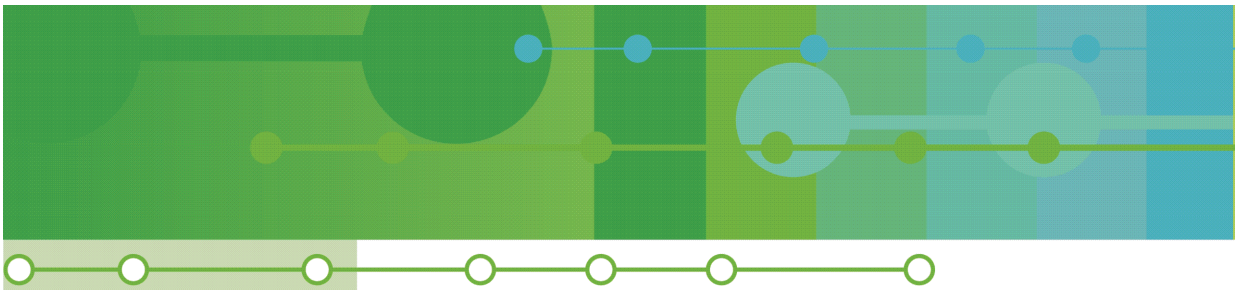

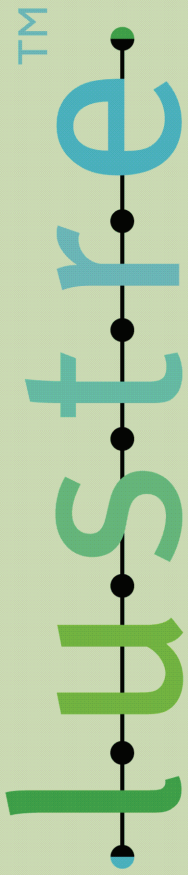

Lustre® 1.6 Operations Manual

Version 1.6_man_v1.8

Lustre 1.6 Operations Manual

Version 1.6_man_v1.8 (September 29, 2007)

This publication is intended to help Cluster File Systems, Inc. (CFS) Customers and Partners who are involved in installing, configuring, and administering Lustre.

The information contained in this document has not been submitted to any formal CFS test and is distributed AS IS. The use of this information or the implementation of any of these techniques is the customer's responsibility and depends on the customer's ability to evaluate and integrate them into the customer's operational environment. While each item may have been reviewed by CFS for accuracy in a specific situation, there is no guarantee that the same or similar results will be obtained elsewhere. Customers attempting to adapt these techniques to their own environments do so at their own risk.

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Conventions for Command Syntax

All the commands in this manual appear as 9-point, green New Courier font with the sign '| $' at the beginning. Other conventions used in the manual indicate the following:

Convention		Description
Vertical Bar	|	Alternative, mutually-exclusive elements
Square Brackets	[ ]	Optional elements
Braces	{ }	A choice is required
Braces within brackets	[{ }]	A choice is required within an optional element
Backslash	\	The command line continues on the next line
Boldface		The word/command must be entered exactly as shown
Italics		A variable or argument to be replaced by an actual value

Explanation of Symbols

The following symbols appear throughout this manual to emphasize important information.

WARNING:
Indicates a situation that may possibly cause data loss or damage equipment.

NOTE:
Indicates important information about a specific aspect of Lustre.

TIP:
Indicates helpful information to make it easier or more convenient to use Lustre.

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Chapter I - 1. A Cluster with Lustre

This chapter describes Lustre software and components, and includes the following sections:

1.1 What is Lustre?

Lustre® is a high-performance, multi-network, fault-tolerant, POSIX[1]-compliant network file system for Linux clusters.

The key features of Lustre:

- Capacity to run over a wide range of network fabrics
- Fine-grained locking for efficient concurrent file access
- Failover ability to reconstruct the state if a server node fails
- Distributed file object handling for scalable data access

Lustre is a complete, software-only, open-source solution for any hardware that can run Linux. It has native drivers for many of the fastest networking fabrics. Lustre can use any storage medium that looks like a block device.

