardware can be used and applied within the EC2 environment. However, you should be use the limitations and advice already given to ensure that any potential failures do not lose you any data. Also, because the relative power of each EC2 instance is so low, you should be prepared to alter your application to use sharding and add further EC2 instances to improve the performance of your application.

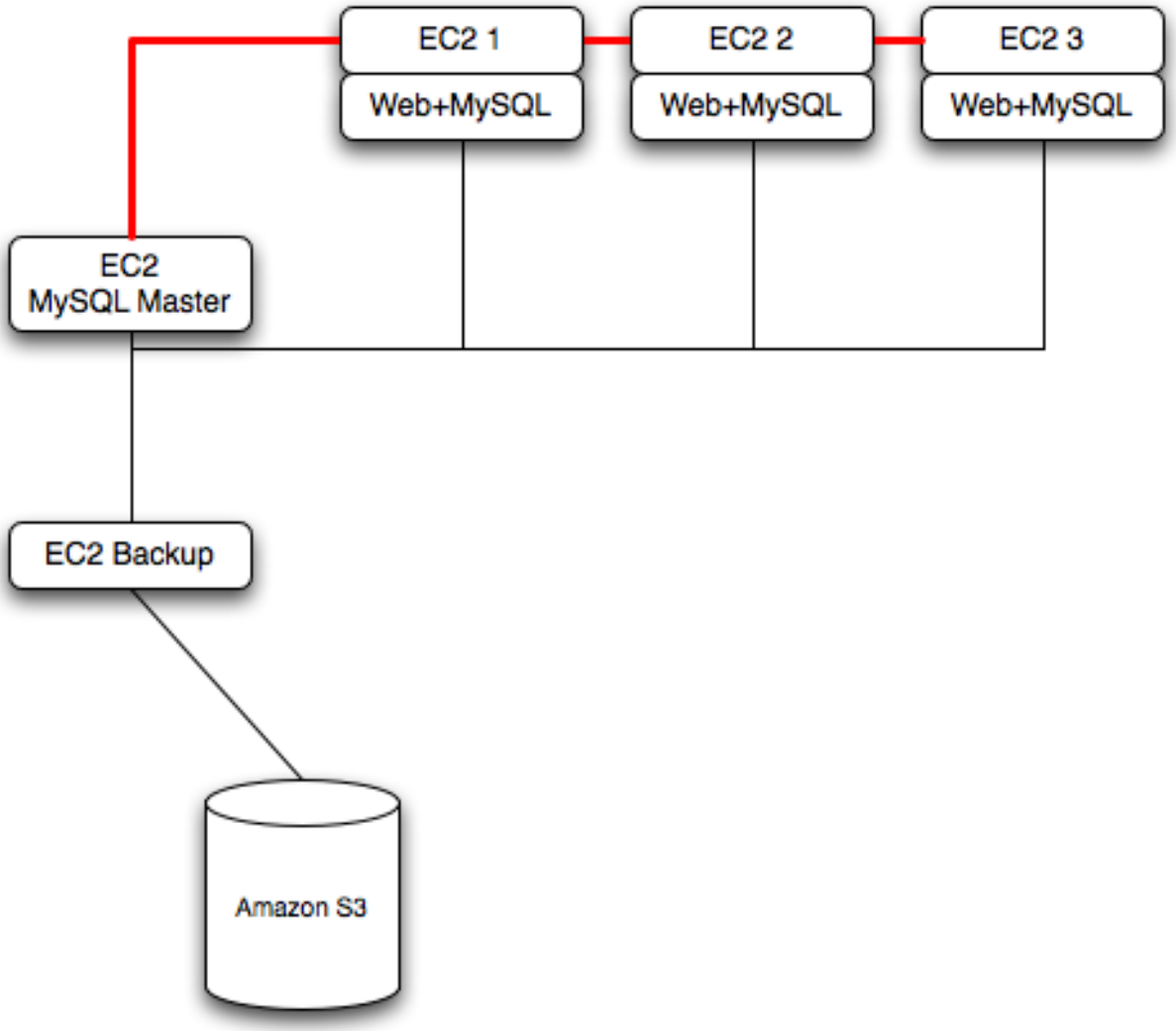
For example, take the typical scale-out environment shown following, where a single master replicates to one or more slaves (three in this example), with a web server running on each replication slave.



You can reproduce this structure completely within the EC2 environment, using an EC2 instance for the master, and one instance for each of the web and MySQL slave servers.

> **Note**
>
> Within the EC2 environment, internal (private) IP addresses used by the EC2 instances are constant. You should always use these internal addresses and names when communicating between instances. Only use public IP addresses when communicating with the outside world - for example, when publicizing your application.

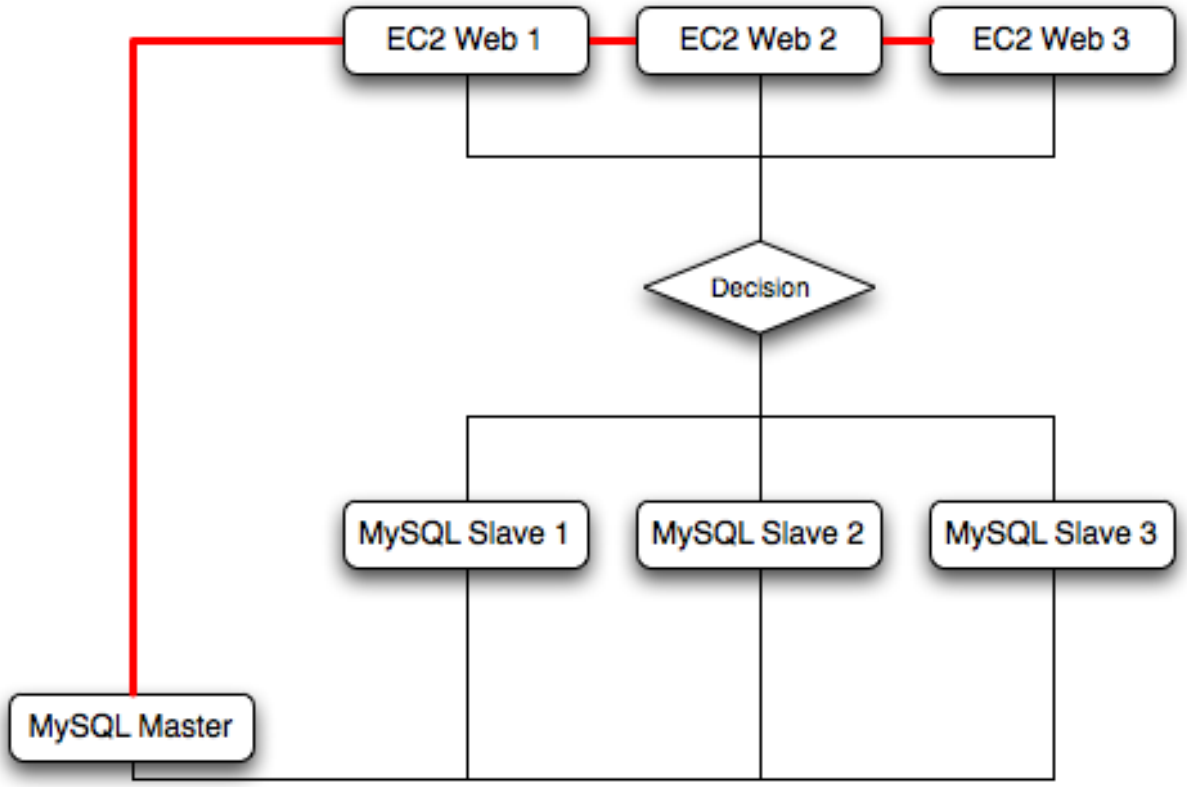
To ensure reliability of your database, you should add at least one replication slave dedicated to providing an active backup and storage to the Amazon S3 facility. You can see an example of this in the following topology.



Using `memcached` within your EC2 instances should provide better performance. The large and extra large instances have a significant amount of RAM. To use `memcached` in your application, when loading information from the database, first check whether the item exists in the cache. If the data you are looking for exists in the cache, use it. If not, reload the data from the database and populate the cache.

Sharding divides up data in your entire database by allocating individual machines or machine groups to provide a unique set of data according to an appropriate group. For example, you might put all users with a surname ending in the letters A-D onto a single server. When a user connects to the application and their surname is known, queries can be redirected to the appropriate MySQL server.

When using sharding with EC2 you should separate the web server and MySQL server into separate EC2 instances, and then apply the sharding decision logic into your application. Once you know which MySQL server you should be using for accessing the data you then distribute queries to the appropriate server. You can see a sample of this in the following illustration.



Warning

With sharding and EC2 you should be careful that the potential for failure of an instance does not affect your application. If the EC2 instance that provides the MySQL server for a particular shard fails, then all of the data on that shard will be unavailable.

5.3. Virtualization Resources

For more information on virtualization, see the following links:

- MySQL Virtualization Forum
- Amazon Elastic Compute Cloud (Amazon EC2)
- MySQL and Cloud Computing
- MySQL Enterprise for Amazon EC2

Chapter 6. MySQL Proxy

The MySQL Proxy is an application that communicates over the network using the MySQL Network Protocol and provides communication between one or more MySQL servers and one or more MySQL clients. In the most basic configuration, MySQL Proxy simply passes on queries from the client to the MySQL Server and returns the responses from the MySQL Server to the client.

Because MySQL Proxy uses the MySQL network protocol, any MySQL compatible client (include the command line client, any clients using the MySQL client libraries, and any connector that supports the MySQL network protocol) can connect to the proxy without modification.

In addition to the basic pass-through configuration, the MySQL Proxy is also capable of monitoring and altering the communication between the client and the server. This interception of the queries enables you to add profiling, and the interception of the exchanges is scriptable using the Lua scripting language.

By intercepting the queries from the client, the proxy can insert additional queries into the list of queries sent to the server, and remove the additional results when they are returned by the server. Using this functionality you can add informational statements to each query, for example to monitor their execution time or progress, and separately log the results, while still returning the results from the original query to the client.

