



Red Hat Enterprise Linux 7

Global File System 2

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Abstract

This book provides information about configuring and maintaining Red Hat GFS2 (Red Hat Global File System 2) for Red Hat Enterprise Linux 7.

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CHAPTER 1. GFS2 OVERVIEW

The Red Hat GFS2 file system is included in the Resilient Storage Add-On. It is a native file system that interfaces directly with the Linux kernel file system interface (VFS layer). When implemented as a cluster file system, GFS2 employs distributed metadata and multiple journals. Red Hat supports the use of GFS2 file systems only as implemented in the High Availability Add-On.



NOTE

Although a GFS2 file system can be implemented in a standalone system or as part of a cluster configuration, for the Red Hat Enterprise Linux 7 release Red Hat does not support the use of GFS2 as a single-node file system. Red Hat does support a number of high-performance single node file systems which are optimized for single node and thus have generally lower overhead than a cluster file system. Red Hat recommends using these file systems in preference to GFS2 in cases where only a single node needs to mount the file system.

Red Hat will continue to support single-node GFS2 file systems for mounting snapshots of cluster file systems (for example, for backup purposes).



NOTE

Red Hat does not support using GFS2 for cluster file system deployments greater than 16 nodes.

GFS2 is based on a 64-bit architecture, which can theoretically accommodate an 8 EB file system. However, the current supported maximum size of a GFS2 file system for 64-bit hardware is 100TB. The current supported maximum size of a GFS2 file system for 32-bit hardware is 16TB. If your system requires larger GFS2 file systems, contact your Red Hat service representative.

When determining the size of your file system, you should consider your recovery needs. Running the `fsck.gfs2` command on a very large file system can take a long time and consume a large amount of memory. Additionally, in the event of a disk or disk subsystem failure, recovery time is limited by the speed of your backup media. For information on the amount of memory the `fsck.gfs2` command requires, see [Section 3.11, “Repairing a File System”](#).

When configured in a cluster, Red Hat GFS2 nodes can be configured and managed with High Availability Add-On configuration and management tools. Red Hat GFS2 then provides data sharing among GFS2 nodes in a cluster, with a single, consistent view of the file system name space across the GFS2 nodes. This allows processes on different nodes to share GFS2 files in the same way that processes on the same node can share files on a local file system, with no discernible difference. For information about the High Availability Add-On see *Configuring and Managing a Red Hat Cluster*.

While a GFS2 file system may be used outside of LVM, Red Hat supports only GFS2 file systems that are created on a CLVM logical volume. CLVM is included in the Resilient Storage Add-On. It is a cluster-wide implementation of LVM, enabled by the CLVM daemon `clvmd`, which manages LVM logical volumes in a cluster. The daemon makes it possible to use LVM2 to manage logical volumes across a cluster, allowing all nodes in the cluster to share the logical volumes. For information on the LVM volume manager, see *Logical Volume Manager Administration*.

The `gfs2.ko` kernel module implements the GFS2 file system and is loaded on GFS2 cluster nodes.

**NOTE**

When you configure a GFS2 file system as a cluster file system, you must ensure that all nodes in the cluster have access to the shared storage. Asymmetric cluster configurations in which some nodes have access to the shared storage and others do not are not supported. This does not require that all nodes actually mount the GFS2 file system itself.

This chapter provides some basic, abbreviated information as background to help you understand GFS2. It contains the following sections:

- [Section 1.1, “New and Changed Features”](#)
- [Section 1.2, “Before Setting Up GFS2”](#)
- [Section 1.3, “Installing GFS2”](#)
- [Section 2.9, “GFS2 Node Locking”](#)

1.1. NEW AND CHANGED FEATURES

This section lists new and changed features of the GFS2 file system and the GFS2 documentation that are included with the initial and subsequent releases of Red Hat Enterprise Linux 7.

1.1.1. New and Changed Features for Red Hat Enterprise Linux 7.0

Red Hat Enterprise Linux 7.0 includes the following documentation and feature updates and changes.

- For Red Hat Enterprise Linux 7, a cluster that includes a GFS2 file system requires that you configure your cluster with Pacemaker according to the procedure described in [Chapter 5, *Configuring a GFS2 File System in a Cluster*](#).
- The `gfs2_tool` command is not supported in Red Hat Enterprise Linux 7. Replacement functions for the `gfs2_tool` are summarized in [Section 1.4, “Replacement Functions for `gfs2_tool` in Red Hat Enterprise Linux 7”](#).

1.1.2. New and Changed Features for Red Hat Enterprise Linux 7.1

For Red Hat Enterprise Linux 7.1, [Appendix A, *GFS2 Performance Analysis with Performance Co-Pilot*](#) has been updated.

In addition, small technical corrections and clarifications have been made throughout the document.

1.1.3. New and Changed Features for Red Hat Enterprise Linux 7.2

Small technical corrections and clarifications have been made throughout the document.

1.1.4. New and Changed Features for Red Hat Enterprise Linux 7.4

As of Red Hat Enterprise Linux 7.4, Security Enhanced Linux (SELinux) is supported for use with GFS2 file systems. For information on SELinux and GFS2, see [Section 2.5.3, “SELinux on GFS2”](#).

1.2. BEFORE SETTING UP GFS2

Before you install and set up GFS2, note the following key characteristics of your GFS2 file systems:

GFS2 nodes

Determine which nodes in the cluster will mount the GFS2 file systems.

Number of file systems

Determine how many GFS2 file systems to create initially. (More file systems can be added later.)

File system name

Determine a unique name for each file system. The name must be unique for all `lock_dlm` file systems over the cluster. Each file system name is required in the form of a parameter variable. For example, this book uses file system names `mydataa1` and `mydataa2` in some example procedures.

Journals

Determine the number of journals for your GFS2 file systems. One journal is required for each node that mounts a GFS2 file system. GFS2 allows you to add journals dynamically at a later point as additional servers mount a file system. For information on adding journals to a GFS2 file system, see [Section 3.7, “Adding Journals to a File System”](#).

Storage devices and partitions

Determine the storage devices and partitions to be used for creating logical volumes (using CLVM) in the file systems.

Time protocol

Make sure that the clocks on the GFS2 nodes are synchronized. It is recommended that you use the Precision Time Protocol (PTP) or, if necessary for your configuration, the Network Time Protocol (NTP) software provided with your Red Hat Enterprise Linux distribution.



NOTE

The system clocks in GFS2 nodes must be within a few minutes of each other to prevent unnecessary inode time stamp updating. Unnecessary inode time stamp updating severely impacts cluster performance.



NOTE

You may see performance problems with GFS2 when many create and delete operations are issued from more than one node in the same directory at the same time. If this causes performance problems in your system, you should localize file creation and deletions by a node to directories specific to that node as much as possible.

For further recommendations on creating, using, and maintaining a GFS2 file system. see [Chapter 2, GFS2 Configuration and Operational Considerations](#)

1.3. INSTALLING GFS2

In addition to the packages required for the Red Hat High Availability Add-On, you must install the `gfs2-utils` package for GFS2 and the `lvm2-cluster` package for the Clustered Logical Volume Manager (CLVM). The `lvm2-cluster` and `gfs2-utils` packages are part of **ResilientStorage**

channel, which must be enabled before installing the packages.

You can use the following `yum install` command to install the Red Hat High Availability Add-On software packages:

```
# yum install lvm2-cluster gfs2-utils
```

For general information on the Red Hat High Availability Add-On and cluster administration, see the *Cluster Administration* manual.

1.4. REPLACEMENT FUNCTIONS FOR GFS2_TOOL IN RED HAT ENTERPRISE LINUX 7

The `gfs2_tool` command is not supported in Red Hat Enterprise Linux 7. [Table 1.1, “gfs2_tool Equivalent Functions in Red Hat Enterprise Linux 7”](#) summarizes the equivalent functionality for the `gfs2_tool` command options in Red Hat Enterprise Linux 7.

Table 1.1. `gfs2_tool` Equivalent Functions in Red Hat Enterprise Linux 7

<code>gfs2_tool</code> option	Replacement Functionality
<code>clearflag Flag File1 File2 ...</code> Clear an attribute flag on a file	Linux standard <code>chattr</code> command
<code>freeze mountpoint</code> Freeze (quiesce) a GFS2 file system	Linux standard <code>fsfreeze -f mountpoint</code> command
<code>gettune mountpoint</code> Print out current values of tuning parameters	For many cases, has been replaced by <code>mount (get mount options)</code> . Other tuning parameters may be fetched from the respective <code>sysfs</code> files: <code>/sys/fs/gfs2/dm-3/tune/*</code> .
<code>journals mountpoint</code> Print out information on the journals in a GFS2 file system	Information about journals can be fetched with <code>gfs2_edit -p journals device</code> . You can run this command when the file system is mounted. <pre># gfs2_edit -p journals /dev/clus_vg/lv1 Block #Journal Status: of 2620416 (0x27fc00) ----- Journal List ----- journal0: 0x14 128MB clean. journal1: 0x805b 128MB clean. -----</pre>

gfs2_tool option	Replacement Functionality
<p>lockdump <i>mountpoint</i></p> <p>Print out information about the locks this machine holds for a given file system</p>	<p>The GFS2 lock information may be obtained by mounting debugfs, then executing a command like such as the following:</p> <pre># cat /sys/kernel/debug/gfs2/<i>clusternam</i> <i>e</i>:<i>file_system_name</i>/glocks</pre>
<p>sb device proto [<i>newvalue</i>]</p> <p>View (and possibly replace) the locking protocol</p>	<p>To fetch the current value of the locking protocol, you can use the following command:</p> <pre># tuneGFS2 -l device grep protocol</pre> <p>To replace the current value of the locking protocol, you can use the following command:</p> <pre># tuneGFS2 -o lockproto=lock_dlm device</pre>
<p>sb device table [<i>newvalue</i>]</p> <p>View (and possibly replace) the name of the locking table</p>	<p>To fetch the current value of the name of the locking table, you can use the following command:</p> <pre># tuneGFS2 -l device grep table</pre> <p>To replace the current value of the name of the locking table, you can use the following command:</p> <pre># tuneGFS2 -o locktable=<i>file_system_name</i> device</pre>
<p>sb device ondisk [<i>newvalue</i>]</p> <p>View (and possibly replace) the ondisk format number</p>	<p>Do not perform this task.</p>
<p>sb device multihost [<i>newvalue</i>]</p> <p>View (and possibly replace) the multihost format number</p>	<p>Do not perform this task.</p>

gfs2_tool option	Replacement Functionality
<p>sb device uuid [newvalue]</p> <p>View (and possibly replace) the uuid value</p>	<p>To fetch the current value of the uuid, you can use the following command:</p> <pre># tuneGFS2 -l device grep UUID</pre> <p>To replace the current value of the uuid, you can use the following command:</p> <pre># tuneGFS2 -U uuid device</pre>
<p>sb device all</p> <p>Print out the GFS2 superblock</p>	<pre># tuneGFS2 -l device</pre>
<p>setflag Flag File1 File2 ...</p> <p>Sets an attribute flag on a file</p>	<p>Linux standard chattr command</p>
<p>setTune mountpoint parameter newvalue</p> <p>Set the value of a tuning parameter</p>	<p>For many cases, has been replaced by mount (-o remount with options). Other tuning parameters may be set by the respective sysfs files: /sys/fs/gfs2/cluster_name:file_system_name/tune/*</p>
<p>unfreeze mountpoint</p> <p>Unfreeze a GFS2 file system</p>	<p>Linux standard fsfreeze -unfreeze mountpoint command</p>
<p>version</p> <p>Displays version of the gfs2_tool command</p>	<p>N/A</p>
<p>withdraw mountpoint</p> <p>Cause GFS2 to abnormally shutdown a given file system</p>	<pre># echo 1 > /sys/fs/gfs2/cluster_name:file_system_name/tune/withdraw</pre>

CHAPTER 2. GFS2 CONFIGURATION AND OPERATIONAL CONSIDERATIONS

The Global File System 2 (GFS2) file system allows several computers (“nodes”) in a cluster to cooperatively share the same storage. To achieve this cooperation and maintain data consistency among the nodes, the nodes employ a cluster-wide locking scheme for file system resources. This locking scheme uses communication protocols such as TCP/IP to exchange locking information.

You can improve performance by following the recommendations described in this chapter, including recommendations for creating, using, and maintaining a GFS2 file system.



IMPORTANT

Make sure that your deployment of the Red Hat High Availability Add-On meets your needs and can be supported. Consult with an authorized Red Hat representative to verify your configuration prior to deployment.

2.1. FORMATTING CONSIDERATIONS

This section provides recommendations for how to format your GFS2 file system to optimize performance.

2.1.1. File System Size: Smaller Is Better

GFS2 is based on a 64-bit architecture, which can theoretically accommodate an 8 EB file system. However, the current supported maximum size of a GFS2 file system for 64-bit hardware is 100TB and the current supported maximum size of a GFS2 file system for 32-bit hardware is 16TB.

Note that even though GFS2 large file systems are possible, that does not mean they are recommended. The rule of thumb with GFS2 is that smaller is better: it is better to have 10 1TB file systems than one 10TB file system.

There are several reasons why you should keep your GFS2 file systems small:

- Less time is required to back up each file system.
- Less time is required if you need to check the file system with the `fsck.gfs2` command.
- Less memory is required if you need to check the file system with the `fsck.gfs2` command.

In addition, fewer resource groups to maintain mean better performance.

Of course, if you make your GFS2 file system too small, you might run out of space, and that has its own consequences. You should consider your own use cases before deciding on a size.

2.1.2. Block Size: Default (4K) Blocks Are Preferred

The `mkfs.gfs2` command attempts to estimate an optimal block size based on device topology. In general, 4K blocks are the preferred block size because 4K is the default page size (memory) for Linux. Unlike some other file systems, GFS2 does most of its operations using 4K kernel buffers. If your block size is 4K, the kernel has to do less work to manipulate the buffers.

It is recommended that you use the default block size, which should yield the highest performance. You may need to use a different block size only if you require efficient storage of many very small files.

2.1.3. Number of Journals: One For Each Node That Mounts

GFS2 requires one journal for each node in the cluster that needs to mount the file system. For example, if you have a 16-node cluster but need to mount only the file system from two nodes, you need only two journals. If you need to mount from a third node, you can always add a journal with the `gfs2_jadd` command. With GFS2, you can add journals on the fly.

2.1.4. Journal Size: Default (128MB) Is Usually Optimal

When you run the `mkfs.gfs2` command to create a GFS2 file system, you may specify the size of the journals. If you do not specify a size, it will default to 128MB, which should be optimal for most applications.

Some system administrators might think that 128MB is excessive and be tempted to reduce the size of the journal to the minimum of 8MB or a more conservative 32MB. While that might work, it can severely impact performance. Like many journaling file systems, every time GFS2 writes metadata, the metadata is committed to the journal before it is put into place. This ensures that if the system crashes or loses power, you will recover all of the metadata when the journal is automatically replayed at mount time. However, it does not take much file system activity to fill an 8MB journal, and when the journal is full, performance slows because GFS2 has to wait for writes to the storage.

It is generally recommended to use the default journal size of 128MB. If your file system is very small (for example, 5GB), having a 128MB journal might be impractical. If you have a larger file system and can afford the space, using 256MB journals might improve performance.

2.1.5. Size and Number of Resource Groups

When a GFS2 file system is created with the `mkfs.gfs2` command, it divides the storage into uniform slices known as resource groups. It attempts to estimate an optimal resource group size (ranging from 32MB to 2GB). You can override the default with the `-r` option of the `mkfs.gfs2` command.

Your optimal resource group size depends on how you will use the file system. Consider how full it will be and whether or not it will be severely fragmented.

You should experiment with different resource group sizes to see which results in optimal performance. It is a best practice to experiment with a test cluster before deploying GFS2 into full production.