1. Portable Operating System Interface for UNIX (POSIX)

1.2 Lustre Software

The Lustre software consists of three interactive areas:

- **Patched Linux kernel**

  Lustre requires significant changes from the standard Linux kernel to facilitate some of its performance improvements. These changes are distributed in the form of patches against specific kernels. Several specific, pre-patched kernels are available at our download site at http://www.clusterfs.com/download.html. Additionally, the Lustre client, but not Lustre servers, can run on certain unmodified kernels (known as "patchless" kernels).

- **Lustre modules**

  Lustre's kernel modules provide server and client capabilities for the file system.

- **Userspace utilities**

  Several userspace utilities are required for Lustre configuration and the startup and shutdown of Lustre servers and clients.

1.3 Lustre Components

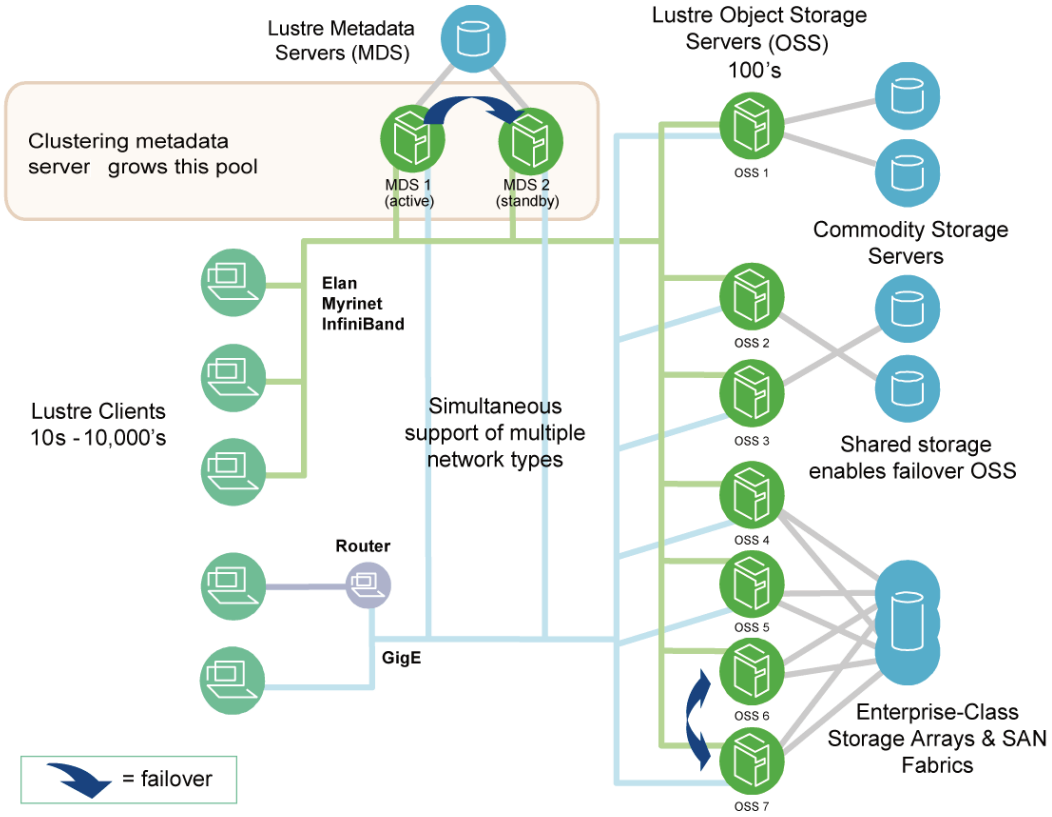
A Lustre file system consists of four major components:

- Management Server
- Meta Data Target
- Object Storage Targets
- Lustre clients

Lustre clients provide remote access a Lustre file system. The file system is served jointly by the Object Storage Targets (OSTs) for file contents and the Meta Data Target (MDT) for file meta data (directory structure, file size, and so on).