The proxy allows you to perform additional monitoring, filtering or manipulation on queries without you having to make any modifications to the client and without the client even being aware that it is communicating with anything but a genuine MySQL server.

> **Warning**
>
> MySQL Proxy is currently an Alpha release and should not be used within production environments.

> **Important**
>
> MySQL Proxy is compatible with MySQL 5.0.x or later. Testing has not been performed with Version 4.1. Please provide feedback on your experiences via the MySQL Proxy Forum.

6.1. MySQL Proxy Supported Platforms

MySQL Proxy is currently available as a pre-compiled binary for the following platforms:

- Linux (including RedHat, Fedora, Debian, SuSE) and derivatives.
- Mac OS X
- FreeBSD
- IBM AIX
- Sun Solaris
- Microsoft Windows (including Microsoft Windows XP, and Microsoft Windows Server 2003)

Other Unix/Linux platforms not listed should be compatible by using the source package and building MySQL Proxy locally.

System requirements for the MySQL Proxy application are the same as the main MySQL server. Currently MySQL Proxy is compatible only with MySQL 5.0.1 and later. MySQL Proxy is provided as a standalone, statically linked binary. You do not need to have MySQL or Lua installed.

6.2. Installing MySQL Proxy

You have three choices for installing MySQL Proxy:

- Pre-compiled binaries are available for a number of different platforms. See Section 6.2.1, “Installing MySQL Proxy from a binary distribution”.
- You can install from the source code if you want to build on an environment not supported by the binary distributions. See Section 6.2.2, “Installing MySQL Proxy from a source distribution”.
- The latest version of the MySQL proxy source code is available through a development repository is the best way to stay up to date with the latest fixes and revisions. See Section 6.2.3, “Installing MySQL Proxy from the Subversion repository”.

6.2.1. Installing MySQL Proxy from a binary distribution

If you download the binary packages then you need only to extract the package and then copy the `mysql-proxy` file to your desired location. For example:

```
shell> tar zxf mysql-proxy-0.5.0.tar.gz
shell> cp ./mysql-proxy-0.5.0/sbin/mysql-proxy /usr/local/sbin
```

6.2.2. Installing MySQL Proxy from a source distribution

If you have downloaded the source package then you will need to compile the MySQL Proxy before using it. To build you will need to have the following installed:

- libevent 1.x or higher (1.3b or later is preferred)
- lua 5.1.x or higher
- glib2 2.6.0 or higher
- pkg-config
- MySQL 5.0.x or higher developer files

> **Note**
>
> On some operating systems you may need to manually build the required components to get the latest version. If you are having trouble compiling MySQL Proxy then consider using one of the binary distributions.

Once these components are installed, you need to configure and then build:

```
shell> tar zxf mysql-proxy-0.5.0.tar.gz
shell> cd mysql-proxy-0.5.0
shell> ./configure
shell> make
```

If you want to test the build, then use the `check` target to `make`:

```
shell> make check
```

The tests try to connect to `localhost` using the `root` user. If you need to provide a password, set the `MYSQL_PASSWORD` environment variable:

```
shell> MYSQL_PASSWORD=root_pwd make check
```

You can install using the `install` target:

```
shell> make install
```

By default `mysql-proxy` is installed into `/usr/local/sbin/mysql-proxy`. The Lua example scripts are copied into `/usr/local/share`.

6.2.3. Installing MySQL Proxy from the Subversion repository

The MySQL Proxy source is available through a public Subversion repository and is the quickest way to get hold of the latest releases and fixes.

To build from the Subversion repository, you need the following components already installed:

- Subversion 1.3.0 or higher
- `libtool` 1.5 or higher
- `autoconf` 2.56 or higher
- `automake` 1.9 or higher
- `libevent` 1.x or higher (1.3b or later is preferred)

- `lua` 5.1.x or higher
- `glib2` 2.4.0 or higher
- `pkg-config`
- `MySQL` 5.0.x or higher developer files

To checkout a local copy of the Subversion repository, use `svn`:

```
shell> svn co http://svn.MySQL.com/svnpublic/mysql-proxy/ mysql-proxy
```

The above command will download a complete version of the Subversion repository for `mysql-proxy`. The main source files are located within the `trunk` subdirectory. The configuration scripts need to be generated before you can configure and build `mysql-proxy`. The `autogen.sh` script will generate the configuration scripts for you:

```
shell> sh ./autogen.sh
```

The script creates the standard `configure` script, which you can then use to configure and build with `make`:

```
shell> ./configure
shell> make
shell> make install
```

If you want to create a standalone source distribution, identical to the source distribution available for download:

```
shell> make distcheck
```

The above will create the file `mysql-proxy-0.5.0.tar.gz` within the current directory.

6.3. MySQL Proxy Command-Line Options

To start `mysql-proxy` you can just run the command directly. However, for most situations you will want to specify at the very least the address/host name and port number of the backend MySQL server to which the MySQL Proxy should pass on queries.

You can get a list of the supported command-line options using the `--help-all` command-line option. The majority of these options set up the environment, either in terms of the address/port number that `mysql-proxy` should listen on for connections, or the onward connection to a MySQL server. A full description of the options is shown below:

- `--help-all` — show all help options.
- `--help-admin` — show options for the admin-module.
- `--help-proxy` — Show options for the proxy-module.
- `--admin-address=host:port` — specify the host name (or IP address) and port for the administration port. The default is `localhost:4041`.
- `--proxy-address=host:port` — the listening host name (or IP address) and port of the proxy server. The default is `localhost:4040`.
- `--proxy-read-only-backend-address=host:port` — the listening host name (or IP address) and port of the proxy server for read-only connections. The default is for this information not to be set.
- `--proxy-backend-addresses=host:port` — the host name (or IP address) and port of the MySQL server to connect to. You can specify multiple backend servers by supplying multiple options. Clients are connected to each backend server in round-robin fashion. For example, if you specify two servers A and B, the first client connection will go to server A; the second client connection to server B and the third client connection to server A.
- `--proxy-skip-profiling` — disables profiling of queries (tracking time statistics). The default is for tracking to be enabled.
- `--proxy-fix-bug-25371` — gets round an issue when connecting to a MySQL server later than 5.1.12 when using a MySQL client library of any earlier version.
- `--proxy-lua-script=file` — specify the Lua script file to be loaded. Note that the script file is not physically loaded and parsed until a connection is made. Also note that the specified Lua script is reloaded for each connection; if the content of

the Lua script changes while `mysql-proxy` is running then the updated content will automatically be used when a new connection is made.

- `--daemon` — starts the proxy in daemon mode.
- `--pid-file=file` — sets the name of the file to be used to store the process ID.
- `--version` — show the version number.

The most common usage is as a simple proxy service (i.e. without addition scripting). For basic proxy operation you must specify at least one `proxy-backend-addresses` option to specify the MySQL server to connect to by default:

```
shell> mysql-proxy
--proxy-backend-addresses=MySQL.example.com:3306
```

The default proxy port is `4040`, so you can connect to your MySQL server through the proxy by specifying the host name and port details:

```
shell> mysql --host=localhost --port=4040
```

If your server requires authentication information then this will be passed through natively without alteration by `mysql-proxy`, so you must also specify the authentication information if required:

```
shell> mysql --host=localhost --port=4040 \
   --user=username --password=password
```

You can also connect to a read-only port (which filters out `UPDATE` and `INSERT` queries) by connecting to the read-only port. By default the host name is the default, and the port is `4042`, but you can alter the host/port information by using the `--proxy-read-only-address` command-line option.

For more detailed information on how to use these command line options, and `mysql-proxy` in general in combination with Lua scripts, see Section 6.5, “Using MySQL Proxy”.

6.4. MySQL Proxy Scripting

You can control how MySQL Proxy manipulates and works with the queries and results that are passed on to the MySQL server through the use of the embedded Lua scripting language. You can find out more about the Lua programming language from the Lua Website.

The primary interaction between MySQL Proxy and the server is provided by defining one or more functions through an Lua script. A number of functions are supported, according to different events and operations in the communication sequence between a client and one or more backend MySQL servers:

- `connect_server()` — this function is called each time a connection is made to MySQL Proxy from a client. You can use this function during load-balancing to intercept the original connection and decide which server the client should ultimately be attached to. If you do not define a special solution, then a simple round-robin style distribution is used by default.
- `read_handshake()` — this function is called when the initial handshake information is returned by the server. You can capture the handshake information returned and provide additional checks before the authorization exchange takes place.
- `read_auth()` — this function is called when the authorization packet (user name, password, default database) are submitted by the client to the server for authentication.
- `read_auth_result()` — this function is called when the server returns an authorization packet to the client indicating whether the authorization succeeded.
- `read_query()` — this function is called each time a query is sent by the client to the server. You can use this to edit and manipulate the original query, including adding new queries before and after the original statement. You can also use this function to return information directly to the client, bypassing the server, which can be useful to filter unwanted queries or queries that exceed known limits.
- `read_query_result()` — this function is called each time a result is returned from the server, providing you have manually injected queries into the query queue. If you have not explicitly inject queries within the `read_query()` function then this function is not triggered. You can use this to edit the result set, or to remove or filter the result sets generated from additional queries you injected into the queue when using `read_query()`.

The table below describes the direction of flow of information at the point when the function is triggered.