If your file system has too many resource groups (each of which is too small), block allocations can waste too much time searching tens of thousands (or hundreds of thousands) of resource groups for a free block. The more full your file system, the more resource groups that will be searched, and every one of them requires a cluster-wide lock. This leads to slow performance.

If, however, your file system has too few resource groups (each of which is too big), block allocations might contend more often for the same resource group lock, which also impacts performance. For example, if you have a 10GB file system that is carved up into five resource groups of 2GB, the nodes in your cluster will fight over those five resource groups more often than if the same file system were carved into 320 resource groups of 32MB. The problem is exacerbated if your file system is nearly full because every block allocation might have to look through several resource groups before it finds one with a free block. GFS2 tries to mitigate this problem in two ways:

- First, when a resource group is completely full, it remembers that and tries to avoid checking it for future allocations (until a block is freed from it). If you never delete files, contention will be less severe. However, if your application is constantly deleting blocks and allocating new blocks on a file system that is mostly full, contention will be very high and this will severely impact performance.

- Second, when new blocks are added to an existing file (for example, appending) GFS2 will attempt to group the new blocks together in the same resource group as the file. This is done to increase performance: on a spinning disk, seeks take less time when they are physically close together.

The worst case scenario is when there is a central directory in which all the nodes create files because all of the nodes will constantly fight to lock the same resource group.

2.2. FILE SYSTEM FRAGMENTATION

While there is no defragmentation tool for GFS2 on Red Hat Enterprise Linux, you can defragment individual files by identifying them with the `filefrag` tool, copying them to temporary files, and renaming the temporary files to replace the originals.

2.3. BLOCK ALLOCATION ISSUES

This section provides a summary of issues related to block allocation in GFS2 file systems. Even though applications that only write data typically do not care how or where a block is allocated, a little knowledge about how block allocation works can help you optimize performance.

2.3.1. Leave Free Space in the File System

When a GFS2 file system is nearly full, the block allocator starts to have a difficult time finding space for new blocks to be allocated. As a result, blocks given out by the allocator tend to be squeezed into the end of a resource group or in tiny slices where file fragmentation is much more likely. This file fragmentation can cause performance problems. In addition, when a GFS2 file system is nearly full, the GFS2 block allocator spends more time searching through multiple resource groups, and that adds lock contention that would not necessarily be there on a file system that has ample free space. This also can cause performance problems.

For these reasons, it is recommended that you not run a file system that is more than 85 percent full, although this figure may vary depending on workload.

2.3.2. Have Each Node Allocate Its Own Files, If Possible

Due to the way the distributed lock manager (DLM) works, there will be more lock contention if all files are allocated by one node and other nodes need to add blocks to those files.

In GFS (version 1), all locks were managed by a central lock manager whose job was to control locking throughout the cluster. This grand unified lock manager (GULM) was problematic because it was a single point of failure. GFS2's replacement locking scheme, DLM, spreads the locks throughout the cluster. If any node in the cluster goes down, its locks are recovered by the other nodes.

With DLM, the first node to lock a resource (like a file) becomes the "lock master" for that lock. Other nodes may lock that resource, but they have to ask permission from the lock master first. Each node knows which locks for which it is the lock master, and each node knows which node it has lent a lock to. Locking a lock on the master node is much faster than locking one on another node that has to stop and ask permission from the lock's master.

As in many file systems, the GFS2 allocator tries to keep blocks in the same file close to one another to reduce the movement of disk heads and boost performance. A node that allocates blocks to a file will likely need to use and lock the same resource groups for the new blocks (unless all the blocks in that resource group are in use). The file system will run faster if the lock master for the resource group containing the file allocates its data blocks (it is faster to have the node that first opened the file do all the writing of new blocks).

2.3.3. Preallocate, If Possible

If files are preallocated, block allocations can be avoided altogether and the file system can run more efficiently. Newer versions of GFS2 include the `fallocate(1)` system call, which you can use to preallocate blocks of data.

2.4. CLUSTER CONSIDERATIONS

When determining the number of nodes that your system will contain, note that there is a trade-off between high availability and performance. With a larger number of nodes, it becomes increasingly difficult to make workloads scale. For that reason, Red Hat does not support using GFS2 for cluster file system deployments greater than 16 nodes.

Deploying a cluster file system is not a "drop in" replacement for a single node deployment. Red Hat recommends that you allow a period of around 8-12 weeks of testing on new installations in order to test the system and ensure that it is working at the required performance level. During this period any performance or functional issues can be worked out and any queries should be directed to the Red Hat support team.

Red Hat recommends that customers considering deploying clusters have their configurations reviewed by Red Hat support before deployment to avoid any possible support issues later on.

2.5. USAGE CONSIDERATIONS

This section provides general recommendations about GFS2 usage.

2.5.1. Mount Options: `noatime` and `nodiratime`

It is generally recommended to mount GFS2 file systems with the `noatime` and `nodiratime` arguments. This allows GFS2 to spend less time updating disk inodes for every access.

2.5.2. VFS Tuning Options: Research and Experiment

Like all Linux file systems, GFS2 sits on top of a layer called the virtual file system (VFS). You can tune the VFS layer to improve underlying GFS2 performance by using the `sysctl(8)` command. For example, the values for `dirty_background_ratio` and `vfs_cache_pressure` may be adjusted depending on your situation. To fetch the current values, use the following commands:

```
# sysctl -n vm.dirty_background_ratio
# sysctl -n vm.vfs_cache_pressure
```

The following commands adjust the values:

```
# sysctl -w vm.dirty_background_ratio=20
# sysctl -w vm.vfs_cache_pressure=500
```

You can permanently change the values of these parameters by editing the `/etc/sysctl.conf` file.

To find the optimal values for your use cases, research the various VFS options and experiment on a test cluster before deploying into full production.

2.5.3. SELinux on GFS2

As of Red Hat Enterprise Linux 7.4 and later, Security Enhanced Linux (SELinux) is supported for use with GFS2 file systems.

Use of SELinux with GFS2 incurs a small performance penalty. To avoid this overhead, you may choose not to use SELinux with GFS2 even on a system with SELinux in enforcing mode. When mounting a GFS2 file system, you can ensure that SELinux will not attempt to read the `seclabel` element on each file system object by using one of the `context` options as described on the `mount(8)` man page; SELinux will assume that all content in the file system is labeled with the `seclabel` element provided in the `context` mount options. This will also speed up processing as it avoids another disk read of the extended attribute block that could contain `seclabel` elements.

For example, on a system with SELinux in enforcing mode, you can use the following `mount` command to mount the GFS2 file system if the file system is going to contain Apache content. This label will apply to the entire file system; it remains in memory and is not written to disk.

```
# mount -t gfs2 -o context=system_u:object_r:httpd_sys_content_t:s0  
/dev/mapper/xyz/mnt/gfs2
```

If you are not sure whether the file system will contain Apache content, you can use the labels `public_content_rw_t` or `public_content_t`, or you could define a new label altogether and define a policy around it.

Note that in a Pacemaker cluster you should always use Pacemaker to manage a GFS2 file system. You can specify the mount options when you create a GFS2 file system resource, as described in [Chapter 5, Configuring a GFS2 File System in a Cluster](#).

2.5.4. Setting Up NFS Over GFS2

Due to the added complexity of the GFS2 locking subsystem and its clustered nature, setting up NFS over GFS2 requires taking many precautions and careful configuration. This section describes the caveats you should take into account when configuring an NFS service over a GFS2 file system.



WARNING

If the GFS2 file system is NFS exported, and NFS client applications use POSIX locks, then you must mount the file system with the `locallocks` option. The intended effect of this is to force POSIX locks from each server to be local: non-clustered, independent of each other. (A number of problems exist if GFS2 attempts to implement POSIX locks from NFS across the nodes of a cluster.) For applications running on NFS clients, localized POSIX locks means that two clients can hold the same lock concurrently if the two clients are mounting from different servers. If all clients mount NFS from one server, then the problem of separate servers granting the same locks independently goes away. If you are not sure whether to mount your file system with the `locallocks` option, you should not use the option; it is always safer to have the locks working on a clustered basis.

In addition to the locking considerations, you should take the following into account when configuring an NFS service over a GFS2 file system.

- Red Hat supports only Red Hat High Availability Add-On configurations using NFSv3 with locking in an active/passive configuration with the following characteristics:
 - The back-end file system is a GFS2 file system running on a 2 to 16 node cluster.
 - An NFSv3 server is defined as a service exporting the entire GFS2 file system from a single cluster node at a time.
 - The NFS server can fail over from one cluster node to another (active/passive configuration).
 - No access to the GFS2 file system is allowed *except* through the NFS server. This includes both local GFS2 file system access as well as access through Samba or Clustered Samba.
 - There is no NFS quota support on the system.

This configuration provides High Availability (HA) for the file system and reduces system downtime since a failed node does not result in the requirement to execute the `fsck` command when failing the NFS server from one node to another.

- The `fsid= NFS` option is mandatory for NFS exports of GFS2.
- If problems arise with your cluster (for example, the cluster becomes inquorate and fencing is not successful), the clustered logical volumes and the GFS2 file system will be frozen and no access is possible until the cluster is quorate. You should consider this possibility when determining whether a simple failover solution such as the one defined in this procedure is the most appropriate for your system.

2.5.5. Samba (SMB or Windows) File Serving Over GFS2

You can use Samba (SMB or Windows) file serving from a GFS2 file system with CTDB, which allows active/active configurations.

Simultaneous access to the data in the Samba share from outside of Samba is not supported. There is currently no support for GFS2 cluster leases, which slows Samba file serving.

2.5.6. Configuring Virtual Machines for GFS2

When using a GFS2 file system with a virtual machine, it is important that your VM storage settings on each node be configured properly in order to force the cache off. For example, including these settings for `cache` and `io` in the `libvirt` domain should allow GFS2 to behave as expected.

```
<driver name='qemu' type='raw' cache='none' io='native'/>
```

Alternately, you can configure the `shareable` attribute within the device element. This indicates that the device is expected to be shared between domains (as long as hypervisor and OS support this). If `shareable` is used, `cache='no'` should be used for that device.

2.6. FILE SYSTEM BACKUPS

It is important to make regular backups of your GFS2 file system in case of emergency, regardless of the size of your file system. Many system administrators feel safe because they are protected by RAID, multipath, mirroring, snapshots, and other forms of redundancy, but there is no such thing as safe enough.

It can be a problem to create a backup since the process of backing up a node or set of nodes usually involves reading the entire file system in sequence. If this is done from a single node, that node will retain all the information in cache until other nodes in the cluster start requesting locks. Running this type of backup program while the cluster is in operation will negatively impact performance.

Dropping the caches once the backup is complete reduces the time required by other nodes to regain ownership of their cluster locks/caches. This is still not ideal, however, because the other nodes will have stopped caching the data that they were caching before the backup process began. You can drop caches using the following command after the backup is complete:

```
echo -n 3 > /proc/sys/vm/drop_caches
```

It is faster if each node in the cluster backs up its own files so that the task is split between the nodes. You might be able to accomplish this with a script that uses the `rsync` command on node-specific directories.

Red Hat recommends making a GFS2 backup by creating a hardware snapshot on the SAN, presenting the snapshot to another system, and backing it up there. The backup system should mount the snapshot with `-o lockproto=lock_noLOCK` since it will not be in a cluster.

2.7. HARDWARE CONSIDERATIONS

You should take the following hardware considerations into account when deploying a GFS2 file system.

- Use Higher Quality Storage Options

GFS2 can operate on cheaper shared storage options, such as iSCSI or Fibre Channel over Ethernet (FCoE), but you will get better performance if you buy higher quality storage with larger caching capacity. Red Hat performs most quality, sanity, and performance tests on SAN storage with Fibre Channel interconnect. As a general rule, it is always better to deploy something that has been tested first.

- Test Network Equipment Before Deploying

Higher quality, faster network equipment makes cluster communications and GFS2 run faster with better reliability. However, you do not have to purchase the most expensive hardware. Some of the most expensive network switches have problems passing multicast packets, which are used for passing `fcntl` locks (flocks), whereas cheaper commodity network switches are sometimes faster and more reliable. Red Hat recommends trying equipment before deploying it into full production.

2.8. PERFORMANCE ISSUES: CHECK THE RED HAT CUSTOMER PORTAL

For information on recommendations for deploying and upgrading Red Hat Enterprise Linux clusters using the High Availability Add-On and Red Hat Global File System 2 (GFS2) see the article "Red Hat Enterprise Linux Cluster, High Availability, and GFS Deployment Best Practices" on the Red Hat Customer Portal at <https://access.redhat.com/kb/docs/DOC-40821>.

2.9. GFS2 NODE LOCKING

In order to get the best performance from a GFS2 file system, it is very important to understand some of the basic theory of its operation. A single node file system is implemented alongside a cache, the

purpose of which is to eliminate latency of disk accesses when using frequently requested data. In Linux the page cache (and historically the buffer cache) provide this caching function.

With GFS2, each node has its own page cache which may contain some portion of the on-disk data. GFS2 uses a locking mechanism called *glocks* (pronounced gee-locks) to maintain the integrity of the cache between nodes. The glock subsystem provides a cache management function which is implemented using the *distributed lock manager* (DLM) as the underlying communication layer.

The glocks provide protection for the cache on a per-inode basis, so there is one lock per inode which is used for controlling the caching layer. If that glock is granted in shared mode (DLM lock mode: PR) then the data under that glock may be cached upon one or more nodes at the same time, so that all the nodes may have local access to the data.

If the glock is granted in exclusive mode (DLM lock mode: EX) then only a single node may cache the data under that glock. This mode is used by all operations which modify the data (such as the `write` system call).

If another node requests a glock which cannot be granted immediately, then the DLM sends a message to the node or nodes which currently hold the glocks blocking the new request to ask them to drop their locks. Dropping glocks can be (by the standards of most file system operations) a long process. Dropping a shared glock requires only that the cache be invalidated, which is relatively quick and proportional to the amount of cached data.

Dropping an exclusive glock requires a log flush, and writing back any changed data to disk, followed by the invalidation as per the shared glock.

The difference between a single node file system and GFS2, then, is that a single node file system has a single cache and GFS2 has a separate cache on each node. In both cases, latency to access cached data is of a similar order of magnitude, but the latency to access uncached data is much greater in GFS2 if another node has previously cached that same data.

NOTE

Due to the way in which GFS2's caching is implemented the best performance is obtained when either of the following takes place:

- An inode is used in a read only fashion across all nodes.
- An inode is written or modified from a single node only.

Note that inserting and removing entries from a directory during file creation and deletion counts as writing to the directory inode.

It is possible to break this rule provided that it is broken relatively infrequently. Ignoring this rule too often will result in a severe performance penalty.

If you `mmap()` a file on GFS2 with a read/write mapping, but only read from it, this only counts as a read. On GFS though, it counts as a write, so GFS2 is much more scalable with `mmap()` I/O.

If you do not set the `noatime` mount parameter, then reads will also result in writes to update the file timestamps. We recommend that all GFS2 users should mount with `noatime` unless they have a specific requirement for `atime`.

2.9.1. Issues with Posix Locking

When using Posix locking, you should take the following into account:

- Use of Flocks will yield faster processing than use of Posix locks.
- Programs using Posix locks in GFS2 should avoid using the **GETLK** function since, in a clustered environment, the process ID may be for a different node in the cluster.

2.9.2. Performance Tuning with GFS2

It is usually possible to alter the way in which a troublesome application stores its data in order to gain a considerable performance advantage.

A typical example of a troublesome application is an email server. These are often laid out with a spool directory containing files for each user (**mbox**), or with a directory for each user containing a file for each message (**maildir**). When requests arrive over IMAP, the ideal arrangement is to give each user an affinity to a particular node. That way their requests to view and delete email messages will tend to be served from the cache on that one node. Obviously if that node fails, then the session can be restarted on a different node.