A single Lustre file system may have multiple OSTs, each serving a subset of the file data. There is not necessarily a 1:1 correspondence between a file and an OST; a file may be spread over many OSTs to optimize performance. Each OST and the MDT may have a failover partner to provide access to the back-end storage if the server node fails. Figure 1 shows the expected interactions between servers and clients in a Lustre file system.

Figure 1 Scaling with clustered metadata servers



The MDT, OSTs and Lustre clients can all run concurrently (in any mixture) on a single node. However, a more typical configuration is an MDT on a dedicated node, two or more OSTs on each Object Storage node, and a client on each of a large number of computer nodes.

1.3.1 MGS

The Management Server (MGS) defines configuration information for all Lustre file systems at a site. Each Lustre target contacts the MGS to provide information, and Lustre clients contact the MGS to retrieve information. The MGS can provide live updates to the configuration of targets and clients. The MGS requires its own disk for storage. However, there is a provision that allows the MGS to share a disk ("co-locate") with a single MDT. The MGS is not considered "part" of an individual file system; it provides configuration mechanisms to other Lustre components.

1.3.2 MDT

The MDT provides back-end storage for metadata for a single file system. The Metadata Server (MDS) provides the network request handling for one or more local MDTs.[1]

The metadata managed by the MDT consists of the file hierarchy ("namespace"), along with file attributes such as permissions and references to the data objects stored on the OSTs.

1. For historical reasons, the term “MDS” traditionally has referred to both the MDS and a single MDT. This manual version (and future versions) use the more specific meaning.

1.3.3 OSTs

An OST provides back-end storage for file object data (effectively, chunks of user files). Typically, multiple OSTs provide access to different file chunks. The MDT tracks the location of the chunks. On a node serving OSTs, an Object Storage Server (OSS) component provides the network request handling for one or more local OSTs.

1.3.4 Lustre Client Nodes

Lustre clients are the "users" of the file system. Typically, the clients are computation, visualization, or desktop nodes. Lustre clients require Lustre software to mount a Lustre file system—Lustre is not NFS.

The Lustre client software consists of an interface between the Linux Virtual File System and the Lustre servers. Each target has a client counterpart: Metadata Client (MDC), Object Storage Client (OSC), and a Management Client (MGC). A group of OSCs are wrapped into a single Logical Object Volume (LOV). Working in concert, the OSCs provide transparent access to the file system.

All clients which mount the file system see a single, coherent, synchronized namespace at all times. Different clients can write to different parts of the same file at the same time, while other clients can read from the file. This is a common situation for large simulations and is an area in which Lustre excels.

Almost all activity on the Targets is driven by requests from Lustre clients.

1.3.5 LNET

Servers and clients communicate with one another over a custom networking API known as Lustre Networking (LNET). LNET interoperates with a variety of network transports through Network Abstraction Layers (NAL).

LNET provides the delivery and event generation in connection with network messages. It also provides advanced capabilities such as using remote direct memory access (RDMA), if the underlying network transport layer supports it, and autonomous routing between different network transports on different nodes.

Chapter I - 2. Understanding Lustre Networking

This chapter describes LNET and supported networks, and includes the following sections:

2.1 Introduction to LNET

In a Lustre network, servers and clients communicate with one another over LNET, a custom networking API which abstracts away all transport-specific interaction. In turn, LNET operates with a variety of network transports through Lustre Network Drivers (LNDs).

Key features of LNET include:

- RDMA, when supported by underlying networks such as Elan, Myrinet, and InfiniBand
- Support for many commonly-used network types such as InfiniBand and IP
- High availability and recovery features enabling transparent recovery in conjunction with failover servers
- Simultaneous availability of multiple network types with routing between them

LNET is designed for complex topologies, superior routing capabilities and simplified configuration.

2.2 Supported Network Types

Lustre supports the following network types:

- TCP (Ethernet)
- openib (Mellanox-Gold InfiniBand)
- iib (Infinicon InfiniBand)
- vib (Voltaire InfiniBand)
- o2ib (OFED)
- ra (RapidArray)
- Elan (Quadrics Elan)
- gm and mx (Myrinet)
- LNET

2.3 Important Terms

The following terms are important to understanding Lustre networking.