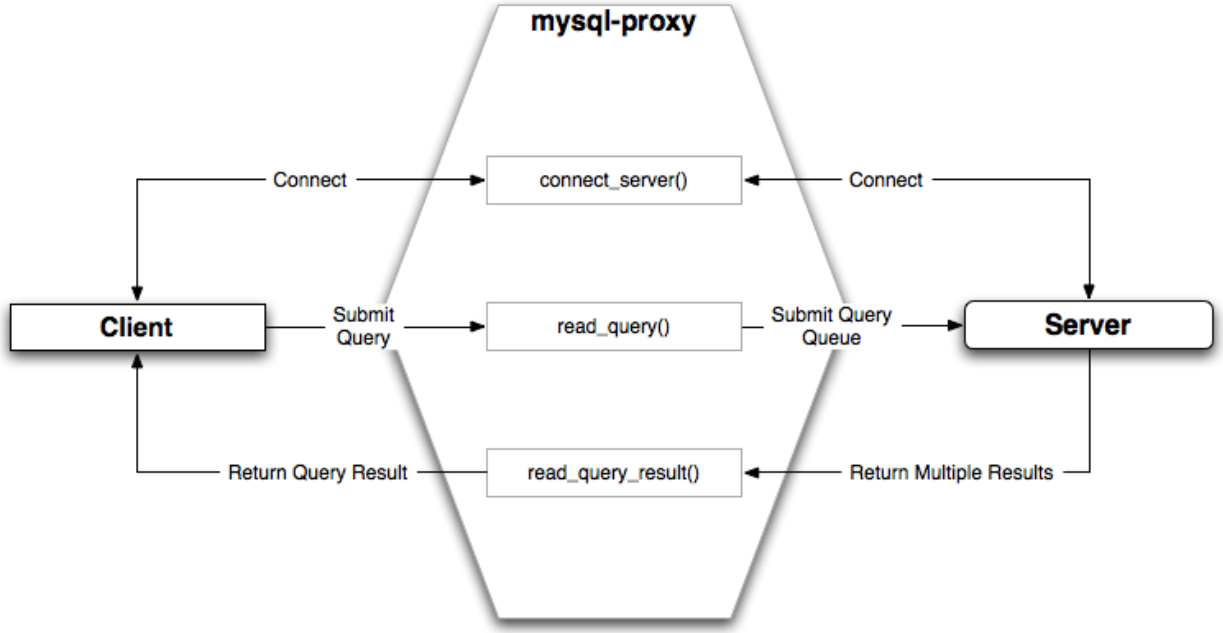
Function	Supplied Information	Direction
`connect_server()`	None	Client to Server
`read_handshake()`	Handshake packet	Server to Client
`read_auth()`	Authorization packet	Client to Server
`read_auth_result()`	Authorization response	Server to Client
`read_query()`	Query	Client to Server
`read_query_result()`	Query result	Server to Client

By default, all functions return a result that indicates that the data should be passed on to the client or server (depending on the direction of the information being transferred). This return value can be overridden by explicitly returning a constant indicating that a particular response should be sent. For example, it is possible to construct result set information by hand within `read_query()` and to return the resultset directly to the client without ever sending the original query to the server.

In addition to these functions, a number of built-in structures provide control over how MySQL Proxy forwards on queries and returns the results by providing a simplified interface to elements such as the list of queries and the groups of result sets that are returned.

6.4.1. Proxy Scripting Sequence During Query Injection

The figure below gives an example of how the proxy might be used when injecting queries into the query queue. Because the proxy sits between the client and MySQL server, what the proxy sends to the server, and the information that the proxy ultimately returns to the client do not have to match or correlate. Once the client has connected to the proxy, the following sequence occurs for each individual query sent by the client.



1. The client submits one query to the proxy, the `read_query()` function within the proxy is triggered. The function adds the query to the query queue.
2. Once manipulation by `read_query()` has completed, the queries are submitted, sequentially, to the MySQL server.
3. The MySQL server returns the results from each query, one result set for each query submitted. The `read_query_result()` function is triggered for each result set, and each invocation can decide which result set to return to the client

For example, you can queue additional queries into the global query queue to be processed by the server. This can be used to add statistical information by adding queries before and after the original query, changing the original query:

```
SELECT * FROM City;
```

Into a sequence of queries:

```
SELECT NOW();
SELECT * FROM City;
SELECT NOW();
```

You can also modify the original statement, for example to add `EXPLAIN` to each statement executed to get information on how the statement was processed, again altering our original SQL statement into a number of statements:

```
SELECT * FROM City;
EXPLAIN SELECT * FROM City;
```

In both of these examples, the client would have received more result sets than expected. Regardless of how you manipulate the incoming query and the returned result, the number of queries returned by the proxy must match the number of original queries sent by the client.

You could adjust the client to handle the multiple result sets sent by the proxy, but in most cases you will want the existence of the proxy to remain transparent. To ensure that the number of queries and result sets match, you can use the MySQL Proxy `read_query_result()` to extract the additional result set information and return only the result set the client originally requested back to the client. You can achieve this by giving each query that you add to the query queue a unique ID, and then filter out queries that do not match the original query ID when processing them with `read_query_result()`.

6.4.2. Internal Structures

There are a number of internal structures within the scripting element of MySQL Proxy. The primary structure is `proxy` and this provides an interface to the many common structures used throughout the script, such as connection lists and configured backend servers. Other structures, such as the incoming packet from the client and result sets are only available within the context of one of the scriptable functions.

Attribute	Description
`connection`	A structure containing the active client connections. For a list of attributes, see `proxy.connection`.
`servers`	A structure containing the list of configured backend servers. For a list of attributes, see `proxy.backends`.
`queries`	A structure containing the queue of queries that will be sent to the server during a single client query. For a list of attributes, see `proxy.queries`.
`PROXY_VERSION`	The version number of MySQL Proxy, encoded in hex. You can use this to check that the version number supports a particular option from within the Lua script. Note that the value is encoded as a hex value, so to check the version is at least 0.5.1 you compare against `0x00501`.

`proxy.connection`

The `proxy.connection` object is read only, and provides information about the current connection.

Attribute	Description
`thread_id`	The thread ID of the connection.
`backend_ndx`	The ID of the server used for this connection. This is an ID valid against the list of configured servers available through the `proxy.backends` object.

`proxy.backends`

The `proxy.backends` table is partially writable and contains an array of all the configured backend servers and the server metadata (IP address, status, etc.). You can determine the array index of the current connection using `proxy.connection["backend_ndx"]` which is the index into this table of the backend server being used by the active connection.

The attributes for each entry within the `proxy.backends` table are shown in this table.

Attribute	Description
`address`	The host name/port combination used for this connection
`connected_clients`	The number of clients currently connected.
`state`	The status of the backend server. See Section 6.4.2, “Internal Structures” [79]

proxy.queries

The proxy.queries object is a queue representing the list of queries to be sent to the server. The queue is not populated automatically, but if you do not explicitly populate the queue then queries are passed on to the backend server verbatim. Also, if you do not populate the query queue by hand, then the read_query_result() function is not triggered.

The following methods are supported for populating the proxy.queries object.

Function	Description
append(id,packet)	Appends a query to the end of the query queue. The id is an integer identifier that you can use to recognize the query results when they are returned by the server. The packet should be a properly formatted query packet.
prepend(id,packet)	Prepends a query to the query queue. The id is an identifier that you can use to recognize the query results when they are returned by the server. The packet should be a properly formatted query packet.
reset()	Empties the query queue.
len()	Returns the number of query packets in the queue.

For example, you could append a query packet to the proxy.queries queue by using the append():

```
proxy.queries:append(1,packet)
```

proxy.response

The proxy.response structure is used when you want to return your own MySQL response, instead of forwarding a packet that you have received a backend server. The structure holds the response type information, an optional error message, and the result set (rows/columns) that you want to return.

Attribute	Description
type	The type of the response. The type must be either MYSQLD_PACKET_OK or MYSQLD_PACKET_ERR. If the MYSQLD_PACKET_ERR, then you should set the value of the mysql.response.errmsg with a suitable error message.
errmsg	A string containing the error message that will be returned to the client.
resultset	A structure containing the result set information (columns and rows), identical to what would be returned when returning a results from a SELECT query.

When using proxy.response you either set proxy.response.type to proxy.MYSQLD_PACKET_OK and then build resultset to contain the results that you want to return, or set proxy.response.type to proxy.MYSQLD_PACKET_ERR and set the proxy.response.errmsg to a string with the error message. To send the completed resultset or error message, you should return the proxy.PROXY_SEND_RESULT to trigger the return of the packet information.

An example of this can be seen in the tutorial-resultset.lua script within the MySQL Proxy package:

```
if string.lower(command) == "show" and string.lower(option) == "querycounter" then
        ---
        -- proxy.PROXY_SEND_RESULT requires
        --
        -- proxy.response.type to be either
        -- * proxy.MYSQLD_PACKET_OK or
        -- * proxy.MYSQLD_PACKET_ERR
        --
        -- for proxy.MYSQLD_PACKET_OK you need a resultset
        -- * fields
        -- * rows
        --
        -- for proxy.MYSQLD_PACKET_ERR
        -- * errmsg
        proxy.response.type = proxy.MYSQLD_PACKET_OK
        proxy.response.resultset = {
                fields = {
                        { type = proxy.MYSQL_TYPE_LONG, name = "global_query_counter", },
                        { type = proxy.MYSQL_TYPE_LONG, name = "query_counter", },
                },
                rows = {
                        { proxy.global.query_counter, query_counter }
                }
        }
        -- we have our result, send it back
        return proxy.PROXY_SEND_RESULT
elseif string.lower(command) == "show" and string.lower(option) == "myerror" then
        proxy.response.type = proxy.MYSQLD_PACKET_ERR
        proxy.response.errmsg = "my first error"
```

```
        return proxy.PROXY_SEND_RESULT
```

proxy.response.resultset

The proxy.response.resultset structure should be populated with the rows and columns of data that you want to return. The structure contains the information about the entire result set, with the individual elements of the data shown in the table below.

Attribute	Description
fields	The definition of the columns being returned. This should be a dictionary structure with the type specifying the MySQL data type, and the name specifying the column name. Columns should be listed in the order of the column data that will be returned.
flags	A number of flags related to the resultset. Valid flags include auto_commit (whether an automatic commit was triggered), no_good_index_used (the query executed without using an appropriate index), and no_index_used (the query executed without using any index).
rows	The actual row data. The information should be returned as an array of arrays. Each inner array should contain the column data, with the outer array making up the entire result set.
warning_count	The number of warnings for this result set.
affected_rows	The number of rows affected by the original statement.
insert_id	The last insert ID for an auto-incremented column in a table.
query_status	The status of the query operation. You can use the MYSQLD_PACKET_OK or MYSQLD_PACKET_ERR constants to populate this parameter.

For an example of the population of this table, see Section 6.4.2, “Internal Structures” [78].

Proxy Return State Constants

The following constants are used internally by the proxy to specify the response to send to the client or server. All constants are exposed as values within the main proxy table.