When mail arrives by means of SMTP, then again the individual nodes can be set up so as to pass a certain user's mail to a particular node by default. If the default node is not up, then the message can be saved directly into the user's mail spool by the receiving node. Again this design is intended to keep particular sets of files cached on just one node in the normal case, but to allow direct access in the case of node failure.

This setup allows the best use of GFS2's page cache and also makes failures transparent to the application, whether **imap** or **smtp**.

Backup is often another tricky area. Again, if it is possible it is greatly preferable to back up the working set of each node directly from the node which is caching that particular set of inodes. If you have a backup script which runs at a regular point in time, and that seems to coincide with a spike in the response time of an application running on GFS2, then there is a good chance that the cluster may not be making the most efficient use of the page cache.

Obviously, if you are in the (enviable) position of being able to stop the application in order to perform a backup, then this will not be a problem. On the other hand, if a backup is run from just one node, then after it has completed a large portion of the file system will be cached on that node, with a performance penalty for subsequent accesses from other nodes. This can be mitigated to a certain extent by dropping the VFS page cache on the backup node after the backup has completed with following command:

```
echo -n 3 >/proc/sys/vm/drop_caches
```

However this is not as good a solution as taking care to ensure the working set on each node is either shared, mostly read only across the cluster, or accessed largely from a single node.

2.9.3. Troubleshooting GFS2 Performance with the GFS2 Lock Dump

If your cluster performance is suffering because of inefficient use of GFS2 caching, you may see large and increasing I/O wait times. You can make use of GFS2's lock dump information to determine the cause of the problem.

This section provides an overview of the GFS2 lock dump. For a more complete description of the GFS2 lock dump, see [Appendix B, GFS2 Tracepoints and the debugfs glocks File](#)

The GFS2 lock dump information can be gathered from the `debugfs` file which can be found at the following path name, assuming that `debugfs` is mounted on `/sys/kernel/debug/`:

```
/sys/kernel/debug/gfs2/fsname/glocks
```

The content of the file is a series of lines. Each line starting with G: represents one glock, and the following lines, indented by a single space, represent an item of information relating to the glock immediately before them in the file.

The best way to use the `debugfs` file is to use the `cat` command to take a copy of the complete content of the file (it might take a long time if you have a large amount of RAM and a lot of cached inodes) while the application is experiencing problems, and then looking through the resulting data at a later date.



NOTE

It can be useful to make two copies of the `debugfs` file, one a few seconds or even a minute or two after the other. By comparing the holder information in the two traces relating to the same glock number, you can tell whether the workload is making progress (it is just slow) or whether it has become stuck (which is always a bug and should be reported to Red Hat support immediately).

Lines in the `debugfs` file starting with H: (holders) represent lock requests either granted or waiting to be granted. The flags field on the holders line f: shows which: The 'W' flag refers to a waiting request, the 'H' flag refers to a granted request. The glocks which have large numbers of waiting requests are likely to be those which are experiencing particular contention.

[Table 2.1, “Glock flags”](#) shows the meanings of the different glock flags and [Table 2.2, “Glock holder flags”](#) shows the meanings of the different glock holder flags.

Table 2.1. Glock flags

Flag	Name	Meaning
b	Blocking	Valid when the locked flag is set, and indicates that the operation that has been requested from the DLM may block. This flag is cleared for demotion operations and for "try" locks. The purpose of this flag is to allow gathering of stats of the DLM response time independent from the time taken by other nodes to demote locks.
d	Pending demote	A deferred (remote) demote request
D	Demote	A demote request (local or remote)
f	Log flush	The log needs to be committed before releasing this glock
F	Frozen	Replies from remote nodes ignored - recovery is in progress. This flag is not related to file system freeze, which uses a different mechanism, but is used only in recovery.
i	Invalidate in progress	In the process of invalidating pages under this glock

Flag	Name	Meaning
I	Initial	Set when DLM lock is associated with this glock
l	Locked	The glock is in the process of changing state
L	LRU	Set when the glock is on the LRU list
o	Object	Set when the glock is associated with an object (that is, an inode for type 2 glocks, and a resource group for type 3 glocks)
p	Demote in progress	The glock is in the process of responding to a demote request
q	Queued	Set when a holder is queued to a glock, and cleared when the glock is held, but there are no remaining holders. Used as part of the algorithm that calculates the minimum hold time for a glock.
r	Reply pending	Reply received from remote node is awaiting processing
y	Dirty	Data needs flushing to disk before releasing this glock

Table 2.2. Glock holder flags

Flag	Name	Meaning
a	Async	Do not wait for glock result (will poll for result later)
A	Any	Any compatible lock mode is acceptable
c	No cache	When unlocked, demote DLM lock immediately
e	No expire	Ignore subsequent lock cancel requests
E	exact	Must have exact lock mode
F	First	Set when holder is the first to be granted for this lock
H	Holder	Indicates that requested lock is granted
p	Priority	Enqueue holder at the head of the queue
t	Try	A "try" lock
T	Try 1CB	A "try" lock that sends a callback
W	Wait	Set while waiting for request to complete

Having identified a glock which is causing a problem, the next step is to find out which inode it relates to. The glock number (n: on the G: line) indicates this. It is of the form *type/number* and if *type* is 2, then the glock is an inode glock and the *number* is an inode number. To track down the inode, you can then run `find -inum number` where *number* is the inode number converted from the hex format in the glocks file into decimal.



WARNING

If you run the `find` command on a file system when it is experiencing lock contention, you are likely to make the problem worse. It is a good idea to stop the application before running the `find` command when you are looking for contended inodes.

Table 2.3, “Glock types” shows the meanings of the different glock types.

Table 2.3. Glock types

Type number	Lock type	Use
1	Trans	Transaction lock
2	Inode	Inode metadata and data
3	Rgrp	Resource group metadata
4	Meta	The superblock
5	lopen	Inode last closer detection
6	Flock	<code>flock(2)</code> syscall
8	Quota	Quota operations
9	Journal	Journal mutex

If the glock that was identified was of a different type, then it is most likely to be of type 3: (resource group). If you see significant numbers of processes waiting for other types of glock under normal loads, report this to Red Hat support.

If you do see a number of waiting requests queued on a resource group lock there may be a number of reasons for this. One is that there are a large number of nodes compared to the number of resource groups in the file system. Another is that the file system may be very nearly full (requiring, on average, longer searches for free blocks). The situation in both cases can be improved by adding more storage and using the `gfs2_grow` command to expand the file system.

CHAPTER 3. MANAGING GFS2

This chapter describes the tasks and commands for managing GFS2 and consists of the following sections:

- [Section 3.1, “Making a File System”](#)
- [Section 3.2, “Mounting a File System”](#)
- [Section 3.3, “Unmounting a File System”](#)
- [Section 3.5, “GFS2 Quota Management”](#)
- [Section 3.6, “Growing a File System”](#)
- [Section 3.7, “Adding Journals to a File System”](#)
- [Section 3.8, “Data Journaling”](#)
- [Section 3.9, “Configuring atime Updates”](#)
- [Section 3.10, “Suspending Activity on a File System”](#)
- [Section 3.11, “Repairing a File System”](#)
- [Section 3.12, “The GFS2 Withdraw Function”](#)

3.1. MAKING A FILE SYSTEM

You create a GFS2 file system with the `mkfs.gfs2` command. You can also use the `mkfs` command with the `-t gfs2` option specified. A file system is created on an activated LVM volume. The following information is required to run the `mkfs.gfs2` command:

- Lock protocol/module name (the lock protocol for a cluster is `lock_dlm`)
- Cluster name (needed when specifying the `LockTableName` parameter)
- Number of journals (one journal required for each node that may be mounting the file system)

When creating a GFS2 file system, you can use the `mkfs.gfs2` command directly, or you can use the `mkfs` command with the `-t` parameter specifying a file system of type `gfs2`, followed by the GFS2 file system options.



NOTE

Once you have created a GFS2 file system with the `mkfs.gfs2` command, you cannot decrease the size of the file system. You can, however, increase the size of an existing file system with the `gfs2_grow` command, as described in [Section 3.6, “Growing a File System”](#).

Usage

When creating a clustered GFS2 file system, you can use either of the following formats:

```
mkfs.gfs2 -p LockProtoName -t LockTableName -j NumberJournals BlockDevice
```

```
mkfs -t gfs2 -p LockProtoName -t LockTableName -j NumberJournals
BlockDevice
```

When creating a local GFS2 file system, you can use either of the following formats:



NOTE

As of the Red Hat Enterprise Linux 6 release, Red Hat does not support the use of GFS2 as a single-node file system.

```
mkfs.gfs2 -p LockProtoName -j NumberJournals BlockDevice
```

```
mkfs -t gfs2 -p LockProtoName -j NumberJournals BlockDevice
```



WARNING

Make sure that you are very familiar with using the *LockProtoName* and *LockTableName* parameters. Improper use of the *LockProtoName* and *LockTableName* parameters may cause file system or lock space corruption.

LockProtoName

Specifies the name of the locking protocol to use. The lock protocol for a cluster is **lock_dlm**.

LockTableName

This parameter is specified for a GFS2 file system in a cluster configuration. It has two parts separated by a colon (no spaces) as follows: **ClusterName:FSName**

- **ClusterName**, the name of the cluster for which the GFS2 file system is being created.
- **FSName**, the file system name, can be 1 to 16 characters long. The name must be unique for all **lock_dlm** file systems over the cluster, and for all file systems (**lock_dlm** and **lock_noLOCK**) on each local node.

Number

Specifies the number of journals to be created by the **mkfs.gfs2** command. One journal is required for each node that mounts the file system. For GFS2 file systems, more journals can be added later without growing the file system, as described in [Section 3.7, “Adding Journals to a File System”](#).

BlockDevice

Specifies a logical or physical volume.

Examples

In these examples, **lock_dlm** is the locking protocol that the file system uses, since this is a clustered file system. The cluster name is **alpha**, and the file system name is **mydata1**. The file system contains eight journals and is created on **/dev/vg01/lvol0**.

```
# mkfs.gfs2 -p lock_dlm -t alpha:mydata1 -j 8 /dev/vg01/lvol0
```

```
# mkfs -t gfs2 -p lock_dlm -t alpha:mydata1 -j 8 /dev/vg01/lvol0
```

In these examples, a second **lock_dlm** file system is made, which can be used in cluster **alpha**. The file system name is **mydata2**. The file system contains eight journals and is created on **/dev/vg01/lvol1**.

```
mkfs.gfs2 -p lock_dlm -t alpha:mydata2 -j 8 /dev/vg01/lvol1
```

```
mkfs -t gfs2 -p lock_dlm -t alpha:mydata2 -j 8 /dev/vg01/lvol1
```

Complete Options

Table 3.1, “[Command Options: mkfs.gfs2](#)” describes the **mkfs.gfs2** command options (flags and parameters).

Table 3.1. Command Options: **mkfs.gfs2**

Flag	Parameter	Description
-c	<i>Megabytes</i>	Sets the initial size of each journal's quota change file to <i>Megabytes</i> .
-D		Enables debugging output.
-h		Help. Displays available options.
-J	<i>Megabytes</i>	Specifies the size of the journal in megabytes. Default journal size is 128 megabytes. The minimum size is 8 megabytes. Larger journals improve performance, although they use more memory than smaller journals.
-j	<i>Number</i>	Specifies the number of journals to be created by the mkfs.gfs2 command. One journal is required for each node that mounts the file system. If this option is not specified, one journal will be created. For GFS2 file systems, you can add additional journals at a later time without growing the file system.
-O		Prevents the mkfs.gfs2 command from asking for confirmation before writing the file system.

Flag	Parameter	Description
-p	<i>LockProtoName</i>	<p>Specifies the name of the locking protocol to use. Recognized locking protocols include:</p> <p>lock_dlm – The standard locking module, required for a clustered file system.</p> <p>lock_nolock – Used when GFS2 is acting as a local file system (one node only).</p>
-q		Quiet. Do not display anything.
-r	<i>Megabytes</i>	Specifies the size of the resource groups in megabytes. The minimum resource group size is 32 megabytes. The maximum resource group size is 2048 megabytes. A large resource group size may increase performance on very large file systems. If this is not specified, mkfs.gfs2 chooses the resource group size based on the size of the file system: average size file systems will have 256 megabyte resource groups, and bigger file systems will have bigger RGs for better performance.
-t	<i>LockTableName</i>	<p>A unique identifier that specifies the lock table field when you use the lock_dlm protocol; the lock_nolock protocol does not use this parameter.</p> <p>This parameter has two parts separated by a colon (no spaces) as follows: ClusterName : FSName.</p> <p>ClusterName is the name of the cluster for which the GFS2 file system is being created; only members of this cluster are permitted to use this file system. The cluster name is set in the /etc/cluster/cluster.conf file by means of the Cluster Configuration Tool and displayed at the Cluster Status Tool in the Red Hat Cluster Suite cluster management GUI.</p> <p>FSName, the file system name, can be 1 to 16 characters in length, and the name must be unique among all file systems in the cluster.</p>
-u	<i>Megabytes</i>	Specifies the initial size of each journal's unlinked tag file.
-V		Displays command version information.

3.2. MOUNTING A FILE SYSTEM

Before you can mount a GFS2 file system, the file system must exist (see [Section 3.1, “Making a File System”](#)), the volume where the file system exists must be activated, and the supporting clustering and locking systems must be started (see *Configuring and Managing a Red Hat Cluster*). After those requirements have been met, you can mount the GFS2 file system as you would any Linux file system.

To manipulate file ACLs, you must mount the file system with the `-o acl` mount option. If a file system is mounted without the `-o acl` mount option, users are allowed to view ACLs (with `getfacl`), but are not allowed to set them (with `setfacl`).

Usage

Mounting Without ACL Manipulation

```
mount BlockDevice MountPoint
```

Mounting With ACL Manipulation

```
mount -o acl BlockDevice MountPoint
```

`-o acl`

GFS2-specific option to allow manipulating file ACLs.

BlockDevice

Specifies the block device where the GFS2 file system resides.

MountPoint

Specifies the directory where the GFS2 file system should be mounted.

Example

In this example, the GFS2 file system on `/dev/vg01/lvol0` is mounted on the `/mygfs2` directory.

```
# mount /dev/vg01/lvol0 /mygfs2
```

Complete Usage

```
mount BlockDevice MountPoint -o option
```

The `-o option` argument consists of GFS2-specific options (see [Table 3.2, “GFS2-Specific Mount Options”](#)) or acceptable standard Linux `mount -o` options, or a combination of both. Multiple *option* parameters are separated by a comma and no spaces.



NOTE

The `mount` command is a Linux system command. In addition to using GFS2-specific options described in this section, you can use other, standard, `mount` command options (for example, `-r`). For information about other Linux `mount` command options, see the Linux `mount` man page.

Table 3.2, “GFS2-Specific Mount Options” describes the available GFS2-specific **-o option** values that can be passed to GFS2 at mount time.



NOTE

This table includes descriptions of options that are used with local file systems only. Note, however, that as of the Red Hat Enterprise Linux 6 release, Red Hat does not support the use of GFS2 as a single-node file system. Red Hat will continue to support single-node GFS2 file systems for mounting snapshots of cluster file systems (for example, for backup purposes).

Table 3.2. GFS2-Specific Mount Options

Option	Description
acl	Allows manipulating file ACLs. If a file system is mounted without the acl mount option, users are allowed to view ACLs (with getfacl), but are not allowed to set them (with setfacl).
data=[ordered writeback]	When data=ordered is set, the user data modified by a transaction is flushed to the disk before the transaction is committed to disk. This should prevent the user from seeing uninitialized blocks in a file after a crash. When data=writeback mode is set, the user data is written to the disk at any time after it is dirtied; this does not provide the same consistency guarantee as ordered mode, but it should be slightly faster for some workloads. The default value is ordered mode.
ignore_local_fs Caution: This option should <i>not</i> be used when GFS2 file systems are shared.	Forces GFS2 to treat the file system as a multi-host file system. By default, using lock_nolock automatically turns on the localflocks flag.
localflocks Caution: This option should not be used when GFS2 file systems are shared.	Tells GFS2 to let the VFS (virtual file system) layer do all flock and fcntl. The localflocks flag is automatically turned on by lock_nolock .
lockproto=LockModuleName	Allows the user to specify which locking protocol to use with the file system. If LockModuleName is not specified, the locking protocol name is read from the file system superblock.
locktable=LockTableName	Allows the user to specify which locking table to use with the file system.