Constant	Description
PROXY_SEND_QUERY	Causes the proxy to send the current contents of the queries queue to the server.
PROXY_SEND_RESULT	Causes the proxy to send a result set back to the client.
PROXY_IGNORE_RESULT	Causes the proxy to drop the result set (nothing is returned to the client).

As constants, these entities are available without qualification in the Lua scripts. For example, at the end of the read_query_result() you might return PROXY_IGNORE_RESULT:

```
return proxy.PROXY_IGNORE_RESULT
```

Packet State Constants

The following states describe the status of a network packet. These items are entries within the main proxy table.

Constant	Description
MYSQLD_PACKET_OK	The packet is OK.
MYSQLD_PACKET_ERR	The packet contains error information.
MYSQLD_PACKET_RAW	The packet contains raw data.

Backend State/Type Constants

The following constants are used either to define the status of the backend server (the MySQL server to which the proxy is connected) or the type of backend server. These items are entries within the main proxy table.

Constant	Description
BACKEND_STATE_UNKNOWN	The current status is unknown.
BACKEND_STATE_UP	The backend is known to be up (available).
BACKEND_STATE_DOWN	The backend is known to be down (unavailable).

Constant	Description
BACKEND_TYPE_UNKNOWN	Backend type is unknown.
BACKEND_TYPE_RW	Backend is available for read/write.
BACKEND_TYPE_RO	Backend is available only for read-only use.

Server Command Constants

The following values are used in the packets exchanged between the client and server to identify the information in the rest of the packet. These items are entries within the main proxy table. The packet type is defined as the first character in the sent packet. For example, when intercepting packets from the client to edit or monitor a query you would check that the first byte of the packet was of type proxy.COM_QUERY.

Constant	Description
COM_SLEEP	Sleep
COM_QUIT	Quit
COM_INIT_DB	Initialize database
COM_QUERY	Query
COM_FIELD_LIST	Field List
COM_CREATE_DB	Create database
COM_DROP_DB	Drop database
COM_REFRESH	Refresh
COM_SHUTDOWN	Shutdown
COM_STATISTICS	Statistics
COM_PROCESS_INFO	Process List
COM_CONNECT	Connect
COM_PROCESS_KILL	Kill
COM_DEBUG	Debug
COM_PING	Ping
COM_TIME	Time
COM_DELAYED_INSERT	Delayed insert
COM_CHANGE_USER	Change user
COM_BINLOG_DUMP	Binlog dump
COM_TABLE_DUMP	Table dump
COM_CONNECT_OUT	Connect out
COM_REGISTER_SLAVE	Register slave
COM_STMT_PREPARE	Prepare server-side statement
COM_STMT_EXECUTE	Execute server-side statement
COM_STMT_SEND_LONG_DATA	Long data
COM_STMT_CLOSE	Close server-side statement
COM_STMT_RESET	Reset statement
COM_SET_OPTION	Set option
COM_STMT_FETCH	Fetch statement
COM_DAEMON	Daemon (MySQL 5.1 only)
COM_ERROR	Error

MySQL Type Constants

These constants are used to identify the field types in the query result data returned to clients from the result of a query. These items are entries within the main proxy table.

Constant	Field Type
MYSQL_TYPE_DECIMAL	Decimal

Constant	Field Type
MYSQL_TYPE_NEWDECIMAL	Decimal (MySQL 5.0 or later)
MYSQL_TYPE_TINY	Tiny
MYSQL_TYPE_SHORT	Short
MYSQL_TYPE_LONG	Long
MYSQL_TYPE_FLOAT	Float
MYSQL_TYPE_DOUBLE	Double
MYSQL_TYPE_NULL	Null
MYSQL_TYPE_TIMESTAMP	Timestamp
MYSQL_TYPE_LONGLONG	Long long
MYSQL_TYPE_INT24	Integer
MYSQL_TYPE_DATE	Date
MYSQL_TYPE_TIME	Time
MYSQL_TYPE_DATETIME	Datetime
MYSQL_TYPE_YEAR	Year
MYSQL_TYPE_NEWDATE	Date (MySQL 5.0 or later)
MYSQL_TYPE_ENUM	Enumeration
MYSQL_TYPE_SET	Set
MYSQL_TYPE_TINY_BLOB	Tiny Blob
MYSQL_TYPE_MEDIUM_BLOB	Medium Blob
MYSQL_TYPE_LONG_BLOB	Long Blob
MYSQL_TYPE_BLOB	Blob
MYSQL_TYPE_VAR_STRING	Varstring
MYSQL_TYPE_STRING	String
MYSQL_TYPE_TINY	Tiny (compatible with MYSQL_TYPE_CHAR)
MYSQL_TYPE_ENUM	Enumeration (compatible with MYSQL_TYPE_INTERVAL)
MYSQL_TYPE_GEOMETRY	Geometry
MYSQL_TYPE_BIT	Bit

6.4.3. Capturing a connection with connect_server()

When the proxy accepts a connection from a MySQL client, the connect_server() function is called.

There are no arguments to the function, but you can use and if necessary manipulate the information in the proxy.connection table, which is unique to each client session.

For example, if you have multiple backend servers then you can set the server to be used by that connection by setting the value of proxy.connection.backend_ndx to a valid server number. The code below will choose between two servers based on whether the current time in minutes is odd or even:

```
function connect_server()
        print("--> a client really wants to talk to a server")
        if (tonumber(os.date("%M")) % 2 == 0) then
                proxy.connection.backend_ndx = 2
                print("Choosing backend 2")
        else
                proxy.connection.backend_ndx = 1
                print("Choosing backend 1")
        end
        print("Using " .. proxy.backends[proxy.connection.backend_ndx].address)
end
```

In this example the IP address/port combination is also displayed by accessing the information from the internal proxy.backends table.

6.4.4. Examining the handshake with read_handshake()

Handshake information is sent by the server to the client after the initial connection (through connect_server()) has been

made. The handshake information contains details about the MySQL version, the ID of the thread that will handle the connection information, and the IP address of the client and server. This information is exposed through a Lua table as the only argument to the function.

- `mysqld_version` — the version of the MySQL server.
- `thread_id` — the thread ID.
- `scramble` — the password scramble buffer.
- `server_addr` — the IP address of the server.
- `client_addr` — the IP address of the client.

For example, you can print out the handshake data and refuse clients by IP address with the following function:

```
function read_handshake( auth )
        print("<-- let's send him some information about us")
        print("    mysqld-version: " .. auth.mysqld_version)
        print("    thread-id     : " .. auth.thread_id)
        print("    scramble-buf  : " .. string.format("%q", auth.scramble))
        print("    server-addr   : " .. auth.server_addr)
        print("    client-addr   : " .. auth.client_addr)
        if not auth.client_addr:match("^127.0.0.1:") then
                proxy.response.type = proxy.MYSQLD_PACKET_ERR
                proxy.response.errmsg = "only local connects are allowed"
                print("we don't like this client");
                return proxy.PROXY_SEND_RESULT
        end
end
```

Note that you have to return an error packet to the client by using `proxy.PROXY_SEND_RESULT`.

6.4.5. Examining the authentication credentials with `read_auth()`

The `read_auth()` function is triggered when an authentication handshake is initiated by the client. In the execution sequence, `read_auth()` occurs immediately after `read_handshake()`, so the server selection has already been made, but the connection and authorization information has not yet been provided to the backend server.

The function accepts a single argument, an Lua table containing the authorization information for the handshake process. The entries in the table are:

- `username` — the user login for connecting to the server.
- `password` — the password, encrypted, to be used when connecting.
- `default_db` — the default database to be used once the connection has been made.

For example, you can print the user name and password supplied during authorization using:

```
function read_auth( auth )
        print("    username      : " .. auth.username)
        print("    password      : " .. string.format("%q", auth.password))
end
```

You can interrupt the authentication process within this function and return an error packet back to the client by constructing a new packet and returning `proxy.PROXY_SEND_RESULT`:

```
proxy.response.type = proxy.MYSQLD_PACKET_ERR
proxy.response.errmsg = "Logins are not allowed"
return proxy.PROXY_SEND_RESULT
```

6.4.6. Accessing authentication information with `read_auth_result()`

The return packet from the server during authentication is captured by `read_auth_result()`. The only argument to this function is the authentication packet returned by the server. As the packet is a raw MySQL network protocol packet, you must access the first byte to identify the packet type and contents. The `MYSQLD_PACKET_ERR` and `MYSQLD_PACKET_OK` constants can be used to identify whether the authentication was successful:

```
function read_auth_result( auth )
        local state = auth.packet:byte()
        if state == proxy.MYSQLD_PACKET_OK then
```

```
                print("<-- auth ok");
        elseif state == proxy.MYSQLD_PACKET_ERR then
                print("<-- auth failed");
        else
                print("<-- auth ... don't know: " .. string.format("%q", auth.packet));
        end
end
```

6.4.7. Manipulating Queries with `read_query()`

The `read_query()` function is called once for each query submitted by the client and accepts a single argument, the query packet that was provided. To access the content of the packet you must parse the packet contents manually.

For example, you can intercept a query packet and print out the contents using the following function definition:

```
function read_query( packet )
        if packet:byte() == proxy.COM_QUERY then
                print("we got a normal query: " .. packet:sub(2))
        end
end
```

This example checks the first byte of the packet to determine the type. If the type is `COM_QUERY` (see Section 6.4.2, “Internal Structures” [80]), then we extract the query from the packet and print it out. The structure of the packet type supplied is important. In the case of a `COM_QUERY` packet, the remaining contents of the packet are the text of the query string. In this example, no changes have been made to the query or the list of queries that will ultimately be sent to the MySQL server.

To modify a query, or add new queries, you must populate the query queue (`proxy.queries`) and then execute the queries that you have placed into the queue. If you do not modify the original query or the queue, then the query received from the client is sent to the MySQL server verbatim.

When adding queries to the queue, you should follow these guidelines:

- The packets inserted into the queue must be valid query packets. For each packet, you must set the initial byte to the packet type. If you are appending a query, you can append the query statement to the rest of the packet.
- Once you add a query to the queue, the queue is used as the source for queries sent to the server. If you add a query to the queue to add more information, you must also add the original query to the queue or it will not be executed.
- Once the queue has been populated, you must set the return value from `read_query()` to indicate whether the query queue should be sent to the server.
- When you add queries to the queue, you should add an ID. The ID you specify is returned with the result set so that you identify each query and corresponding result set. The ID has no other purpose than as an identifier for correlating the query and result-set. When operating in a passive mode, during profiling for example, you want to identify the original query and the corresponding resultset so that the results expect by the client can be returned correctly.
- Unless your client is designed to cope with more result sets than queries, you should ensure that the number of queries from the client match the number of results sets returned to the client. Using the unique ID and removing result sets you inserted will help.

Normally, the `read_query()` and `read_query_result()` function are used in conjunction with each other to inject additional queries and remove the additional result sets. However, `read_query_result()` is only called if you populate the query queue within `read_query()`.

6.4.8. Manipulating Results with `read_query_result()`

The `read_query_result()` is called for each result set returned by the server only if you have manually injected queries into the query queue. If you have not manipulated the query queue then this function is not called. The function supports a single argument, the result packet, which provides a number of properties:

- `id` — the ID of the result set, which corresponds to the ID that was set when the query packet was submitted to the server when using `append(id)` on the query queue.
- `query` — the text of the original query.
- `query_time` — the number of microseconds required to receive the first row of a result set.
- `response_time` — the number of microseconds required to receive the last row of the result set.

- `resultset` — the content of the result set data.

By accessing the result information from the MySQL server you can extract the results that match the queries that you injected, return different result sets (for example, from a modified query), and even create your own result sets.

The Lua script below, for example, will output the query, followed by the query time and response time (i.e. the time to execute the query and the time to return the data for the query) for each query sent to the server:

```
function read_query( packet )
        if packet:byte() == proxy.COM_QUERY then
                print("we got a normal query: " .. packet:sub(2))
                proxy.queries:append(1, packet )
                return proxy.PROXY_SEND_QUERY
        end
end
function read_query_result(inj)
        print("query-time: " .. (inj.query_time / 1000) .. "ms")
        print("response-time: " .. (inj.response_time / 1000) .. "ms")
end
```

You can access the rows of returned results from the resultset by accessing the rows property of the resultset property of the result that is exposed through `read_query_result()`. For example, you can iterate over the results showing the first column from each row using this Lua fragment:

```
for row in inj.resultset.rows do
        print("injected query returned: " .. row[1])
end
```

Just like `read_query()`, `read_query_result()` can return different values for each result according to the result returned. If you have injected additional queries into the query queue, for example, then you will want to remove the results returned from those additional queries and only return the results from the query originally submitted by the client.

The example below injects additional `SELECT NOW()` statements into the query queue, giving them a different ID to the ID of the original query. Within `read_query_result()`, if the ID for the injected queries is identified, we display the result row, and return the `proxy.PROXY_IGNORE_RESULT` from the function so that the result is not returned to the client. If the result is from any other query, we print out the query time information for the query and return the default, which passes on the result set unchanged. We could also have explicitly returned `proxy.PROXY_IGNORE_RESULT` to the MySQL client.

```
function read_query( packet )
        if packet:byte() == proxy.COM_QUERY then
                proxy.queries:append(2, string.char(proxy.COM_QUERY) .. "SELECT NOW()" )
                proxy.queries:append(1, packet )
                proxy.queries:append(2, string.char(proxy.COM_QUERY) .. "SELECT NOW()" )
                return proxy.PROXY_SEND_QUERY
        end
end
function read_query_result(inj)
        if inj.id == 2 then
                for row in inj.resultset.rows do
                        print("injected query returned: " .. row[1])
                end
                return proxy.PROXY_IGNORE_RESULT
        else
                print("query-time: " .. (inj.query_time / 1000) .. "ms")
                print("response-time: " .. (inj.response_time / 1000) .. "ms")
        end
end
```

For further examples, see Section 6.5, “Using MySQL Proxy”.

6.5. Using MySQL Proxy

There are a number of different ways to use MySQL Proxy. At the most basic level, you can allow MySQL Proxy to pass on queries from clients to a single server. To use MySQL proxy in this mode, you just have to specify the backend server that the proxy should connect to on the command line:

```
shell> mysql-proxy --proxy-backend-addresses=sakila:3306
```

If you specify multiple backend MySQL servers then the proxy will connect each client to each server in a round-robin fashion. For example, imagine you have two MySQL servers, A and B. The first client to connect will be connected to server A, the second to server B, the third to server C. For example:

```
shell> mysql-proxy \
     --proxy-backend-addresses=narcissus:3306 \
     --proxy-backend-addresses=nostromo:3306
```

When you have specified multiple servers in this way, the proxy will automatically identify when a MySQL server has become unavailable and mark it accordingly. New connections will automatically be attached to a server that is available, and a warning will be reported to the standard output from `mysql-proxy`:

```
network-mysqld.c.367: connect(nostromo:3306) failed: Connection refused
network-mysqld-proxy.c.2405: connecting to backend (nostromo:3306) failed, marking it as down for ...
```

Lua scripts enable a finer level of control, both over the connections and their distribution and how queries and result sets are processed. When using an Lua script, you must specify the name of the script on the command line using the `--proxy-lua-script` option:

```
shell> mysql-proxy --proxy-lua-script=mc.lua --proxy-backend-addresses=sakila:3306
```

When you specify a script, the script is not executed until a connection is made. This means that faults with the script will not be raised until the script is executed. Script faults will not affect the distribution of queries to backend MySQL servers.

> **Note**
>
> Because the script is not read until the connection is made, you can modify the contents of the Lua script file while the proxy is still running and the script will automatically be used for the next connection. This ensures that MySQL Proxy remains available because it does not have to be restarted for the changes to take effect.

6.5.1. Using the Administration Interface

The `mysql-proxy` administration interface can be accessed using any MySQL client using the standard protocols. You can use the administration interface to gain information about the proxy server as a whole - standard connections to the proxy are isolated to operate as if you were connected directly to the backend MySQL server. Currently, the interface supports a limited set of functionality designed to provide connection and configuration information.

Because connectivity is provided over the standard MySQL protocol, you must access this information using SQL syntax. By default, the administration port is configured as 4041. You can change this port number using the `--admin-address` command-line option.

To get a list of the currently active connections to the proxy:

```
mysql> select * from proxy_connections;
+------+--------+-------+------+
| id   | type   | state | db   |
+------+--------+-------+------+
|    0 | server | 0     |      |
|    1 | proxy  | 0     |      |
|    2 | server | 10    |      |
+------+--------+-------+------+
3 rows in set (0.00 sec)
```

To get the current configuration:

```
mysql> select * from proxy_config;
+---------------------------+----------------------+
| option                    | value                |
+---------------------------+----------------------+
| admin.address             | :4041                |
| proxy.address             | :4040                |
| proxy.lua_script          | mc.lua               |
| proxy.backend_addresses[0] | mysql:3306           |
| proxy.fix_bug_25371       | 0                    |
| proxy.profiling           | 1                    |
+---------------------------+----------------------+
6 rows in set (0.01 sec)
```

6.6. MySQL Proxy FAQ

Questions

- 6.6.1: Is the system context switch expensive, how much overhead does the lua script add?
- 6.6.2: How do I use a socket with MySQL Proxy? Proxy change logs mention that support for UNIX sockets has been added.
- 6.6.3: Can I use MySQL Proxy with all versions of MySQL?
- 6.6.4: If MySQL Proxy has to live on same machine as MySQL, are there any tuning considerations to ensure both perform optimally?

- 6.6.5: Do proxy applications run on a separate server? If not, what is the overhead incurred by Proxy on the DB server side?
- 6.6.6: Can MySQL Proxy handle SSL connections?
- 6.6.7: What is the limit for `max-connections` on the server?
- 6.6.8: As the script is re-read by proxy, does it cache this or is it looking at the file system with each request?
- 6.6.9: With load balancing, what happen to transactions ? Are all queries sent to the same server ?
- 6.6.10: Can I run MySQL Proxy as a daemon?
- 6.6.11: What about caching the authorization info so clients connecting are given back-end connections that were established with identical authorization information, thus saving a few more round trips?
- 6.6.12: Could MySQL Proxy be used to capture passwords?
- 6.6.13: Can MySQL Proxy be used on slaves and intercept binlog messages?
- 6.6.14: MySQL Proxy can handle about 5000 connections, what is the limit on a MySQL server?
- 6.6.15: How does MySQL Proxy compare to DBSlayer ?
- 6.6.16: I currently use SQL Relay for efficient connection pooling with a number of apache processes connecting to a MySQL server. Can MySQL proxy currently accomplish this. My goal is to minimize connection latency while keeping temporary tables available.
- 6.6.17: The global namespace variable example with quotas does not persist after a reboot, is that correct?
- 6.6.18: I tried using MySQL Proxy without any Lua script to try a round-robin type load balancing. In this case, if the first database in the list is down, MySQL Proxy would not connect the client to the second database in the list.
- 6.6.19: Would the Java-only connection pooling solution work for multiple web servers? With this, I'd assume you can pool across many web servers at once?
- 6.6.20: Is the MySQL Proxy an API ?
- 6.6.21: If you have multiple databases on the same box, can you use proxy to connect to databases on default port 3306?
- 6.6.22: Will Proxy be deprecated for use with connection pooling once MySQL 6.x comes out? Or will 6.x integrate proxy more deeply?
- 6.6.23: In load balancing, how can I separate reads from writes?
- 6.6.24: We've looked at using MySQL Proxy but we're concerned about the alpha status - when do you think the proxy would be considered production ready?
- 6.6.25: Will the proxy road map involve moving popular features from lua to C? For example Read/Write splitting
- 6.6.26: Are these reserved function names (e.g., error_result) that get automatically called?
- 6.6.27: Can you explain the status of your work with `memcached` and MySQL Proxy?
- 6.6.28: Is there any big web site using MySQL Proxy ? For what purpose and what transaction rate have they achieved.
- 6.6.29: So the authentication when connection pooling has to be done at every connection? What's the authentication latency?
- 6.6.30: Is it possible to use the MySQL proxy w/ updating a Lucene index (or Solr) by making TCP calls to that server to update?
- 6.6.31: Isn't MySQL Proxy similar to what is provided by Java connection pools?
- 6.6.32: Are there tools for isolating problems? How can someone figure out if a problem is in the client, in the db or in the proxy?
- 6.6.33: Can you dynamically reconfigure the pool of MySQL servers that MySQL Proxy will load balance to?
- 6.6.34: Given that there is a `connect_server` function, can a Lua script link up with multiple servers?
- 6.6.35: Adding a proxy must add latency to the connection, how big is that latency?
- 6.6.36: In the quick poll, I see "Load Balancer: read-write splitting" as an option, so would it be correct to say that there are no

scripts written for Proxy yet to do this?