Option	Description
quota=[off/account/on]	Turns quotas on or off for a file system. Setting the quotas to be in the account state causes the per UID/GID usage statistics to be correctly maintained by the file system; limit and warn values are ignored. The default value is off .
errors=panic withdraw	When errors=panic is specified, file system errors will cause a kernel panic. When errors=withdraw is specified, which is the default behavior, file system errors will cause the system to withdraw from the file system and make it inaccessible until the next reboot; in some cases the system may remain running.
discard/nodiscard	Causes GFS2 to generate "discard" I/O requests for blocks that have been freed. These can be used by suitable hardware to implement thin provisioning and similar schemes.
barrier/nobarrier	Causes GFS2 to send I/O barriers when flushing the journal. The default value is on . This option is automatically turned off if the underlying device does not support I/O barriers. Use of I/O barriers with GFS2 is highly recommended at all times unless the block device is designed so that it cannot lose its write cache content (for example, if it is on a UPS or it does not have a write cache).
quota_quantum=secs	Sets the number of seconds for which a change in the quota information may sit on one node before being written to the quota file. This is the preferred way to set this parameter. The value is an integer number of seconds greater than zero. The default is 60 seconds. Shorter settings result in faster updates of the lazy quota information and less likelihood of someone exceeding their quota. Longer settings make file system operations involving quotas faster and more efficient.
statfs_quantum=secs	Setting statfs_quantum to 0 is the preferred way to set the slow version of statfs . The default value is 30 secs which sets the maximum time period before statfs changes will be synced to the master statfs file. This can be adjusted to allow for faster, less accurate statfs values or slower more accurate values. When this option is set to 0, statfs will always report the true values.
statfs_percent=value	Provides a bound on the maximum percentage change in the statfs information on a local basis before it is synced back to the master statfs file, even if the time period has not expired. If the setting of statfs_quantum is 0, then this setting is ignored.

3.3. UNMOUNTING A FILE SYSTEM

The GFS2 file system can be unmounted the same way as any Linux file system – by using the **umount** command.



NOTE

The **umount** command is a Linux system command. Information about this command can be found in the Linux **umount** command man pages.

Usage

```
umount MountPoint
```

MountPoint

Specifies the directory where the GFS2 file system is currently mounted.

3.4. SPECIAL CONSIDERATIONS WHEN MOUNTING GFS2 FILE SYSTEMS

GFS2 file systems that have been mounted manually rather than automatically through Pacemaker will not be known to the system when file systems are unmounted at system shutdown. As a result, the GFS2 script will not unmount the GFS2 file system. After the GFS2 shutdown script is run, the standard shutdown process kills off all remaining user processes, including the cluster infrastructure, and tries to unmount the file system. This unmount will fail without the cluster infrastructure and the system will hang.

To prevent the system from hanging when the GFS2 file systems are unmounted, you should do one of the following:

- Always use Pacemaker to manage the GFS2 file system. For information on configuring a GFS2 file system in a Pacemaker cluster, see [Chapter 5, Configuring a GFS2 File System in a Cluster](#).
- If a GFS2 file system has been mounted manually with the **mount** command, be sure to unmount the file system manually with the **umount** command before rebooting or shutting down the system.

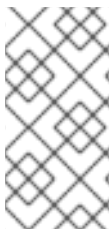
If your file system hangs while it is being unmounted during system shutdown under these circumstances, perform a hardware reboot. It is unlikely that any data will be lost since the file system is synced earlier in the shutdown process.

3.5. GFS2 QUOTA MANAGEMENT

File system quotas are used to limit the amount of file system space a user or group can use. A user or group does not have a quota limit until one is set. When a GFS2 file system is mounted with the **quota=on** or **quota=account** option, GFS2 keeps track of the space used by each user and group even when there are no limits in place. GFS2 updates quota information in a transactional way so system crashes do not require quota usages to be reconstructed.

To prevent a performance slowdown, a GFS2 node synchronizes updates to the quota file only periodically. The fuzzy quota accounting can allow users or groups to slightly exceed the set limit. To minimize this, GFS2 dynamically reduces the synchronization period as a hard quota limit is

approached.



NOTE

GFS2 supports the standard Linux quota facilities. In order to use this you will need to install the **quota** RPM. This is the preferred way to administer quotas on GFS2 and should be used for all new deployments of GFS2 using quotas. This section documents GFS2 quota management using these facilities.

3.5.1. Configuring Disk Quotas

To implement disk quotas, use the following steps:

1. Set up quotas in enforcement or accounting mode.
2. Initialize the quota database file with current block usage information.
3. Assign quota policies. (In accounting mode, these policies are not enforced.)

Each of these steps is discussed in detail in the following sections.

3.5.1.1. Setting Up Quotas in Enforcement or Accounting Mode

In GFS2 file systems, quotas are disabled by default. To enable quotas for a file system, mount the file system with the **quota=on** option specified.

It is possible to keep track of disk usage and maintain quota accounting for every user and group without enforcing the limit and warn values. To do this, mount the file system with the **quota=account** option specified.

To mount a file system with quotas enabled, specify **quota=on** for the **options** argument when creating the GFS2 file system resource in a cluster. For example, the following command specifies that the GFS2 **Filesystem** resource being created will be mounted with quotas enabled.

```
# pcs resource create gfs2mount Filesystem options="quota=on"  
device=BLOCKDEVICE directory=MOUNTPOINT fstype=gfs2 clone
```

For information on configuring a GFS2 file system in a Pacemaker cluster, see [Chapter 5, Configuring a GFS2 File System in a Cluster](#).

To mount a file system with quota accounting maintained, even though the quota limits are not enforced, specify **quota=account** for the **options** argument when creating the GFS2 file system resource in a cluster.

To mount a file system with quotas disabled, specify **quota=off** for the **options** argument when creating the GFS2 file system resource in a cluster.

3.5.1.2. Creating the Quota Database Files

After each quota-enabled file system is mounted, the system is capable of working with disk quotas. However, the file system itself is not yet ready to support quotas. The next step is to run the **quotacheck** command.

The **quotacheck** command examines quota-enabled file systems and builds a table of the current disk usage per file system. The table is then used to update the operating system's copy of disk usage. In addition, the file system's disk quota files are updated.

To create the quota files on the file system, use the **-u** and the **-g** options of the **quotacheck** command; both of these options must be specified for user and group quotas to be initialized. For example, if quotas are enabled for the **/home** file system, create the files in the **/home** directory:

```
quotacheck -ug /home
```

3.5.1.3. Assigning Quotas Per User

The last step is assigning the disk quotas with the **edquota** command. Note that if you have mounted your file system in accounting mode (with the **quota=account** option specified), the quotas are not enforced.

To configure the quota for a user, as root in a shell prompt, execute the command:

```
# edquota username
```

Perform this step for each user who needs a quota. For example, if a quota is enabled for the **/home** partition (**/dev/VolGroup00/LogVol02** in the example below) and the command **edquota testuser** is executed, the following is shown in the editor configured as the default for the system:

```
Disk quotas for user testuser (uid 501):
Filesystem          blocks      soft      hard      inodes      soft
hard
/dev/VolGroup00/LogVol02  440436          0          0
```



NOTE

The text editor defined by the **EDITOR** environment variable is used by **edquota**. To change the editor, set the **EDITOR** environment variable in your **~/.bash_profile** file to the full path of the editor of your choice.

The first column is the name of the file system that has a quota enabled for it. The second column shows how many blocks the user is currently using. The next two columns are used to set soft and hard block limits for the user on the file system.

The soft block limit defines the maximum amount of disk space that can be used.

The hard block limit is the absolute maximum amount of disk space that a user or group can use. Once this limit is reached, no further disk space can be used.

The GFS2 file system does not maintain quotas for inodes, so these columns do not apply to GFS2 file systems and will be blank.

If any of the values are set to 0, that limit is not set. In the text editor, change the limits. For example:

```
Disk quotas for user testuser (uid 501):
Filesystem          blocks      soft      hard      inodes      soft
hard
/dev/VolGroup00/LogVol02  440436    500000    550000
```

To verify that the quota for the user has been set, use the command:

```
quota testuser
```

3.5.1.4. Assigning Quotas Per Group

Quotas can also be assigned on a per-group basis. Note that if you have mounted your file system in accounting mode (with the `account=on` option specified), the quotas are not enforced.

To set a group quota for the `devel` group (the group must exist prior to setting the group quota), use the following command:

```
edquota -g devel
```

This command displays the existing quota for the group in the text editor:

```
Disk quotas for group devel (gid 505):
Filesystem                blocks      soft          hard    inodes     soft         hard
/dev/VolGroup00/LogVol02  440400          0              0
```

The GFS2 file system does not maintain quotas for inodes, so these columns do not apply to GFS2 file systems and will be blank. Modify the limits, then save the file.

To verify that the group quota has been set, use the following command:

```
$ quota -g devel
```

3.5.2. Managing Disk Quotas

If quotas are implemented, they need some maintenance – mostly in the form of watching to see if the quotas are exceeded and making sure the quotas are accurate.

Of course, if users repeatedly exceed their quotas or consistently reach their soft limits, a system administrator has a few choices to make depending on what type of users they are and how much disk space impacts their work. The administrator can either help the user determine how to use less disk space or increase the user's disk quota.

You can create a disk usage report by running the `repquota` utility. For example, the command `repquota /home` produces this output:

```
*** Report for user quotas on device /dev/mapper/VolGroup00-LogVol02
Block grace time: 7days; Inode grace time: 7days
   Block limits  File limits
User  used soft hard grace used soft hard grace
-----
root   --    36      0      0          4      0      0
kristin --   540      0      0         125      0      0
testuser -- 440400 500000 550000      37418      0      0
```

To view the disk usage report for all (option `-a`) quota-enabled file systems, use the command:

```
# repquota -a
```

While the report is easy to read, a few points should be explained. The `--` displayed after each user is a quick way to determine whether the block limits have been exceeded. If the block soft limit is exceeded, a `+` appears in place of the first `-` in the output. The second `-` indicates the inode limit, but GFS2 file systems do not support inode limits so that character will remain as `-`. GFS2 file systems do not support a grace period, so the `grace` column will remain blank.

Note that the `repquota` command is not supported over NFS, irrespective of the underlying file system.

3.5.3. Keeping Quotas Accurate

If you enable quotas on your file system after a period of time when you have been running with quotas disabled, you should run the `quotacheck` command to create, check, and repair quota files.

Additionally, you may want to run the `quotacheck` command if you think your quota files may not be accurate, as may occur when a file system is not unmounted cleanly after a system crash.

For more information about the `quotacheck` command, see the `quotacheck` man page.



NOTE

Run `quotacheck` when the file system is relatively idle on all nodes because disk activity may affect the computed quota values.

3.5.4. Synchronizing Quotas with the `quotasync` Command

GFS2 stores all quota information in its own internal file on disk. A GFS2 node does not update this quota file for every file system write; rather, by default it updates the quota file once every 60 seconds. This is necessary to avoid contention among nodes writing to the quota file, which would cause a slowdown in performance.

As a user or group approaches their quota limit, GFS2 dynamically reduces the time between its quota-file updates to prevent the limit from being exceeded. The normal time period between quota synchronizations is a tunable parameter, `quota_quantum`. You can change this from its default value of 60 seconds using the `quota_quantum=` mount option, as described in [Table 3.2, “GFS2-Specific Mount Options”](#). The `quota_quantum` parameter must be set on each node and each time the file system is mounted. Changes to the `quota_quantum` parameter are not persistent across unmounts. You can update the `quota_quantum` value with the `mount -o remount`.

You can use the `quotasync` command to synchronize the quota information from a node to the on-disk quota file between the automatic updates performed by GFS2.

Usage

Synchronizing Quota Information

```
quotasync [-ug] -a|mntpnt...
```

u

Sync the user quota files.

g

Sync the group quota files

a

Sync all file systems that are currently quota-enabled and support sync. When **-a** is absent, a file system mountpoint should be specified.

mntpnt

Specifies the GFS2 file system to which the actions apply.

Tuning the Time Between Synchronizations

```
mount -o quota_quantum=secs,remount BlockDevice MountPoint
```

MountPoint

Specifies the GFS2 file system to which the actions apply.

secs

Specifies the new time period between regular quota-file synchronizations by GFS2. Smaller values may increase contention and slow down performance.

Examples

This example synchronizes all the cached dirty quotas from the node it is run on to the on-disk quota file for the file system **/mnt/mygfs2**.

```
# quotasync -ug /mnt/mygfs2
```

This example changes the default time period between regular quota-file updates to one hour (3600 seconds) for file system **/mnt/mygfs2** when remounting that file system on logical volume **/dev/volgroup/logical_volume**.

```
# mount -o quota_quantum=3600,remount /dev/volgroup/logical_volume  
/mnt/mygfs2
```

3.5.5. References

For more information on disk quotas, see the **man** pages of the following commands:

- **quotacheck**
- **edquota**
- **repquota**
- **quota**

3.6. GROWING A FILE SYSTEM

The **gfs2_grow** command is used to expand a GFS2 file system after the device where the file system resides has been expanded. Running the **gfs2_grow** command on an existing GFS2 file system fills all spare space between the current end of the file system and the end of the device with a newly

initialized GFS2 file system extension. When the fill operation is completed, the resource index for the file system is updated. All nodes in the cluster can then use the extra storage space that has been added.

The `gfs2_grow` command must be run on a mounted file system, but only needs to be run on one node in a cluster. All the other nodes sense that the expansion has occurred and automatically start using the new space.



NOTE

Once you have created a GFS2 file system with the `mkfs.gfs2` command, you cannot decrease the size of the file system.

Usage

```
gfs2_grow MountPoint
```

MountPoint

Specifies the GFS2 file system to which the actions apply.

Comments

Before running the `gfs2_grow` command:

- Back up important data on the file system.
- Determine the volume that is used by the file system to be expanded by running the `df MountPoint` command.
- Expand the underlying cluster volume with LVM. For information on administering LVM volumes, see *Logical Volume Manager Administration*.

After running the `gfs2_grow` command, run the `df` command to check that the new space is now available in the file system.

Examples

In this example, the file system on the `/mygfs2fs` directory is expanded.

```
# gfs2_grow /mygfs2fs
FS: Mount Point: /mygfs2fs
FS: Device:      /dev/mapper/gfs2testvg-gfs2testlv
FS: Size:        524288 (0x80000)
FS: RG size:     65533 (0xffffd)
DEV: Size:       655360 (0xa0000)
The file system grew by 512MB.
gfs2_grow complete.
```

Complete Usage

```
gfs2_grow [Options] {MountPoint | Device} [MountPoint | Device]
```

MountPoint

Specifies the directory where the GFS2 file system is mounted.

Device

Specifies the device node of the file system.

Table 3.3, “GFS2-specific Options Available While Expanding A File System” describes the GFS2-specific options that can be used while expanding a GFS2 file system.

Table 3.3. GFS2-specific Options Available While Expanding A File System

Option	Description
-h	Help. Displays a short usage message.
-q	Quiet. Turns down the verbosity level.
-r Megabytes	Specifies the size of the new resource group. The default size is 256 megabytes.
-T	Test. Do all calculations, but do not write any data to the disk and do not expand the file system.
-V	Displays command version information.