- 6.6.37: Is it "safe" to use `LuaSocket` with proxy scripts?
- 6.6.38: How different is MySQL Proxy from DBCP (Database connection pooling) for Apache in terms of connection pooling?
- 6.6.39: Do you have make one large script and call at proxy startup, can I change scripts without stopping and restarting (interrupting) the proxy?

Questions and Answers

6.6.1: Is the system context switch expensive, how much overhead does the lua script add?

Lua is fast and the overhead should be small enough for most applications. The raw packet-overhead is around 400 microseconds.

6.6.2: How do I use a socket with MySQL Proxy? Proxy change logs mention that support for UNIX sockets has been added.

Just specify the path to the socket:

```
--proxy-backend-addresses=/path/to/socket
```

However it appears that `--proxy-address=/path/to/socket` does not work on the front end. It would be nice if someone added this feature.

6.6.3: Can I use MySQL Proxy with all versions of MySQL?

MySQL Proxy is designed to work with MySQL 5.0 or higher, and supports the MySQL network protocol for 5.0 and higher.

6.6.4: If MySQL Proxy has to live on same machine as MySQL, are there any tuning considerations to ensure both perform optimally?

MySQL Proxy can live on any box: application, db or its own box. MySQL Proxy uses comparatively little CPU or RAM, so additional requirements or overhead is negligible.

6.6.5: Do proxy applications run on a separate server? If not, what is the overhead incurred by Proxy on the DB server side?

You can run the proxy on the application server, on its own box or on the DB-server depending on the use-case

6.6.6: Can MySQL Proxy handle SSL connections?

No, being the man-in-the-middle, Proxy can't handle encrypted sessions because it cannot share the SSL information.

6.6.7: What is the limit for `max-connections` on the server?

Around 1024 connections the MySQL Server may run out of threads it can spawn. Leaving it at around 100 is advised.

6.6.8: As the script is re-read by proxy, does it cache this or is it looking at the file system with each request?

It looks for the script at client-connect and reads it if it has changed, otherwise it uses the cached version.

6.6.9: With load balancing, what happen to transactions ? Are all queries sent to the same server ?

Without any special customization the whole connection is sent to the same server. That keeps the whole connection state intact.

6.6.10: Can I run MySQL Proxy as a daemon?

Starting from version 0.6.0, the Proxy is launched as a daemon by default. If you want to avoid this, use the `-D` or `--no-daemon` option. To keep track of the process ID, the daemon can be started with the additional option `--pid-file=file`, to save the PID to a known file name. On version 0.5.x, the Proxy can't be started natively as a daemon

6.6.11: What about caching the authorization info so clients connecting are given back-end connections that were established with identical authorization information, thus saving a few more round trips?

There is an option that provides this functionality `--proxy-pool-no-change-user`.

6.6.12: Could MySQL Proxy be used to capture passwords?

The MySQL network protocol does not allow passwords to be sent in clear-text, all you could capture is the encrypted version.

6.6.13: Can MySQL Proxy be used on slaves and intercept binlog messages?

We are working on that. See http://jan.kneschke.de/2008/5/30/mysql-proxy-rbr-to-sbr-decoding for an example.

6.6.14: MySQL Proxy can handle about 5000 connections, what is the limit on a MySQL server?

Se your `max-connections` settings. By default the setting is 150, the proxy can handle a lot more.

6.6.15: How does MySQL Proxy compare to DBSlayer ?

DBSlayer is a REST->MySQL tool, MySQL Proxy is transparent to your application. No change to the application is needed.

6.6.16: I currently use SQL Relay for efficient connection pooling with a number of apache processes connecting to a MySQL server. Can MySQL proxy currently accomplish this. My goal is to minimize connection latency while keeping temporary tables available.

Yes.

6.6.17: The global namespace variable example with quotas does not persist after a reboot, is that correct?

Yes. if you restart the proxy, you lose the results, unless you save them in a file.

6.6.18: I tried using MySQL Proxy without any Lua script to try a round-robin type load balancing. In this case, if the first database in the list is down, MySQL Proxy would not connect the client to the second database in the list.

This issue is fixed in version 0.7.0.

6.6.19: Would the Java-only connection pooling solution work for multiple web servers? With this, I'd assume you can pool across many web servers at once?

Yes. But you can also start one proxy on each application server to get a similar behaviour as you have it already.

6.6.20: Is the MySQL Proxy an API ?

No, MySQL Proxy is an application that forwards packets from a client to a server using the MySQL network protocol. The MySQL proxy provides a API allowing you to change its behaviour.

6.6.21: If you have multiple databases on the same box, can you use proxy to connect to databases on default port 3306?

Yes, MySQL Proxy can listen on any port. Providing none of the MySQL servers are listening on the same port.

6.6.22: Will Proxy be deprecated for use with connection pooling once MySQL 6.x comes out? Or will 6.x integrate proxy more deeply?

The logic about the pooling is controlled by the lua scripts, you can enable and disable it if you like. There are no plans to embed the current MySQL Proxy functionality into the MySQL Server.

6.6.23: In load balancing, how can I separate reads from writes?

There is no automatic separation of queries that perform reads or writes to the different backend servers. However, you can specify to `mysql-proxy` that one or more of the 'backend' MyuSQL servers are read-only.

```
$ mysql-proxy \
--proxy-backend-addresses=10.0.1.2:3306 \
--proxy-read-only-backend-addresses=10.0.1.3:3306 &
```

In the next releases we will add connection pooling and read/write splitting to make this more useful. See also Chapter 7, *MySQL Load Balancer*.

6.6.24: We've looked at using MySQL Proxy but we're concerned about the alpha status - when do you think the proxy would be considered production ready?

We are on the road to the next feature release: 0.7.0. It will improve the performance quite a bit. After that we may be able to enter the beta phase.

6.6.25: Will the proxy road map involve moving popular features from lua to C? For example Read/Write splitting

We will keep the high-level parts in the Lua layer to be able to adjust to special situations without a rebuild. Read/Write splitting sometimes needs external knowledge that may only be available by the DBA.

6.6.26: Are these reserved function names (e.g., error_result) that get automatically called?

Only functions and values starting with `proxy.*` are provided by the proxy. All others are provided by you.

6.6.27: Can you explain the status of your work with `memcached` and MySQL Proxy?

There are some ideas to integrate proxy and `memcache` a bit, but no code yet.

6.6.28: Is there any big web site using MySQL Proxy ? For what purpose and what transaction rate have they achieved.

Yes, gaiaonline. They have tested MySQL Proxy and seen it handle 2400 queries per second through the proxy.

6.6.29: So the authentication when connection pooling has to be done at every connection? What's the authentication latency?

You can skip the round-trip and use the connection as it was added to the pool. As long as the application cleans up the temporary tables it used. The overhead is (as always) around 400 microseconds.

6.6.30: Is it possible to use the MySQL proxy w/ updating a Lucene index (or Solr) by making TCP calls to that server to update?

Yes, but it isn't advised for now.

6.6.31: Isn't MySQL Proxy similar to what is provided by Java connection pools?

Yes and no. Java connection pools are specific to Java applications, MySQL Proxy works with any client API that talks the MySQL network protocol. Also, connection pools do not provide any functionality for intelligently examining the network packets and modifying the contents.

6.6.32: Are there tools for isolating problems? How can someone figure out if a problem is in the client, in the db or in the proxy?

You can set a debug script in the proxy, which is an exceptionally good tool for this purpose. You can see very clearly which component is causing the problem, if you set the right breakpoints.

6.6.33: Can you dynamically reconfigure the pool of MySQL servers that MySQL Proxy will load balance to?

Not yet, it is on the list. We are working on a administration interface for that purpose.

6.6.34: Given that there is a `connect_server` function, can a Lua script link up with multiple servers?

The proxy provides some tutorials in the source-package, one is `examples/tutorial-keepalive.lua`.

6.6.35: Adding a proxy must add latency to the connection, how big is that latency?

In the range of 400microseconds

6.6.36: In the quick poll, I see "Load Balancer: read-write splitting" as an option, so would it be correct to say that there are no scripts written for Proxy yet to do this?

There is a proof of concept script for that included. But its far from perfect and may not work for you yet.

6.6.37: Is it "safe" to use `LuaSocket` with proxy scripts?

You can, but it is not advised as it may block.

6.6.38: How different is MySQL Proxy from DBCP (Database connection pooling) for Apache in terms of connection pooling?

Connection Pooling is just one use-case of the MySQL Proxy. You can use it for a lot more and it works in cases where you can't use DBCP (like if you don't have Java).

6.6.39: Do you have make one large script and call at proxy startup, can I change scripts without stopping and restarting (interrupting) the proxy?

You can just change the script and the proxy will reload it when a client connects.

Chapter 7. MySQL Load Balancer

> **Important**
>
> For more information on MySQL Load Balancer, including how to be included in the beta programme, contact <enterprise-beta@mysql.com>.

The MySQL Load Balancer is an application that communicates with one or more MySQL servers and provides connectivity to those servers for multiple clients. The MySQL Load Balancer is logically placed between the clients and the MySQL server; instead of clients connecting directly to each MySQL server, all clients connect to the MySQL Load Balancer, and the MySQL Load Balancer forwards the connection on to one of the MySQL servers.

The initial release of the MySQL Load Balancer provides read-only load balancing over a number of MySQL servers. Initially, you populate the MySQL Load Balancer configuration with the list of available MySQL servers to use when distributing work. The MySQL Load Balancer automatically and evenly distributes connections from clients to each server. Distribution is handled by a simple count for the number connections distributed to each server - new connections are automatically sent to the server with the lowest count.

The MySQL Load Balancer also monitors the master and slaves within the replication setup and additional decisions about the routing of incoming connections to MySQL servers are made based on the replication status:

- If MySQL Load Balancer identifies that the slave is lagging behind the master for its replication threads, then the slave is automatically taken out of the list of available servers. Work will therefore be distributed to other MySQL servers within the slave replication group.
- If the replication thread on a slave is identified as no longer running, the slave is also automatically removed from the list of available servers.
- If either situation changes, such as the replication delay decreases to an acceptable level, or the replication thread on the failed slave is restarted and the replication process catches up, then the slave will be brought back in to the list of available MySQL servers.

The MySQL Load Balancer is based on the MySQL Proxy, and consists of two modules which work together to achieve its goal:

- The *proxy*, which uses Lua scripts to customize the handling of connections and query execution. The `proxy` connects to several backend MySQL instances to which it can send queries.
- The *monitor* plugin connects to each of the backends the proxy knows about and executes queries on each one in regular intervals. The results of those queries are used to determine the state of each backend.

For more information on MySQL Proxy, see Chapter 6, *MySQL Proxy*.

7.1. Installing MySQL Load Balancer

> **Important**
>
> For more information on MySQL Load Balancer, including how to be included in the beta programme, contact <enterprise-beta@mysql.com>.

MySQL Load Balancer is provided as a TAR/GZipped package. To install, extract the package:

```
shell> gzip -cd load-balancer mysql-load-balancer-0.7.0-438-linux-fc4-x86-32bit.tar.gz | tar xf -
```

The standard package contents are organized into four directories:

```
/bin
/lib
/sbin
/share
```

The `bin` contains wrapper scripts around the dynamically linked binaries in `sbin`. The `lib` directory contains the required libraries, and the `share` directory contains the scripts and support files used by the MySQL Load Balancer during execution.

You can run MySQL Load Balancer directly from this directory, or you can copy the contents to a global directory, such as `/usr/local`:

```
shell> cp -R * /usr/local/
```

7.2. Getting Started

> **Important**
>
> For more information on MySQL Load Balancer, including how to be included in the beta programme, contact <enterprise-beta@mysql.com>.

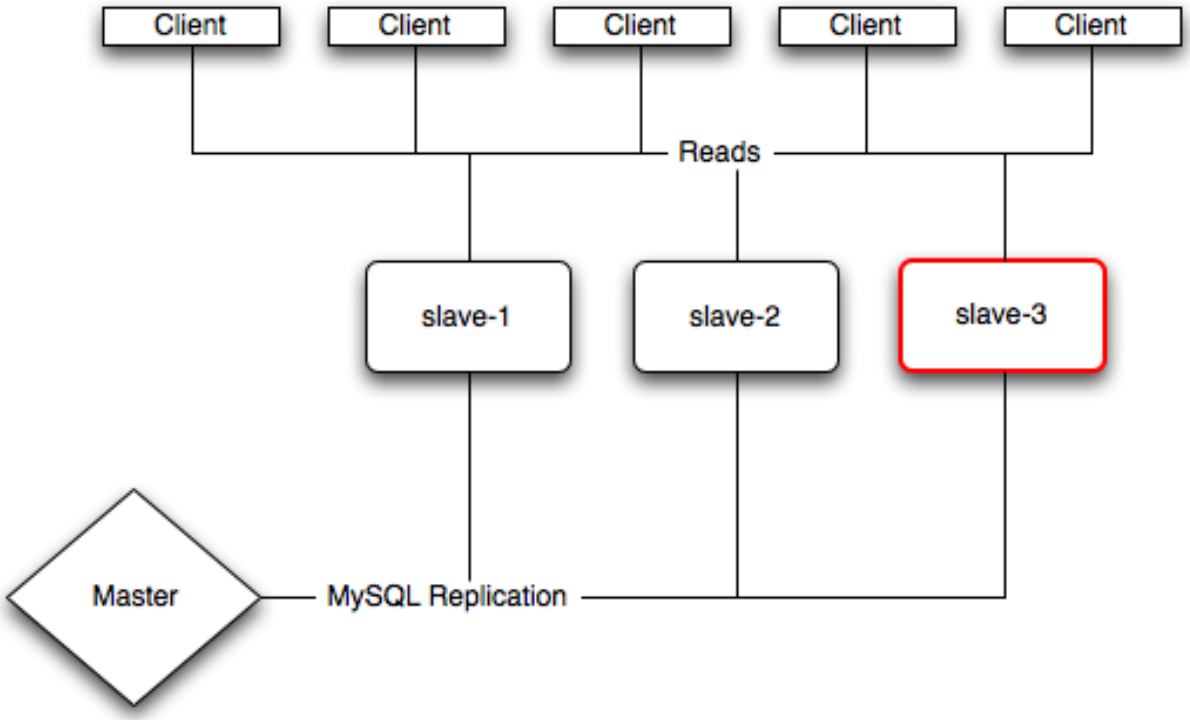
The easiest way to understand MySQL Load Balancer is to look at a typical example of how MySQL Load Balancer can be used to improve the distribution of work to multiple MySQL servers.

Given an existing setup of several replicating MySQL servers, you can set up the MySQL Load Balancer to provide you with replication-aware load distribution.

Suppose you have three slaves replicating from one master, the slaves running on the machines *slave-1*, *slave-2*, and *slave-3*, the master being on *master-1*. Each MySQL server listens on the default port of 3306.

For client connectivity, typical configurations are in one of two topologies. The first topology uses applications that are aware of multiple clients and choose a MySQL server based either on a random selection or by choosing a slave based on a known quantity, such as user ID.

Figure 7.1. Replication architecture with clients using multiple MySQL slaves

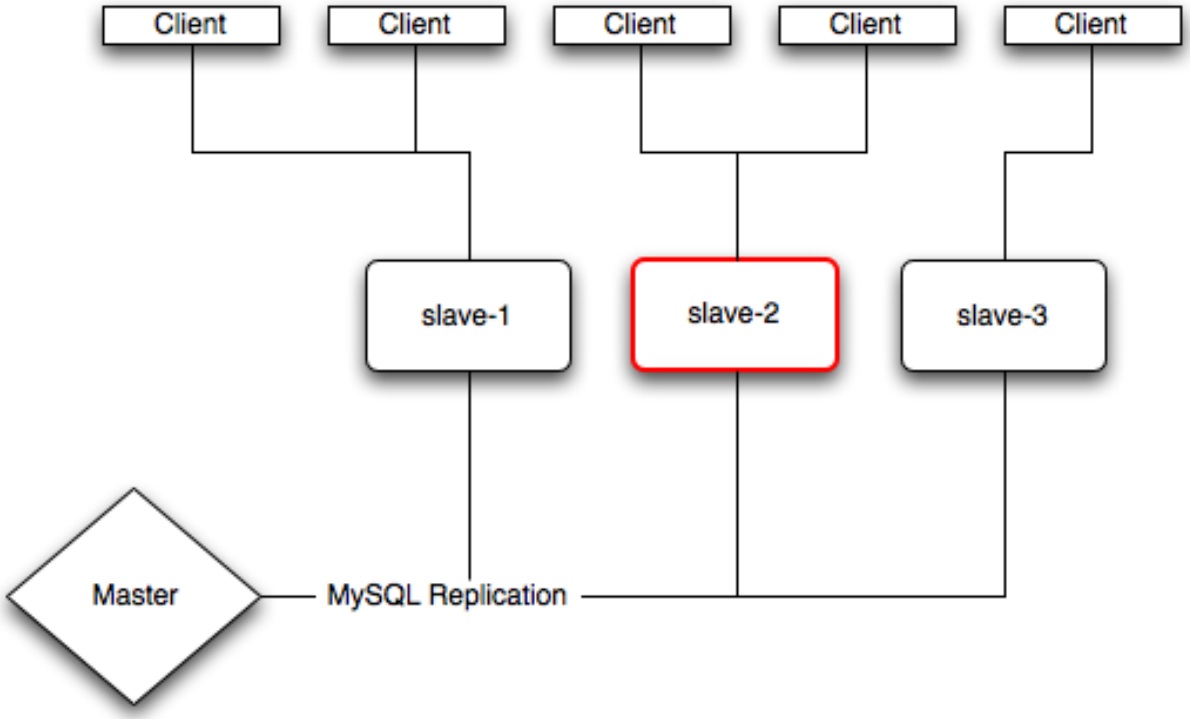


In this scenario, it is possible for a client application to choose a slave that is unavailable, or in a replication situation, a slave that is not up to date compared to the master, or lagging behind the master in terms of processing replication data such that queries accessing the information would fail to return data, or return data that was out of date. In all these cases, the client would be unable to determine the issue (without checking the situation itself). In the event of a failed server, the connection would timeout and another server could be chosen, but the delay could cause problems in the application.

In this scenario, it is also possible for a single MySQL server to become overloaded with requests. For example, if the application was using an ID-based decision model to choose a MySQL server, then a high number of requests for a given ID could produce a very high load on the chosen server. This could affect the replication thread and place the server further behind compared to the master.

The second topology uses a model where each client has a dedicated MySQL server.