3.7. ADDING JOURNALS TO A FILE SYSTEM

The `gfs2_jadd` command is used to add journals to a GFS2 file system. You can add journals to a GFS2 file system dynamically at any point without expanding the underlying logical volume. The `gfs2_jadd` command must be run on a mounted file system, but it needs to be run on only one node in the cluster. All the other nodes sense that the expansion has occurred.



NOTE

If a GFS2 file system is full, the `gfs2_jadd` command will fail, even if the logical volume containing the file system has been extended and is larger than the file system. This is because in a GFS2 file system, journals are plain files rather than embedded metadata, so simply extending the underlying logical volume will not provide space for the journals.

Before adding journals to a GFS2 file system, you can find out how many journals the GFS2 file system currently contains with the `gfs2_edit -p jindex` command, as in the following example:

```
# gfs2_edit -p jindex /dev/sasdrives/scratch|grep journal
3/3 [fc7745eb] 4/25 (0x4/0x19): File    journal0
4/4 [8b70757d] 5/32859 (0x5/0x805b): File    journal1
5/5 [127924c7] 6/65701 (0x6/0x100a5): File    journal2
```


Usage

```
gfs2_jadd -j Number MountPoint
```

Number

Specifies the number of new journals to be added.

MountPoint

Specifies the directory where the GFS2 file system is mounted.

Examples

In this example, one journal is added to the file system on the `/mygfs2` directory.

```
gfs2_jadd -j 1 /mygfs2
```

In this example, two journals are added to the file system on the `/mygfs2` directory.

```
gfs2_jadd -j 2 /mygfs2
```

Complete Usage

```
gfs2_jadd [Options] {MountPoint | Device} [MountPoint | Device]
```

MountPoint

Specifies the directory where the GFS2 file system is mounted.

Device

Specifies the device node of the file system.

[Table 3.4, “GFS2-specific Options Available When Adding Journals”](#) describes the GFS2-specific options that can be used when adding journals to a GFS2 file system.

Table 3.4. GFS2-specific Options Available When Adding Journals

Flag	Parameter	Description
-h		Help. Displays short usage message.
-J	<i>Megabytes</i>	Specifies the size of the new journals in megabytes. Default journal size is 128 megabytes. The minimum size is 32 megabytes. To add journals of different sizes to the file system, the gfs2_jadd command must be run for each size journal. The size specified is rounded down so that it is a multiple of the journal-segment size that was specified when the file system was created.

Flag	Parameter	Description
-j	<i>Number</i>	Specifies the number of new journals to be added by the gfs2_jadd command. The default value is 1.
-q		Quiet. Turns down the verbosity level.
-V		Displays command version information.

3.8. DATA JOURNALING

Ordinarily, GFS2 writes only metadata to its journal. File contents are subsequently written to disk by the kernel's periodic sync that flushes file system buffers. An **fsync()** call on a file causes the file's data to be written to disk immediately. The call returns when the disk reports that all data is safely written.

Data journaling can result in a reduced **fsync()** time for very small files because the file data is written to the journal in addition to the metadata. This advantage rapidly reduces as the file size increases. Writing to medium and larger files will be much slower with data journaling turned on.

Applications that rely on **fsync()** to sync file data may see improved performance by using data journaling. Data journaling can be enabled automatically for any GFS2 files created in a flagged directory (and all its subdirectories). Existing files with zero length can also have data journaling turned on or off.

Enabling data journaling on a directory sets the directory to "inherit jdata", which indicates that all files and directories subsequently created in that directory are journaled. You can enable and disable data journaling on a file with the **chattr** command.

The following commands enable data journaling on the **/mnt/gfs2/gfs2_dir/newfile** file and then check whether the flag has been set properly.

```
# chattr +j /mnt/gfs2/gfs2_dir/newfile
# lsattr /mnt/gfs2/gfs2_dir
-----j--- /mnt/gfs2/gfs2_dir/newfile
```

The following commands disable data journaling on the **/mnt/gfs2/gfs2_dir/newfile** file and then check whether the flag has been set properly.

```
# chattr -j /mnt/gfs2/gfs2_dir/newfile
# lsattr /mnt/gfs2/gfs2_dir
----- /mnt/gfs2/gfs2_dir/newfile
```

You can also use the **chattr** command to set the **j** flag on a directory. When you set this flag for a directory, all files and directories subsequently created in that directory are journaled. The following set of commands sets the **j** flag on the **gfs2_dir** directory, then checks whether the flag has been set properly. After this, the commands create a new file called **newfile** in the **/mnt/gfs2/gfs2_dir** directory and then check whether the **j** flag has been set for the file. Since the **j** flag is set for the directory, then **newfile** should also have journaling enabled.

```
# chattr -j /mnt/gfs2/gfs2_dir
# lsattr /mnt/gfs2
```

```

-----j--- /mnt/gfs2/gfs2_dir
# touch /mnt/gfs2/gfs2_dir/newfile
# lsattr /mnt/gfs2/gfs2_dir
-----j--- /mnt/gfs2/gfs2_dir/newfile

```

3.9. CONFIGURING `atime` UPDATES

Each file inode and directory inode has three time stamps associated with it:

- `ctime` – The last time the inode status was changed
- `mtime` – The last time the file (or directory) data was modified
- `atime` – The last time the file (or directory) data was accessed

If `atime` updates are enabled as they are by default on GFS2 and other Linux file systems then every time a file is read, its inode needs to be updated.

Because few applications use the information provided by `atime`, those updates can require a significant amount of unnecessary write traffic and file locking traffic. That traffic can degrade performance; therefore, it may be preferable to turn off or reduce the frequency of `atime` updates.

Two methods of reducing the effects of `atime` updating are available:

- Mount with `relatime` (relative `atime`), which updates the `atime` if the previous `atime` update is older than the `mtime` or `ctime` update.
- Mount with `noatime`, which disables `atime` updates on that file system.

3.9.1. Mount with `relatime`

The `relatime` (relative `atime`) Linux mount option can be specified when the file system is mounted. This specifies that the `atime` is updated if the previous `atime` update is older than the `mtime` or `ctime` update.

Usage

```
mount BlockDevice MountPoint -o relatime
```

BlockDevice

Specifies the block device where the GFS2 file system resides.

MountPoint

Specifies the directory where the GFS2 file system should be mounted.

Example

In this example, the GFS2 file system resides on `/dev/vg01/lvol10` and is mounted on directory `/mygfs2`. The `atime` updates take place only if the previous `atime` update is older than the `mtime` or `ctime` update.

■

```
# mount /dev/vg01/lvol0 /mygfs2 -o relatime
```

3.9.2. Mount with noatime

The **noatime** Linux mount option can be specified when the file system is mounted, which disables **atime** updates on that file system.

Usage

```
mount BlockDevice MountPoint -o noatime
```

BlockDevice

Specifies the block device where the GFS2 file system resides.

MountPoint

Specifies the directory where the GFS2 file system should be mounted.

Example

In this example, the GFS2 file system resides on **/dev/vg01/lvol0** and is mounted on directory **/mygfs2** with **atime** updates turned off.

```
# mount /dev/vg01/lvol0 /mygfs2 -o noatime
```

3.10. SUSPENDING ACTIVITY ON A FILE SYSTEM

You can suspend write activity to a file system by using the **dmsetup suspend** command. Suspending write activity allows hardware-based device snapshots to be used to capture the file system in a consistent state. The **dmsetup resume** command ends the suspension.

Usage

Start Suspension

```
dmsetup suspend MountPoint
```

End Suspension

```
dmsetup resume MountPoint
```

MountPoint

Specifies the file system.

Examples

This example suspends writes to file system **/mygfs2**.

```
# dmsetup suspend /mygfs2
```

This example ends suspension of writes to file system `/mygfs2`.

```
# dmsetup resume /mygfs2
```

3.11. REPAIRING A FILE SYSTEM

When nodes fail with the file system mounted, file system journaling allows fast recovery. However, if a storage device loses power or is physically disconnected, file system corruption may occur. (Journaling cannot be used to recover from storage subsystem failures.) When that type of corruption occurs, you can recover the GFS2 file system by using the `fsck.gfs2` command.

IMPORTANT

The `fsck.gfs2` command must be run only on a file system that is unmounted from all nodes. When the file system is being managed as a Pacemaker cluster resource, you can disable the file system resource, which unmounts the file system. After running the `fsck.gfs2` command, you enable the file system resource again. The `timeout` value specified with the `--wait` option of the `pcs resource disable` indicates a value in seconds.

```
# pcs resource disable --wait=timeoutvalue resource_id
[fck.gfs2]
# pcs resource enable resource_id
```

To ensure that `fsck.gfs2` command does not run on a GFS2 file system at boot time, you can set the `run_fsck` parameter of the `options` argument when creating the GFS2 file system resource in a cluster. Specifying `"run_fsck=no"` will indicate that you should not run the `fsck` command.



NOTE

If you have previous experience using the `gfs_fsck` command on GFS file systems, note that the `fsck.gfs2` command differs from some earlier releases of `gfs_fsck` in the following ways:

- Pressing **Ctrl+C** while running the `fsck.gfs2` command interrupts processing and displays a prompt asking whether you would like to abort the command, skip the rest of the current pass, or continue processing.
- You can increase the level of verbosity by using the `-v` flag. Adding a second `-v` flag increases the level again.
- You can decrease the level of verbosity by using the `-q` flag. Adding a second `-q` flag decreases the level again.
- The `-n` option opens a file system as read only and answers **no** to any queries automatically. The option provides a way of trying the command to reveal errors without actually allowing the `fsck.gfs2` command to take effect.

Refer to the `fsck.gfs2` man page for additional information about other command options.

Running the `fsck.gfs2` command requires system memory above and beyond the memory used for the operating system and kernel. Each block of memory in the GFS2 file system itself requires approximately five bits of additional memory, or 5/8 of a byte. So to estimate how many bytes of memory you will need to run the `fsck.gfs2` command on your file system, determine how many blocks the file system contains and multiply that number by 5/8.

For example, to determine approximately how much memory is required to run the `fsck.gfs2` command on a GFS2 file system that is 16TB with a block size of 4K, first determine how many blocks of memory the file system contains by dividing 16TB by 4K:

```
17592186044416 / 4096 = 4294967296
```

Since this file system contains 4294967296 blocks, multiply that number by 5/8 to determine how many bytes of memory are required:

```
4294967296 * 5/8 = 2684354560
```

This file system requires approximately 2.6GB of free memory to run the `fsck.gfs2` command. Note that if the block size was 1K, running the `fsck.gfs2` command would require four times the memory, or approximately 11GB.

Usage

```
fsck.gfs2 -y BlockDevice
```

-y

The `-y` flag causes all questions to be answered with **yes**. With the `-y` flag specified, the `fsck.gfs2` command does not prompt you for an answer before making changes.

BlockDevice

Specifies the block device where the GFS2 file system resides.

Example

In this example, the GFS2 file system residing on block device `/dev/testvg/testlv` is repaired. All queries to repair are automatically answered with `yes`.

```
# fsck.gfs2 -y /dev/testvg/testlv
Initializing fsck
Validating Resource Group index.
Level 1 RG check.
(level 1 passed)
Clearing journals (this may take a while)...
Journals cleared.
Starting pass1
Pass1 complete
Starting pass1b
Pass1b complete
Starting pass1c
Pass1c complete
Starting pass2
Pass2 complete
Starting pass3
Pass3 complete
Starting pass4
Pass4 complete
Starting pass5
Pass5 complete
Writing changes to disk
fsck.gfs2 complete
```

3.12. THE GFS2 WITHDRAW FUNCTION

The GFS2 *withdraw* function is a data integrity feature of the GFS2 file system that prevents potential file system damage due to faulty hardware or kernel software. If the GFS2 kernel module detects an inconsistency while using a GFS2 file system on any given cluster node, it withdraws from the file system, leaving it unavailable to that node until it is unmounted and remounted (or the machine detecting the problem is rebooted). All other mounted GFS2 file systems remain fully functional on that node. (The GFS2 withdraw function is less severe than a kernel panic, which causes the node to be fenced.)

The main categories of inconsistency that can cause a GFS2 withdraw are as follows:

- Inode consistency error
- Resource group consistency error
- Journal consistency error
- Magic number metadata consistency error
- Metadata type consistency error

An example of an inconsistency that would cause a GFS2 withdraw is an incorrect block count for a

file's inode. When GFS2 deletes a file, it systematically removes all the data and metadata blocks referenced by that file. When done, it checks the inode's block count. If the block count is not 1 (meaning all that is left is the disk inode itself), that indicates a file system inconsistency, since the inode's block count did not match the actual blocks used for the file.

In many cases, the problem may have been caused by faulty hardware (faulty memory, motherboard, HBA, disk drives, cables, and so forth). It may also have been caused by a kernel bug (another kernel module accidentally overwriting GFS2's memory), or actual file system damage (caused by a GFS2 bug).

In most cases, the GFS2 inconsistency is fixed by rebooting the cluster node. Before rebooting the cluster node, disable the GFS2 file system "clone" service from Pacemaker, which unmounts the file system on that node only.

```
# pcs resource disable --wait=100 mydata_fs_clone
# /sbin/reboot
```



WARNING

Do not try to unmount and remount the file system manually with the **umount** and **mount** commands. You must use the **pcs** command, otherwise Pacemaker will detect the file system service has disappeared and fence the node.

The consistency problem that caused the withdraw may make stopping the file system service impossible as it may cause the system to hang.

If the problem persists after a remount, you should stop the file system service to unmount the file system from all nodes in the cluster, then perform a file system check with the **fsck.gfs2** command before restarting the service with the following procedure.

1. Reboot the affected node.
2. Disable the non-clone file system service in Pacemaker to unmount the file system from every node in the cluster.

```
# pcs resource disable --wait=100 mydata_fs
```

3. From one node of the cluster, run the **fsck.gfs2** command on the file system device to check for and repair any file system damage.

```
# fsck.gfs2 -y /dev/vg_mydata/mydata > /tmp/fsck.out
```

4. Remount the GFS2 file system from all nodes by re-enabling the file system service:

```
# pcs resource enable --wait=100 mydata_fs
```

You can override the GFS2 withdraw function by mounting the file system with the **-o errors=panic** option specified in the file system service.


```
# pcs resource update mydata_fs "options=noatime,errors=panic"
```

When this option is specified, any errors that would normally cause the system to withdraw force a kernel panic instead. This stops the node's communications, which causes the node to be fenced. This is especially useful for clusters that are left unattended for long periods of time without monitoring or intervention.

Internally, the GFS2 withdraw function works by disconnecting the locking protocol to ensure that all further file system operations result in I/O errors. As a result, when the withdraw occurs, it is normal to see a number of I/O errors from the device mapper device reported in the system logs.

CHAPTER 4. DIAGNOSING AND CORRECTING PROBLEMS WITH GFS2 FILE SYSTEMS

This chapter provides information about some common GFS2 issues and how to address them.

4.1. GFS2 FILE SYSTEM SHOWS SLOW PERFORMANCE

You may find that your GFS2 file system shows slower performance than an ext3 file system. GFS2 performance may be affected by a number of influences and in certain use cases. Information that addresses GFS2 performance issues is found throughout this document.

4.2. GFS2 FILE SYSTEM HANGS AND REQUIRES REBOOT OF ONE NODE

If your GFS2 file system hangs and does not return commands run against it, but rebooting one specific node returns the system to normal, this may be indicative of a locking problem or bug. Should this occur, gather the following data:

- The GFS2 lock dump for the file system on each node:

```
cat /sys/kernel/debug/gfs2/fsname/glocks >glocks.fsname.nodename
```

- The DLM lock dump for the file system on each node: You can get this information with the `dlm_tool`:

```
dlm_tool lockdebug -sv lname.
```

In this command, *lname* is the lockspace name used by DLM for the file system in question. You can find this value in the output from the `group_tool` command.

- The output from the `sysrq -t` command.
- The contents of the `/var/log/messages` file.