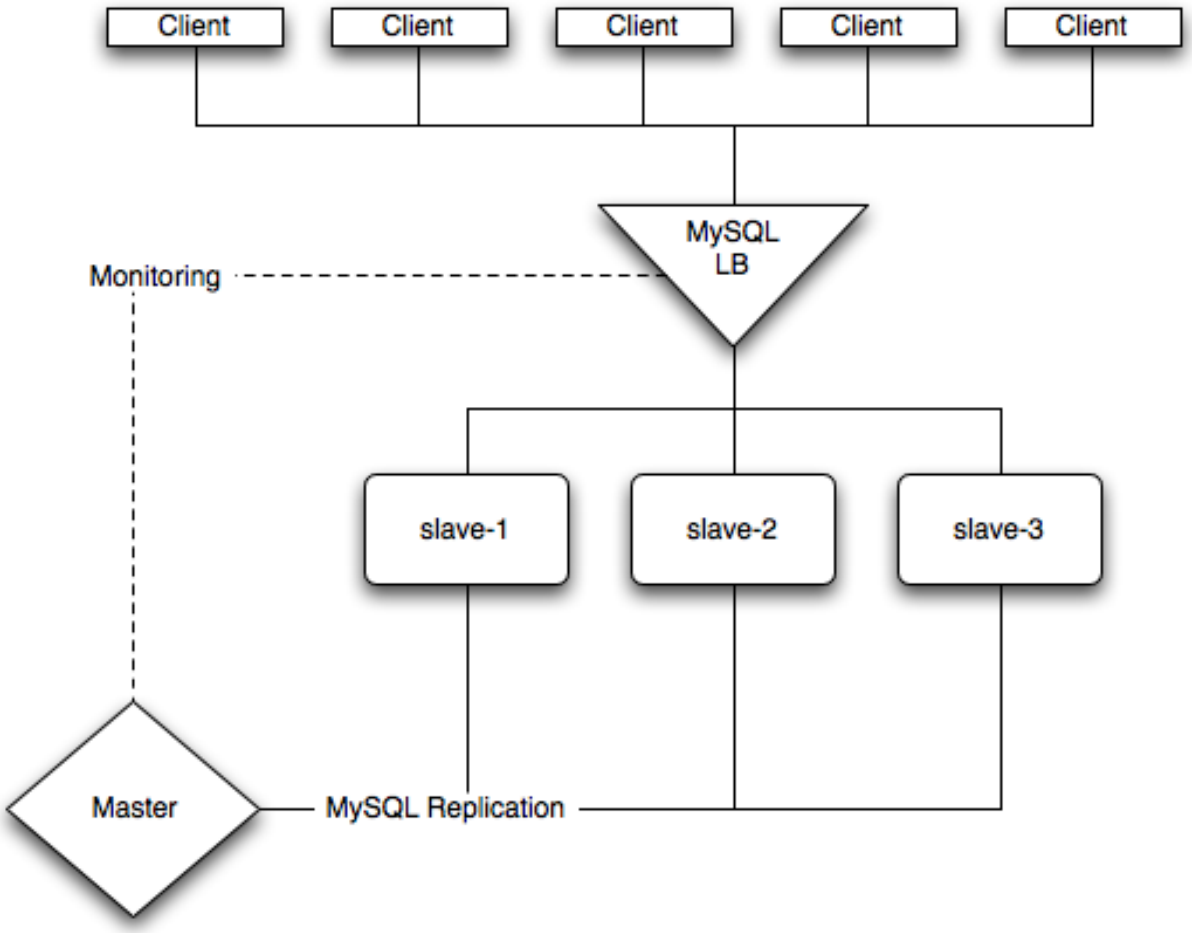
Figure 7.2. Replication architecture with clients using dedicated MySQL slaves



In this scenario, a problem with the MySQL server for an individual client could render the client useless. If the MySQL server is significantly behind the master, you would get out of date or incorrect information. If the MySQL server has failed, the client will be unable to access any information.

Using the MySQL Load Balancer, you can replace the individual connections from the clients to the slaves and instead route the connections through the MySQL Load Balancer. This will distribute the requests over the individual slave servers, automatically taking account of the load, and accounting for problems or delays in the replication of the data from the master.

Figure 7.3. Replication architecture with clients using MySQL Load Balancer



In the scenario using MySQL Load Balancer, any failure of a single MySQL server automatically removes it from the pool of available servers and distributes the incoming client connection to one of the other, available, servers. Problems with replication are addressed in the same way, redirecting the connection to a server that is up to date with the master. The possibility of overloading a single MySQL server should also be reduced, since the connections would be distributed evenly among each server.

To start the MySQL Load Balancer in this scenario you would specify the configuration of the master and slave servers on the command line when starting `mysql-lb`:

```
shell> bin/mysql-lb --proxy-backend-addresses=master-1 \
  --proxy-read-only-backend-addresses=slave-1:3306 \
  --proxy-read-only-backend-addresses=slave-2:3306 \
  --proxy-read-only-backend-addresses=slave-3:3306 \
  --proxy-lua-script=share/mysql-load-balancer/monitored-ro-balance.lua \
  --monitor-lua-script=share/mysql-load-balancer/monitor-backends.lua
```

This will start the load balancer, which listens for incoming client connections on port 4040. The monitor component will connect to each backend MySQL server with the MySQL user `monitor` and no password, to be able to execute queries on them. If you do not have a MySQL user with that name or have a password set for the user, you can specify those using the options `--monitor-username` and `--monitor-password`.

The options in this example set the following options:

- `--proxy-backend-addresses` – sets the address and port number of the MySQL master server in the replication structure. This is required so that MySQL Load Balancer can monitor the status of the server and replication and use this to compare against the status of the slave servers. In the event of a problem, the information gained will be used to prioritize connections to the slaves according to which slave is the most up to date.
- `--proxy-read-only-backend-addresses` – each one of these options sets the address and port number (separated by a colon), of a backend MySQL server. You can specify as many servers as you like on the command line simply by adding further options.

- `--proxy-lua-script` – specifies the Lua script that will be used to manage to the distribution of requests.
- `--monitor-lua-script` – specifies the Lua script that will be used to monitor the backends.

To get a list of all the available options, run

```
shell> mysql-lb --help-all
```

7.3. Using MySQL Load Balancer

> **Important**
>
> For more information on MySQL Load Balancer, including how to be included in the beta programme, contact `<enterprise-beta@mysql.com>`.

When using the MySQL Load Balancer, you must adapt your application to work with the connections provided by the MySQL Load Balancer interface, rather than directly to MySQL servers. The MySQL Load Balancer supports the same MySQL network protocol - you do not need to change the method that you use to communicate with MySQL. You can continue to use the standard MySQL interface appropriate for your application environment.

On each client, you should configure your application to connect to port 4040 on the machine on which you started the MySQL Load Balancer. All MySQL connections for *read* queries should be sent to the MySQL Load Balancer connection. When a client connects, the connection is routed by MySQL Load Balancer to an appropriate MySQL server. All subsequent queries on that connection will run be executed on the same backed MySQL server. The backend will not be changed after the connection has been established.

If MySQL Load Balancer identifies an issue with the backend MySQL server, then connections to the backend server are closed. Your application should be adapted so that it can re-open a connection if it closes during execution, re-executing the query again if there is failure. MySQL Load Balancer will then choose a different MySQL server for the new connection.

The thresholds with which the monitor considers a slave to be too far behind are specified in the `monitor-backends.lua` file. By default it checks for information obtained by `SHOW SLAVE STATUS`, namely `Seconds_Behind_Master` and tries to calculate the amount of data (in bytes) the slave has to read from the master. The default values for those metrics are 10 seconds and 10 kilobytes, respectively.

> **Note**
>
> You need to restart the MySQL Load Balancer if you change the `monitor-backends.lua` script while it is running. This is different from MySQL Proxy, which automatically reloads a script if you modify the script during execution.

The load balancing algorithm is specified in the `monitored-ro-balance.lua` script. For this release, it keeps a counter of how many queries each backend has executed and always picks the backend with the least number of queries. Look at `connect_server()` and `pick_ro_backend_least_queries()` for the code.

7.4. Known Issues

> **Important**
>
> For more information on MySQL Load Balancer, including how to be included in the beta programme, contact `<enterprise-beta@mysql.com>`.

For this alpha release, there are the following known issues:

- Sometimes an assertion in `libevent` fails when shutting down `mysql-lb`. The assertion failure occurs after all client and server connections have been closed already, thus is does not affect the normal operation of the program.
- When using UNIX domain sockets to specify backends, it logs errors like: `network-mysqld.c.1648: can't convert addr-type 1 into a string` This is recorded as a Bug#35216 and will be fixed in the next release. The implication is that the backend address is not available in the Lua scripts, it does not impair normal operations of the program.

7.5. MySQL Load Balancer FAQ

> **Important**

For more information on MySQL Load Balancer, including how to be included in the beta programme, contact <enterprise-beta@mysql.com>.

The following section includes some common questions and answers for MySQL Load Balancer:

Questions

- 7.5.1: The current description says that the load balancer is for read-only operation. Does that mean that MySQL Load Balancer will not accept update statements for the slaves?
- 7.5.2: The MSQL Load Balancer is listed as being 'slave state aware'. Do you check the status of both threads in the replication process.
- 7.5.3: Is it possible to set the amount of acceptable lag?
- 7.5.4: Does MySQL Load Balancer handle load balancing based on CPU load, memory load or I/O load?

Questions and Answers

7.5.1: The current description says that the load balancer is for read-only operation. Does that mean that MySQL Load Balancer will not accept update statements for the slaves?

No. Currently, the MySQL Load Balancer doesn't prevent you from making modifications on the slaves. The read-only description is being used to indicate that you should only use this solution for sending queries to existing slave hosts.

7.5.2: The MSQL Load Balancer is listed as being 'slave state aware'. Do you check the status of both threads in the replication process.

Yes. the monitor module runs `SHOW SLAVE STATUS` and checks the status of the replication process. If there is a problem, either because the slave has lagged too far behind the master, or because the query thread has stopped, then the slave will be taken out of the list of available slaves for distributing queries.

7.5.3: Is it possible to set the amount of acceptable lag?

Yes, you can set the lag time by editing the time within the load balancer Lua script. Edit the file `share/mysql-load-balancer/ro-balance.lua` and change the line:

```
max_seconds_lag = 10,      -- 10 seconds
```

Altering the 10 seconds to the lag time that you want to support.

7.5.4: Does MySQL Load Balancer handle load balancing based on CPU load, memory load or I/O load?

Currently we use indirect measurements and balance the distribution of queries by looking at the replication status of the slave nodes. Since the distribution of work is written using Lua, it is possible to use a number of different criteria. Using more complex criteria will be possible in the future.