Once you have gathered that data, you can open a ticket with Red Hat Support and provide the data you have collected.

4.3. GFS2 FILE SYSTEM HANGS AND REQUIRES REBOOT OF ALL NODES

If your GFS2 file system hangs and does not return commands run against it, requiring that you reboot all nodes in the cluster before using it, check for the following issues.

- You may have had a failed fence. GFS2 file systems will freeze to ensure data integrity in the event of a failed fence. Check the messages logs to see if there are any failed fences at the time of the hang. Ensure that fencing is configured correctly.
- The GFS2 file system may have withdrawn. Check through the messages logs for the word `withdraw` and check for any messages and call traces from GFS2 indicating that the file system has been withdrawn. A withdraw is indicative of file system corruption, a storage failure, or a bug. At the earliest time when it is convenient to unmount the file system, you should perform the following procedure:

1. Reboot the node on which the withdraw occurred.

```
# /sbin/reboot
```

2. Stop the file system resource to unmount the GFS2 file system on all nodes.

```
# pcs resource disable --wait=100 mydata_fs
```

3. Capture the metadata with the `gfs2_edit savemeta...` command. You should ensure that there is sufficient space for the file, which in some cases may be large. In this example, the metadata is saved to a file in the `/root` directory.

```
# gfs2_edit savemeta /dev/vg_mydata/mydata /root/gfs2metadata.gz
```

4. Update the `gfs2-utils` package.

```
# sudo yum update gfs2-utils
```

5. On one node, run the `fsck.gfs2` command on the file system to ensure file system integrity and repair any damage.

```
# fsck.gfs2 -y /dev/vg_mydata/mydata > /tmp/fsck.out
```

6. After the `fsck.gfs2` command has completed, re-enable the file system resource to return it to service:

```
# pcs resource enable --wait=100 mydata_fs
```

7. Open a support ticket with Red Hat Support. Inform them you experienced a GFS2 withdraw and provide logs and the debugging information generated by the `sosreports` and `gfs2_edit savemeta` commands.

In some instances of a GFS2 withdraw, commands can hang that are trying to access the file system or its block device. In these cases a hard reboot is required to reboot the cluster.

For information on the GFS2 withdraw function, see [Section 3.12, “The GFS2 Withdraw Function”](#).

- This error may be indicative of a locking problem or bug. Gather data during one of these occurrences and open a support ticket with Red Hat Support, as described in [Section 4.2, “GFS2 File System Hangs and Requires Reboot of One Node”](#).

4.4. GFS2 FILE SYSTEM DOES NOT MOUNT ON NEWLY ADDED CLUSTER NODE

If you add a new node to a cluster and find that you cannot mount your GFS2 file system on that node, you may have fewer journals on the GFS2 file system than nodes attempting to access the GFS2 file system. You must have one journal per GFS2 host you intend to mount the file system on (with the exception of GFS2 file systems mounted with the `spectator` mount option set, since these do not require a journal). You can add journals to a GFS2 file system with the `gfs2_jadd` command, as described in [Section 3.7, “Adding Journals to a File System”](#).

4.5. SPACE INDICATED AS USED IN EMPTY FILE SYSTEM

If you have an empty GFS2 file system, the `df` command will show that there is space being taken up. This is because GFS2 file system journals consume space (number of journals * journal size) on disk. If you created a GFS2 file system with a large number of journals or specified a large journal size then you will see (number of journals * journal size) as already in use when you execute the `df` command. Even if you did not specify a large number of journals or large journals, small GFS2 file systems (in the 1GB or less range) will show a large amount of space as being in use with the default GFS2 journal size.

CHAPTER 5. CONFIGURING A GFS2 FILE SYSTEM IN A CLUSTER

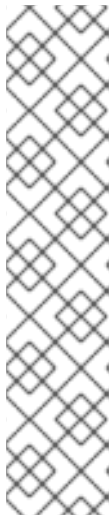
The following procedure is an outline of the steps required to set up a Pacemaker cluster that includes a GFS2 file system.

After installing and starting the cluster software on all nodes, create the cluster. You must configure fencing for the cluster. For information on creating a Pacemaker cluster and configuring fencing for the cluster, see [Creating a Red Hat High-Availability Cluster with Pacemaker](#) in [High Availability Add-On Administration](#). Once you have done this, perform the following procedure.

1. On all nodes of the cluster, install the `lvm2-cluster` and `gfs2-utils` packages, which are part of the Resilient Storage channel.

```
# yum install lvm2-cluster gfs2-utils
```

2. Set the global Pacemaker parameter `no-quorum-policy` to `freeze`.



NOTE

By default, the value of `no-quorum-policy` is set to `stop`, indicating that once quorum is lost, all the resources on the remaining partition will immediately be stopped. Typically this default is the safest and most optimal option, but unlike most resources, GFS2 requires quorum to function. When quorum is lost both the applications using the GFS2 mounts and the GFS2 mount itself cannot be correctly stopped. Any attempts to stop these resources without quorum will fail which will ultimately result in the entire cluster being fenced every time quorum is lost.

To address this situation, you can set the `no-quorum-policy=freeze` when GFS2 is in use. This means that when quorum is lost, the remaining partition will do nothing until quorum is regained.

```
# pcs property set no-quorum-policy=freeze
```

3. Set up a `dlm` resource. This is a required dependency for `clvmd` and GFS2.

```
# pcs resource create dlm ocf:pacemaker:controld op monitor
interval=30s on-fail=fence clone interleave=true ordered=true
```

4. Execute the following command in each node of the cluster to enable clustered locking. This command sets the `locking_type` parameter in the `/etc/lvm/lvm.conf` file to 3.

```
# /sbin/lvmconf --enable-cluster
```

5. Set up `clvmd` as a cluster resource.

```
# pcs resource create clvmd ocf:heartbeat:clvm op monitor
interval=30s on-fail=fence clone interleave=true ordered=true
```

Note that the `clvmd` and `cmirrord` daemons are started and managed by Pacemaker using

the `ocf:heartbeat:clvm` resource agent and do not need to be started during boot with `systemd`. Additionally, the `ocf:heartbeat:clvm` resource agent, as part of the start procedure, sets the `locking_type` parameter in the `/etc/lvm/lvm.conf` file to 3 and disables the `lvm` daemon.

6. Set up `clvmd` and `dlm` dependency and start up order. `clvmd` must start after `dlm` and must run on the same node as `dlm`.

```
# pcs constraint order start dlm-clone then clvmd-clone
# pcs constraint colocation add clvmd-clone with dlm-clone
```

7. Create the clustered logical volume.

```
# pvcreate /dev/vdb
# vgcreate -Ay -cy cluster_vg /dev/vdb
# lvcreate -L5G -n cluster_lv cluster_vg
```



WARNING

When you create volume groups with CLVM on shared storage, you must ensure that all nodes in the cluster have access to the physical volumes that constitute the volume group. Asymmetric cluster configurations in which some nodes have access to the storage and others do not are not supported.

When managing volume groups using CLVMD to allow for concurrent activation of volumes across multiple nodes, the volume groups *must* have the clustered flag enabled. This flag allows CLVMD to identify the volumes it must manage, which is what enables CLVMD to maintain LVM metadata continuity. Failure to adhere to this configuration renders the configuration unsupported by Red Hat and may result in storage corruption and loss of data.

8. Format the logical volume with a GFS2 file system. Ensure that you create enough journals for each of the nodes in your cluster.

```
# mkfs.gfs2 -j2 -p lock_dlm -t rhel7-demo:gfs2-demo
/dev/cluster_vg/cluster_lv
```

**WARNING**

When you create the GFS2 filesystem, it is important to specify a correct value for the `-t LockTableName` option. The correct format is *ClusterName:FSName*. Failure to specify a correct value will prevent the filesystem from mounting and may cause corruption. For more information on the options for the `mkfs.gfs2` command, see [Section 3.1, “Making a File System”](#).

9. Configure a `clusterfs` resource.

You should not add the file system to the `/etc/fstab` file because it will be managed as a Pacemaker cluster resource. Mount options can be specified as part of the resource configuration with `options=options`. Run the `pcs resource describe Filesystem` command for full configuration options.

This cluster resource creation command specifies the `noatime` mount option.

```
# pcs resource create clusterfs Filesystem
device="/dev/cluster_vg/cluster_lv" directory="/var/mountpoint"
fstype="gfs2" "options=noatime" op monitor interval=10s on-
fail=fence clone interleave=true
```

10. Set up GFS2 and `clvmd` dependency and startup order. GFS2 must start after `clvmd` and must run on the same node as `clvmd`.

```
# pcs constraint order start clvmd-clone then clusterfs-clone
# pcs constraint colocation add clusterfs-clone with clvmd-clone
```

11. Verify that GFS2 is mounted as expected.

```
# mount |grep /mnt/gfs2-demo
/dev/mapper/cluster_vg-cluster_lv on /mnt/gfs2-demo type gfs2
(rw,noatime,seclabel)
```

APPENDIX A. GFS2 PERFORMANCE ANALYSIS WITH PERFORMANCE CO-PILOT

Red Hat Enterprise Linux 7 supports Performance Co-Pilot (PCP) with GFS2 performance metrics. This allows you to monitor the performance of a GFS2 file system. This appendix describes the GFS2 performance metrics and how to use them.

A.1. OVERVIEW OF PERFORMANCE CO-PILOT

Performance Co-Pilot (PCP) is a open source toolkit for monitoring, visualizing, recording, and controlling the status, activities and performance of computers, applications and servers. PCP allows the monitoring and management of both real-time data and the logging and retrieval of historical data. Historical data can be used to analyze any patterns with issues by comparing live results over the archived data.

PCP is designed with a client-server architecture. The PCP collector service is the Performance Metric Collector Daemon (PMCD), which can be installed and run on a server. Once it is started, PCMD begins collecting performance data from the installed Performance Metric Domain Agents (PMDAs). PMDAs can be individually loaded or unloaded on the system and are controlled by the PMCD on the same host. The GFS2 PMDA, which is part of the default PCP installation, is used. to gather performance metric data of GFS2 file systems in PCP.

[Table A.1, “PCP Tools”](#) provides a brief list of some PCP tools in the PCP Toolkit that this chapter describes. For information about additional PCP tools, see the **PCPIntro(1)** man page and the additional PCP man pages.

Table A.1. PCP Tools

Tool	Use
pmcd	Performance Metric Collector Service: collects the metric data from the PMDA and makes the metric data available for the other components in PCP
pmlogger	Allows the creation of archive logs of performance metric values which may be played back by other PCP tools
pmproxy	A protocol proxy for pmcd which allows PCP monitoring clients to connect to one or more instances of pmcd by means of pmproxy
pminfo	Displays information about performance metrics on the command line
pmstore	Allows the modification of performance metric values (re-initialize counters or assign new values)
pmdump text	Exports performance metric data either live or from performance archives to an ASCII table
pmchart	Graphical utility that plots performance metric values into charts (pcp-gui package)

A.2. PCP DEPLOYMENT

To monitor an entire cluster, the recommended approach is to install and configure PCP so that the GFS2 PMDA is enabled and loaded on each node of the cluster along with any other PCP services. You will then be able to monitor nodes either locally or remotely on a machine that has PCP installed with the corresponding PMDAs loaded in monitor mode. You may also install the optional **pcp-gui** package to allow graphical representation of trace data through the **pmchart** tool

For additional information, see the **pcp-doc** package, which is installed to `/usr/share/doc/pcp-doc` by default. PCP also provides a man page for every tool.

A.3. PCP INSTALLATION

The most recent tested version of PCP should be available to download from the Red Hat Enterprise Linux 7 repositories.

The **debugfs** file system must be mounted in order for the GFS2 PMDA to operate correctly. If the **debugfs** file system is not mounted, run the following commands before installing the GFS2 PMDA.

```
# mkdir /sys/kernel/debug
# mount -t debugfs none /sys/kernel/debug
```

The GFS2 PMDA is not enabled by default upon installation. In order use GFS2 metric monitoring through PCP, you must enable the GFS2 domain agent. Use the following commands to install PCP and the GFS2 PMDA module and to enable GFS2 PMDA. Note that the PMDA install script must be run as **root**.

```
# yum install pcp pcp-gui pcp-pmda-gfs2
# cd /var/lib/pcp/pmdas/gfs2
# ./Install
```

When running the PMDA installation script, you will be prompted for which role you would like the PMDA to take:

- **collector** allows the collection of performance metrics on the current system
- **monitor** only allows the system to monitor local system or remote systems or both local and remote system
- **both** enables both the **collector** and **monitor** configurations

In most cases the default choice (both collector and monitor) is sufficient to allow the PMDA to operate correctly.

```
# ./Install
```

You will need to choose an appropriate configuration for installation of the "gfs2" Performance Metrics Domain Agent (PMDA).

```
collector collect performance statistics on this system
monitor allow this system to monitor local and/or remote systems
both collector and monitor configuration for this system
```

Please enter c(ollector) or m(onitor) or b(oth) [b]

```

Updating the Performance Metrics Name Space (PMNS) ...
Terminate PMDA if already installed ...
Updating the PMCD control file, and notifying PMCD ...
Waiting for pmcd to terminate ...
Starting pmcd ...
Starting pmlogger ...
Check gfs2 metrics have appeared ... 316 metrics and 205 values

```

If there are any errors or warning with the installation of the GFS2 PMDA, make sure that PMCD is started and running and that **debugfs** is mounted (there may be warnings in the event that there is not at least one GFS2 file system loaded on the system).



NOTE

When installing the GFS2 PMDA on cluster nodes the default choice for PMDA configuration (both) will be sufficient to allow the PMDA to run correctly. On workstation machines where you intend just to monitor the data from remote PCP installations, it is recommended you install the PMDA as a monitor.

A.4. TRACING GFS2 PERFORMANCE DATA

With PCP installed and the GFS2 PMDA enabled, the easiest way to start looking at the performance metrics available for PCP and GFS2 is to make use of the **pminfo** tool. The **pminfo** command line tool displays information about available performance metrics. Normally **pminfo** operates using the local metric namespace but you can change this to view the metrics on a remote host by using the **-h** flag. For further information on the **pminfo** tool, see the **pminfo(1)** man page.

The following command displays a list of all available GFS2 metrics provided by the GFS2 PMDA.

```
# pminfo gfs2
```

You can specify the **-T** flag order to obtain help information and descriptions for each metric along with the **-f** flag to obtain a current reading of the performance value that corresponds to each metric. You can do this for a group of metrics or an individual metric. Most metric data is provided for each mounted GFS2 file system on the system at time of probing.

```

# pminfo -t gfs2.glocks
gfs2.glocks.total [Count of total observed incore GFS2 global locks]
gfs2.glocks.shared [GFS2 global locks in shared state]
gfs2.glocks.unlocked [GFS2 global locks in unlocked state]
gfs2.glocks.deferred [GFS2 global locks in deferred state]
gfs2.glocks.exclusive [GFS2 global locks in exclusive state]

# pminfo -T gfs2.glocks.total

gfs2.glocks.total
Help:
Count of total incore GFS2 glock data structures based on parsing the
contents
of the /sys/kernel/debug/gfs2/bdev/glocks files.

# pminfo -f gfs2.glocks.total

```

```
gfs2.glocks.total
  inst [0 or "testcluster:clvmd_gfs2"] value 74
```

There are six different groups of GFS2 metrics, are arranged so that each different group is a new leaf node from the root GFS2 metric using a '.' as a separator; this is true for all PCP metrics. [Table A.2, “PCP Metric Groups for GFS2”](#) outlines the types of metrics that are available in each of the groups. With each metric, additional information can be found by using the `pminfo` tool with the `-T` flag.

Table A.2. PCP Metric Groups for GFS2

Metric Group	Metric Provided
gfs2.sbstats.*	Timing metrics regarding the information collected from the superblock stats file (sbstats) for each GFS2 file system currently mounted on the system.
gfs2.glocks.*	Metrics regarding the information collected from the glock stats file (glocks) which count the number of glocks in each state that currently exists for each GFS2 file system currently mounted on the system.
gfs2.glstats.*	Metrics regarding the information collected from the glock stats file (glstats) which count the number of each type of glock that currently exists for each GFS2 file system currently mounted on the system.
gfs2.tracepoints.*	Metrics regarding the output from the GFS2 debugfs tracepoints for each file system currently mounted on the system. Each sub-type of these metrics (one of each GFS2 tracepoint) can be individually controlled whether on or off using the control metrics.
gfs2.worst_glock.*	A computed metric making use of the data from the gfs2_glock_lock_time tracepoint to calculate a perceived “current worst glock” for each mounted file system. This metric is useful for discovering potential lock contention and file system slows down if the same lock is suggested multiple times.
gfs2.latency.grant.*	A computed metric making use of the data from both the gfs2_glock_queue and gfs2_glock_state_change tracepoints to calculate an average latency in microseconds for glock grant requests to be completed for each mounted file system. This metric is useful for discovering potential slowdowns on the file system when the grant latency increases.
gfs2.latency.demote.*	A computed metric making use of the data from both the gfs2_glock_state_change and gfs2_demote_rq tracepoints to calculate an average latency in microseconds for glock demote requests to be completed for each mounted file system. This metric is useful for discovering potential slowdowns on the file system when the demote latency increases.

Metric Group	Metric Provided
<code>gfs2.latency.queue.*</code>	A computed metric making use of the data from the <code>gfs2_glock_queue</code> tracepoint to calculate an average latency in microseconds for glock queue requests to be completed for each mounted file system.
<code>gfs2.control.*</code>	Configuration metrics which are used to control what tracepoint metrics are currently enabled or disabled and are toggled by means of the <code>pmstore</code> tool. These configuration metrics are described in Section A.5, “Metric Configuration (using <code>pmstore</code>)” .

A.5. METRIC CONFIGURATION (USING `PMSTORE`)

Some metrics in PCP allow the modification of their values, especially in the case where the metric acts as a control variable. This is the case with the `gfs2.control.*` metrics with the GFS2 PMDA. This is achieved through the use of the `pmstore` command line tool. As with most of the other PCP tools, the `pmstore` tool normally changes the current value for the specified metric on the local system, but you can use the `-h` switch to allow the change of metric values on specified remote systems. For further information, see the `pmstore(3)` man page.

As an example, the following command enables all of the GFS2 tracepoints on the local machine on a system with the GFS2 PMDA installed and loaded. When this command is run, the PMDA will switch on all of the GFS2 tracepoints in the `debugfs` file system.

```
# pmstore gfs2.control.tracepoints.all 1
gfs2.control.tracepoints.all old value=0 new value=1
```

[Table A.3, “Control Tracepoints”](#) describes each of the control tracepoints and its usage. An explanation on the effect of each control tracepoint and its available options is available through the help switch in the `pminfo` tool.

Table A.3. Control Tracepoints

Control Metric	Use and Available Options
<code>gfs2.contol.tracepoint s.all</code>	The GFS2 tracepoint statistics can be manually controlled using 0 [off] or 1 [on]. Setting the value of the metric controls the behavior of the PMDA to whether it tries to collect from tracepoint metrics or not.
<code>gfs2.control.tracepoin ts.*</code>	The GFS2 tracepoint statistics can be manually controlled using 0 [off] or 1 [on]. Setting the value of the metric controls the behavior of the PMDA to whether it tries to collect from each specified tracepoint metric or not.
<code>gfs2.control.global_tr acing</code>	The global tracing can be controlled using 0 [off] or 1 [on]. This is required to be on for most of the GFS2 metrics to function.

Control Metric	Use and Available Options
gfs2.control.worst_glock	Can be individually controlled whether on or off using the control metrics.0 [off] or 1 [on]. Setting the value of the metric controls the behavior of the PMDA to whether it tries to collect the lock_time metrics or not. The machine must have the GFS2 tracepoints available for the glock_lock_time based metrics to function.
gfs2.control.latency	The gfs2.latency statistics can be manually controlled using pmstore gfs2.control.latency 0 [off] or 1 [on]. Setting the value of the metric controls the behavior of the PMDA to whether it tries to collect the latency metrics or not. The machine must have the gfs2 tracepoints available for the latency metrics to function.
gfs2.control.glock_threshold	The number of glocks that will be processed and accepted over all ftrace statistics. This number can be manually altered using the pmstore tool in order to tailor the number of glocks processed. This value must be positive.

A.6. LOGGING PERFORMANCE DATA (USING **PMLOGGER**)

PCP allows you to log performance metric values which can replayed at a later date by creating archived logs of selected metrics on the system through the **pmlogger** tool. These metric archives may be played back at a later date to give retrospective performance analysis.

The **pmlogger** tool provides flexibility and control over the logged metrics by allowing you to specify which metrics are recorded on the system and at what frequency. By default, the configuration file for **pmlogger** is stored at `/var/lib/pcp/config/pmlogger/config.default`; the configuration file outlines which metrics are logged by the primary logging instance.

In order for **pmlogger** to log metric values on the local machine, a primary logging instance must be started. You can use **systemctl** to ensure that **pmlogger** is started as a service when the machine starts.

The following example shows an extract of a **pmlogger** configuration file which enables the recording of GFS2 performance metrics. This extract shows that **pmlogger** will log the performance metric values for the PCP GFS2 latency metrics every 10 seconds, the top 10 worst glock metric every 30 seconds, the tracepoint data every minute, and it will log the data from the **glock**, **glstats** and **sbstats** metrics every 10 minutes.

```
# It is safe to make additions from here on ...
#

log mandatory on every 5 seconds {
    gfs2.latency.grant
    gfs2.latency.queue
    gfs2.latency.demote
    gfs2.glocks
}

log mandatory on every 10 seconds {
    gfs2.worst_glock
```

```

}

log mandatory on every 30 seconds {
    gfs2.tracepoints
}

log mandatory on every 5 minutes {
    gfs2.glstats
    gfs2.sbstats
}

[access]
disallow * : all;
allow localhost : enquire;

```



NOTE

PCP comes with a default set of metrics which it will log on the host when **pmlogger** is enabled. However, no logging of GFS2 metrics occur with this default configuration.

After recording metric data, you have multiple options when it comes to the replaying of PCP log archives on the system. You can export the logs to text files and import them into spreadsheets, or you can replay them in the PCP-GUI application using graphs to visualize the retrospective data alongside live data of the system.

One of the tools available in PCP for viewing the log files is **pmdumptext**. This tool allows the user to parse the selected PCP log archive and export the values into an ASCII table. **pmdumptext** can be used to dump the entire archive log or only select metric values from the log by specifying individual metrics through the command line. For more information on using **pmdumptext**, see the **pmdumptext(1)** man page.

A.7. VISUAL TRACING (USING PCP-GUI AND PMCHART)

Through the use of the PCP-GUI package, you can use the **pmchart** graphical utility to plot performance metric values into graphs. The **pmchart** utility allows multiple charts to be displayed simultaneously, with metrics being sourced from one or more live hosts with alternative options to use metric data from PCP log archives as a source of historical data.

When you open **pmchart**, the PCP charts GUI displays. On the bottom of the display is the **pmtime** VCR-like controls. The start/pause button allows you to control the interval in which the metric data is polled and in the event that you are using historical data, the date and time for the metrics.

From the **File -> New Chart** option in the toolbar, you can select a metric from both the local machine and remote machines by specifying their host name or address and then selecting performance metrics from the remote hosts. Advanced configuration options include the ability to manually set the axis values for the chart and to manually choose the color of the plots.

There are multiple options to take images or record the views created in **pmchart**. You can save an image of the current view through the **File -> Export** option in the toolbar. Recording is made available by the **Record -> Start** option in the toolbar and these recordings can be stopped at a later time using **Record -> Stop**. After the recording has been terminated, the recorded metrics are archived to be viewed at a later date.

You can customize the **pmchart** interface to display the data from performance metrics in multiple

ways, including line plot, bar graphs and utilization graphs. In `pmchart`, the main configuration file known as the “view” allows the metadata associated with one or more charts to be saved. This metadata describes all of the chart's aspects including the metrics used and the chart columns. You can create a custom “view” configuration which can be saved using **File -> Save View** and then loaded again at a later time. For more information about view configuration files and their syntax, see the `pmchart(1)` man page.

The following example `pmchart` view configuration describes a stacking chart graph showing the total number of glocks for the mounted GFS2 file system `loop1` using the `gfs2.glocks` metric. We also have a plot graph underneath which plots the average latency for the glock grant, demote and queue requests for the same file system instance “`loop1`”.

```
#kmchart
version 1

chart title "Total number of Glocks /loop1" style stacking antialiasing
off
    plot legend "Shared"    metric gfs2.glocks.shared    instance "loop1"
    plot legend "Unlocked"  metric gfs2.glocks.unlocked  instance "loop1"
    plot legend "Deferred"  metric gfs2.glocks.deferred  instance "loop1"
    plot legend "Exclusive" metric gfs2.glocks.exclusive instance "loop1"

chart title "Average Glock Latency (usecs) /loop1" style plot antialiasing
off
    plot legend "Demote"  metric gfs2.latency.demote.all instance "loop1"
    plot legend "Grant"   metric gfs2.latency.grant.all  instance "loop1"
    plot legend "Queue"   metric gfs2.latency.queue.all  instance "loop1"
```

APPENDIX B. GFS2 TRACEPOINTS AND THE DEBUGFS GLOCKS FILE

This appendix describes both the `glock debugfs` interface and the GFS2 tracepoints. It is intended for advanced users who are familiar with file system internals who would like to learn more about the design of GFS2 and how to debug GFS2-specific issues.

B.1. GFS2 TRACEPOINT TYPES

There are currently three types of GFS2 tracepoints: *glock* (pronounced "gee-lock") tracepoints, *bmap* tracepoints and *log* tracepoints. These can be used to monitor a running GFS2 file system and give additional information to that which can be obtained with the debugging options supported in previous releases of Red Hat Enterprise Linux. Tracepoints are particularly useful when a problem, such as a hang or performance issue, is reproducible and thus the tracepoint output can be obtained during the problematic operation. In GFS2, glocks are the primary cache control mechanism and they are the key to understanding the performance of the core of GFS2. The bmap (block map) tracepoints can be used to monitor block allocations and block mapping (lookup of already allocated blocks in the on-disk metadata tree) as they happen and check for any issues relating to locality of access. The log tracepoints keep track of the data being written to and released from the journal and can provide useful information on that part of GFS2.

The tracepoints are designed to be as generic as possible. This should mean that it will not be necessary to change the API during the course of Red Hat Enterprise Linux 7. On the other hand, users of this interface should be aware that this is a debugging interface and not part of the normal Red Hat Enterprise Linux 7 API set, and as such Red Hat makes no guarantees that changes in the GFS2 tracepoints interface will not occur.

Tracepoints are a generic feature of Red Hat Enterprise Linux 7 and their scope goes well beyond GFS2. In particular they are used to implement the `blktrace` infrastructure and the `blktrace` tracepoints can be used in combination with those of GFS2 to gain a fuller picture of the system performance. Due to the level at which the tracepoints operate, they can produce large volumes of data in a very short period of time. They are designed to put a minimum load on the system when they are enabled, but it is inevitable that they will have some effect. Filtering events by a variety of means can help reduce the volume of data and help focus on obtaining just the information which is useful for understanding any particular situation.

B.2. TRACEPOINTS

The tracepoints can be found under the `/sys/kernel/debug/tracing/` directory assuming that `debugfs` is mounted in the standard place at the `/sys/kernel/debug` directory. The `events` subdirectory contains all the tracing events that may be specified and, provided the `gfs2` module is loaded, there will be a `gfs2` subdirectory containing further subdirectories, one for each GFS2 event. The contents of the `/sys/kernel/debug/tracing/events/gfs2` directory should look roughly like the following:

```
[root@chywoon gfs2]# ls
enable                gfs2_bmap             gfs2_glock_queue      gfs2_log_flush
filter                gfs2_demote_rq        gfs2_glock_state_change gfs2_pin
gfs2_block_alloc     gfs2_glock_put        gfs2_log_blocks       gfs2_promote
```

To enable all the GFS2 tracepoints, enter the following command:


```
[root@chywoon gfs2]# echo -n 1
>/sys/kernel/debug/tracing/events/gfs2/enable
```

To enable a specific tracepoint, there is an **enable** file in each of the individual event subdirectories. The same is true of the **filter** file which can be used to set an event filter for each event or set of events. The meaning of the individual events is explained in more detail below.

The output from the tracepoints is available in ASCII or binary format. This appendix does not currently cover the binary interface. The ASCII interface is available in two ways. To list the current content of the ring buffer, you can enter the following command:

```
[root@chywoon gfs2]# cat /sys/kernel/debug/tracing/trace
```

This interface is useful in cases where you are using a long-running process for a certain period of time and, after some event, want to look back at the latest captured information in the buffer. An alternative interface, `/sys/kernel/debug/tracing/trace_pipe`, can be used when all the output is required. Events are read from this file as they occur; there is no historical information available through this interface. The format of the output is the same from both interfaces and is described for each of the GFS2 events in the later sections of this appendix.

A utility called **trace-cmd** is available for reading tracepoint data. For more information on this utility, see the link in [Section B.10, “References”](#). The **trace-cmd** utility can be used in a similar way to the **strace** utility, for example to run a command while gathering trace data from various sources.

B.3. GLOCKS

To understand GFS2, the most important concept to understand, and the one which sets it aside from other file systems, is the concept of glocks. In terms of the source code, a glock is a data structure that brings together the DLM and caching into a single state machine. Each glock has a 1:1 relationship with a single DLM lock, and provides caching for that lock state so that repetitive operations carried out from a single node of the file system do not have to repeatedly call the DLM, and thus they help avoid unnecessary network traffic. There are two broad categories of glocks, those which cache metadata and those which do not. The inode glocks and the resource group glocks both cache metadata, other types of glocks do not cache metadata. The inode glock is also involved in the caching of data in addition to metadata and has the most complex logic of all glocks.

Table B.1. Glock Modes and DLM Lock Modes

Glock mode	DLM lock mode	Notes
UN	IV/NL	Unlocked (no DLM lock associated with glock or NL lock depending on I flag)
SH	PR	Shared (protected read) lock
EX	EX	Exclusive lock
DF	CW	Deferred (concurrent write) used for Direct I/O and file system freeze

Glocks remain in memory until either they are unlocked (at the request of another node or at the request of the VM) and there are no local users. At that point they are removed from the glock hash

table and freed. When a glock is created, the DLM lock is not associated with the glock immediately. The DLM lock becomes associated with the glock upon the first request to the DLM, and if this request is successful then the 'I' (initial) flag will be set on the glock. [Table B.4, “Glock flags”](#) shows the meanings of the different glock flags. Once the DLM has been associated with the glock, the DLM lock will always remain at least at NL (Null) lock mode until the glock is to be freed. A demotion of the DLM lock from NL to unlocked is always the last operation in the life of a glock.

Each glock can have a number of "holders" associated with it, each of which represents one lock request from the higher layers. System calls relating to GFS2 queue and dequeue holders from the glock to protect the critical section of code.

The glock state machine is based on a work queue. For performance reasons, tasklets would be preferable; however, in the current implementation we need to submit I/O from that context which prohibits their use.



NOTE

Workqueues have their own tracepoints which can be used in combination with the GFS2 tracepoints.

[Table B.2, “Glock Modes and Data Types”](#) shows what state may be cached under each of the glock modes and whether that cached state may be dirty. This applies to both inode and resource group locks, although there is no data component for the resource group locks, only metadata.

Table B.2. Glock Modes and Data Types

Glock mode	Cache Data	Cache Metadata	Dirty Data	Dirty Metadata
UN	No	No	No	No
SH	Yes	Yes	No	No
DF	No	Yes	No	No
EX	Yes	Yes	Yes	Yes

B.4. THE GLOCK DEBUGFS INTERFACE

The glock `debugfs` interface allows the visualization of the internal state of the glocks and the holders and it also includes some summary details of the objects being locked in some cases. Each line of the file either begins G: with no indentation (which refers to the glock itself) or it begins with a different letter, indented with a single space, and refers to the structures associated with the glock immediately above it in the file (H: is a holder, I: an inode, and R: a resource group) . Here is an example of what the content of this file might look like:

```
G:  s:SH n:5/75320 f:I t:SH d:EX/0 a:0 r:3
  H: s:SH f:EH e:0 p:4466 [postmark] gfs2_inode_lookup+0x14e/0x260 [gfs2]
G:  s:EX n:3/258028 f:yI t:EX d:EX/0 a:3 r:4
  H: s:EX f:tH e:0 p:4466 [postmark] gfs2_inplace_reserve_i+0x177/0x780
    [gfs2]
  R: n:258028 f:05 b:22256/22256 i:16800
G:  s:EX n:2/219916 f:yfI t:EX d:EX/0 a:0 r:3
```

```

I: n:75661/219916 t:8 f:0x10 d:0x00000000 s:7522/7522
G: s:SH n:5/127205 f:I t:SH d:EX/0 a:0 r:3
H: s:SH f:EH e:0 p:4466 [postmark] gfs2_inode_lookup+0x14e/0x260 [gfs2]
G: s:EX n:2/50382 f:yfI t:EX d:EX/0 a:0 r:2
G: s:SH n:5/302519 f:I t:SH d:EX/0 a:0 r:3
H: s:SH f:EH e:0 p:4466 [postmark] gfs2_inode_lookup+0x14e/0x260 [gfs2]
G: s:SH n:5/313874 f:I t:SH d:EX/0 a:0 r:3
H: s:SH f:EH e:0 p:4466 [postmark] gfs2_inode_lookup+0x14e/0x260 [gfs2]
G: s:SH n:5/271916 f:I t:SH d:EX/0 a:0 r:3
H: s:SH f:EH e:0 p:4466 [postmark] gfs2_inode_lookup+0x14e/0x260 [gfs2]
G: s:SH n:5/312732 f:I t:SH d:EX/0 a:0 r:3
H: s:SH f:EH e:0 p:4466 [postmark] gfs2_inode_lookup+0x14e/0x260 [gfs2]

```

The above example is a series of excerpts (from an approximately 18MB file) generated by the command `cat /sys/kernel/debug/gfs2/unity:myfs/glocks >my.lock` during a run of the postmark benchmark on a single node GFS2 file system. The glocks in the figure have been selected in order to show some of the more interesting features of the glock dumps.

The glock states are either EX (exclusive), DF (deferred), SH (shared) or UN (unlocked). These states correspond directly with DLM lock modes except for UN which may represent either the DLM null lock state, or that GFS2 does not hold a DLM lock (depending on the `l` flag as explained above). The `s:` field of the glock indicates the current state of the lock and the same field in the holder indicates the requested mode. If the lock is granted, the holder will have the `H` bit set in its flags (`f:` field). Otherwise, it will have the `W` wait bit set.

The `n:` field (number) indicates the number associated with each item. For glocks, that is the type number followed by the glock number so that in the above example, the first glock is `n:5/75320`; which indicates an `iopen` glock which relates to inode 75320. In the case of inode and `iopen` glocks, the glock number is always identical to the inode's disk block number.



NOTE

The glock numbers (`n:` field) in the `debugfs glocks` file are in hexadecimal, whereas the tracepoints output lists them in decimal. This is for historical reasons; glock numbers were always written in hex, but decimal was chosen for the tracepoints so that the numbers could easily be compared with the other tracepoint output (from `blktrace` for example) and with output from `stat(1)`.

The full listing of all the flags for both the holder and the glock are set out in [Table B.4, “Glock flags”](#) and [Table B.5, “Glock holder flags”](#). The content of lock value blocks is not currently available through the glock `debugfs` interface.

[Table B.3, “Glock Types”](#) shows the meanings of the different glock types.

Table B.3. Glock Types

Type number	Lock type	Use
1	trans	Transaction lock
2	inode	Inode metadata and data

Type number	Lock type	Use
3	rgrp	Resource group metadata
4	meta	The superblock
5	iopen	Inode last closer detection
6	flock	flock(2) syscall
8	quota	Quota operations
9	journal	Journal mutex

One of the more important glock flags is the **I** (locked) flag. This is the bit lock that is used to arbitrate access to the glock state when a state change is to be performed. It is set when the state machine is about to send a remote lock request through the DLM, and only cleared when the complete operation has been performed. Sometimes this can mean that more than one lock request will have been sent, with various invalidations occurring between times.

[Table B.4, “Glock flags”](#) shows the meanings of the different glock flags.

Table B.4. Glock flags

Flag	Name	Meaning
d	Pending demote	A deferred (remote) demote request
D	Demote	A demote request (local or remote)
f	Log flush	The log needs to be committed before releasing this glock
F	Frozen	Replies from remote nodes ignored - recovery is in progress.
i	Invalidate in progress	In the process of invalidating pages under this glock
I	Initial	Set when DLM lock is associated with this glock
l	Locked	The glock is in the process of changing state
L	LRU	Set when the glock is on the LRU list`
o	Object	Set when the glock is associated with an object (that is, an inode for type 2 glocks, and a resource group for type 3 glocks)
p	Demote in progress	The glock is in the process of responding to a demote request

Flag	Name	Meaning
q	Queued	Set when a holder is queued to a glock, and cleared when the glock is held, but there are no remaining holders. Used as part of the algorithm the calculates the minimum hold time for a glock.
r	Reply pending	Reply received from remote node is awaiting processing
y	Dirty	Data needs flushing to disk before releasing this glock

When a remote callback is received from a node that wants to get a lock in a mode that conflicts with that being held on the local node, then one or other of the two flags D (demote) or d (demote pending) is set. In order to prevent starvation conditions when there is contention on a particular lock, each lock is assigned a minimum hold time. A node which has not yet had the lock for the minimum hold time is allowed to retain that lock until the time interval has expired.

If the time interval has expired, then the D (demote) flag will be set and the state required will be recorded. In that case the next time there are no granted locks on the holders queue, the lock will be demoted. If the time interval has not expired, then the d (demote pending) flag is set instead. This also schedules the state machine to clear d (demote pending) and set D (demote) when the minimum hold time has expired.

The I (initial) flag is set when the glock has been assigned a DLM lock. This happens when the glock is first used and the I flag will then remain set until the glock is finally freed (which the DLM lock is unlocked).

B.5. GLOCK HOLDERS

Table B.5, “Glock holder flags” shows the meanings of the different glock holder flags.

Table B.5. Glock holder flags

Flag	Name	Meaning
a	Async	Do not wait for glock result (will poll for result later)
A	Any	Any compatible lock mode is acceptable
c	No cache	When unlocked, demote DLM lock immediately
e	No expire	Ignore subsequent lock cancel requests
E	Exact	Must have exact lock mode
F	First	Set when holder is the first to be granted for this lock
H	Holder	Indicates that requested lock is granted

Flag	Name	Meaning
p	Priority	Enqueue holder at the head of the queue
t	Try	A "try" lock
T	Try 1CB	A "try" lock that sends a callback
W	Wait	Set while waiting for request to complete

The most important holder flags are H (holder) and W (wait) as mentioned earlier, since they are set on granted lock requests and queued lock requests respectively. The ordering of the holders in the list is important. If there are any granted holders, they will always be at the head of the queue, followed by any queued holders.

If there are no granted holders, then the first holder in the list will be the one that triggers the next state change. Since demote requests are always considered higher priority than requests from the file system, that might not always directly result in a change to the state requested.

The glock subsystem supports two kinds of "try" lock. These are useful both because they allow the taking of locks out of the normal order (with suitable back-off and retry) and because they can be used to help avoid resources in use by other nodes. The normal t (try) lock is just what its name indicates; it is a "try" lock that does not do anything special. The T (try 1CB) lock, on the other hand, is identical to the t lock except that the DLM will send a single callback to current incompatible lock holders. One use of the T (try 1CB) lock is with the `iopen` locks, which are used to arbitrate among the nodes when an inode's `i_nlink` count is zero, and determine which of the nodes will be responsible for deallocating the inode. The `iopen` glock is normally held in the shared state, but when the `i_nlink` count becomes zero and `->evict_inode()` is called, it will request an exclusive lock with T (try 1CB) set. It will continue to deallocate the inode if the lock is granted. If the lock is not granted it will result in the node(s) which were preventing the grant of the lock marking their glock(s) with the D (demote) flag, which is checked at `->drop_inode()` time in order to ensure that the deallocation is not forgotten.

This means that inodes that have zero link count but are still open will be deallocated by the node on which the final `close()` occurs. Also, at the same time as the inode's link count is decremented to zero the inode is marked as being in the special state of having zero link count but still in use in the resource group bitmap. This functions like the ext3 file system's orphan list in that it allows any subsequent reader of the bitmap to know that there is potentially space that might be reclaimed, and to attempt to reclaim it.

B.6. GLOCK TRACEPOINTS

The tracepoints are also designed to be able to confirm the correctness of the cache control by combining them with the `blktrace` output and with knowledge of the on-disk layout. It is then possible to check that any given I/O has been issued and completed under the correct lock, and that no races are present.

The `gfs2_glock_state_change` tracepoint is the most important one to understand. It tracks every state change of the glock from initial creation right through to the final demotion which ends with `gfs2_glock_put` and the final NL to unlocked transition. The l (locked) glock flag is always set before a state change occurs and will not be cleared until after it has finished. There are never any granted

holders (the H glock holder flag) during a state change. If there are any queued holders, they will always be in the W (waiting) state. When the state change is complete then the holders may be granted which is the final operation before the I glock flag is cleared.

The `gfs2_demote_rq` tracepoint keeps track of demote requests, both local and remote. Assuming that there is enough memory on the node, the local demote requests will rarely be seen, and most often they will be created by `umount` or by occasional memory reclaim. The number of remote demote requests is a measure of the contention between nodes for a particular inode or resource group.

The `gfs2_glock_lock_time` tracepoint provides information on the time taken by requests to the DLM. The blocking (b) flag was introduced into the glock specifically to be used in combination with this tracepoint.

When a holder is granted a lock, `gfs2_promote` is called, this occurs as the final stages of a state change or when a lock is requested which can be granted immediately due to the glock state already caching a lock of a suitable mode. If the holder is the first one to be granted for this glock, then the f (first) flag is set on that holder. This is currently used only by resource groups.

B.7. BMAP TRACEPOINTS

Block mapping is a task central to any file system. GFS2 uses a traditional bitmap-based system with two bits per block. The main purpose of the tracepoints in this subsystem is to allow monitoring of the time taken to allocate and map blocks.

The `gfs2_bmap` tracepoint is called twice for each bmap operation: once at the start to display the bmap request, and once at the end to display the result. This makes it easy to match the requests and results together and measure the time taken to map blocks in different parts of the file system, different file offsets, or even of different files. It is also possible to see what the average extent sizes being returned are in comparison to those being requested.

The `gfs2_rs` tracepoint traces block reservations as they are created, used, and destroyed in the block allocator.

To keep track of allocated blocks, `gfs2_block_alloc` is called not only on allocations, but also on freeing of blocks. Since the allocations are all referenced according to the inode for which the block is intended, this can be used to track which physical blocks belong to which files in a live file system. This is particularly useful when combined with `blktrace`, which will show problematic I/O patterns that may then be referred back to the relevant inodes using the mapping gained by means this tracepoint.

B.8. LOG TRACEPOINTS

The tracepoints in this subsystem track blocks being added to and removed from the journal (`gfs2_pin`), as well as the time taken to commit the transactions to the log (`gfs2_log_flush`). This can be very useful when trying to debug journaling performance issues.

The `gfs2_log_blocks` tracepoint keeps track of the reserved blocks in the log, which can help show if the log is too small for the workload, for example.

The `gfs2_ail_flush` tracepoint is similar to the `gfs2_log_flush` tracepoint in that it keeps track of the start and end of flushes of the AIL list. The AIL list contains buffers which have been through the log, but have not yet been written back in place and this is periodically flushed in order to release more log space for use by the file system, or when a process requests a `sync` or `fsync`.

B.9. GLOCK STATISTICS

GFS2 maintains statistics that can help track what is going on within the file system. This allows you to spot performance issues.

GFS2 maintains two counters:

- **dcount**, which counts the number of DLM operations requested. This shows how much data has gone into the mean/variance calculations.
- **qcount**, which counts the number of `syscall` level operations requested. Generally **qcount** will be equal to or greater than **dcount**.

In addition, GFS2 maintains three mean/variance pairs. The mean/variance pairs are smoothed exponential estimates and the algorithm used is the one used to calculate round trip times in network code. The mean and variance pairs maintained in GFS2 are not scaled, but are in units of integer nanoseconds.

- **srtt/srttvar**: Smoothed round trip time for non-blocking operations
- **srttb/srttvarb**: Smoothed round trip time for blocking operations
- **irtt/irttvar**: Inter-request time (for example, time between DLM requests)

A non-blocking request is one which will complete right away, whatever the state of the DLM lock in question. That currently means any requests when (a) the current state of the lock is exclusive (b) the requested state is either null or unlocked or (c) the "try lock" flag is set. A blocking request covers all the other lock requests.

Larger times are better for IRTTs, whereas smaller times are better for the RTTs.

Statistics are kept in two `sysfs` files:

- The **glstats** file. This file is similar to the **glocks** file, except that it contains statistics, with one glock per line. The data is initialized from "per cpu" data for that glock type for which the glock is created (aside from counters, which are zeroed). This file may be very large.
- The **lkstats** file. This contains "per cpu" stats for each glock type. It contains one statistic per line, in which each column is a cpu core. There are eight lines per glock type, with types following on from each other.

B.10. REFERENCES

For more information about tracepoints and the GFS2 **glocks** file, see the following resources:

- For information on glock internal locking rules, see <http://git.kernel.org/?p=linux/kernel/git/torvalds/linux-2.6.git;a=blob;f=Documentation/filesystems/gfs2-glocks.txt;h=0494f78d87e40c225eb1dc1a1489acd891210761;hb=HEAD>.
- For information on event tracing, see <https://git.kernel.org/pub/scm/linux/kernel/git/torvalds/linux.git/tree/Documentation/trace/e>
- For information on the `trace-cmd` utility, see <http://lwn.net/Articles/341902/>.

APPENDIX C. REVISION HISTORY

Revision 3.1-0 Preparing document for 7.6 Beta publication.	Tue Aug 9 2018	Steven Levine
Revision 2.1-1 Preparing document for 7.5 GA publication.	Thu Mar 15 2018	Steven Levine
Revision 2.1-0 Preparing document for 7.5 Beta publication.	Thu Dec 14 2017	Steven Levine
Revision 1.3-6 Updated version for 7.4.	Wed Nov 8 2017	Steven Levine
Revision 1.3-3 Document version for 7.4 GA publication.	Thu Jul 27 2017	Steven Levine
Revision 1.3-1 Preparing document for 7.4 Beta publication.	Wed May 10 2017	Steven Levine
Revision 1.2-5 Update to 7.3 GA publication.	Thu Mar 23 2017	Steven Levine
Revision 1.2-4 Version for 7.3 GA publication.	Mon Oct 17 2016	Steven Levine
Revision 1.2-3 Preparing document for 7.3 Beta publication.	Wed Aug 17 2016	Steven Levine
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Revision 0.1-11 7.0 Beta release	Mon Dec 9 2013	Steven Levine
Revision 0.1-1 Branched from the Red Hat Enterprise Linux 6 version of the document	Wed Jan 16 2013	Steven Levine

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