- **LND**: Lustre network driver. A modular sub-component of LNET that implements one of the network types. LNDs are implemented as individual Linux modules and, typically, must be compiled against the network driver software.
- **Network**: A group of nodes that communicate directly with each other. The network is how LNET represents a single cluster. Multiple networks can be used to connect clusters together. Each network has a unique type and number (for example, tcp0, tcp1, or elan0).
- **NID**: Lustre network identifier. The NID uniquely identifies a Lustre network endpoint, including the node and the network type. There is an NID for every network which a node uses.

Chapter II - 1. Prerequisites

This chapter describes Lustre installation requirements and includes the following sections:

1.1 Preparing to Install Lustre

This chapter describes the prerequisites to installing Lustre.

1.1.1 How to Get Lustre

The most current, stable version of Lustre is available at CFS's download website: http://www.clusterfs.com/download.html.

The Lustre software is released under the GNU General Public License (GPL). CFS strongly recommends that you read the complete GPL and release notes before downloading Lustre (if you have not done so already). The GPL and release notes can also be found at the aforementioned website.

1.1.2 Supported Configurations

CFS supports Lustre on the configurations listed in Table 1.

Table 1 Supported Configurations

Aspect	Support Type
Operating Systems	Red Hat Enterprise Linux 3+ SuSE Linux Enterprise Server 9 and 10 Linux 2.4 and 2.6
Platforms	IA-32, IA-64, x86-64 PowerPC architectures and mixed-endian clusters
Interconnect	TCP/IP Quadrics Elan 3 and 4 Myri-10G and Myrinet - 2000 Mellanox InfiniBand (Voltaire, OpenIB and Silverstorm)

Different endians like, i368 and PPC, also support Lustre clients. One limitation is that the PAGE_SIZE on the client must be as large as the PAGE_SIZE of the server. In particular, ia64 clients with large pages (up to 64kB pages) can run with i386 servers (4kB pages). If you are running i386 clients with ia64 servers, you must compile the ia64 kernel with 4kB PAGE_SIZE.

1.2 Using a Pre-packaged Lustre Release

Due to the complexity involved in building and installing Lustre, CFS offers several pre-packaged releases that cover several of the most common configurations. A pre-packaged release consists of five different RPM packages (described below). Install these packages in the following order:

- **kernel-smp-<*release-ver*>.rpm –** This is the Lustre-patched Linux kernel RPM. Use it with matching Lustre Utilities and Lustre Modules packages.
- **kernel-source-<*release-ver*>.rpm –** This is the Lustre-patched Linux kernel source RPM. This RPM comes with the kernel package, but is not required to build or use Lustre.
- **lustre-modules-<*release-ver*>.rpm** – These are the Lustre kernel modules for the above kernel.
- **lustre-<*release-ver*>.rpm** – These are Lustre Utilities or userspace utilities to configure and run Lustre. Only use them with the matching kernel RPM (referenced above).
- **lustre-source-<*release-ver*>.rpm** – This contains the Lustre source code (including the kernel patches). It is not required to build or use Lustre.

  The source package is only required if you need to build your own modules (networking, for example) against the kernel source.

WARNING:
Lustre contains kernel modifications, which interact with your storage devices and may introduce security issues and data loss if not installed, configured, or administered properly. Before using this software, please exercise caution and back up ALL data.

1.2.1 Choosing a Pre-packaged Kernel

Choosing the most suitable pre-packaged kernel depends largely on the combination of hardware and software being used where Lustre will be installed. CFS provides pre-packaged releases on our download website.

1.2.2 Lustre Tools

The **lustre-<*release-ver*>.rpm** package, required for proper Lustre setup and monitoring, contains many tools. The most important tools are:

- **lctl** - Low-level configuration utility that can also be used for troubleshooting and debugging.
- **lfs** - Tool to read/set striping information for the cluster, as well as perform other actions specific to Lustre file systems.
- **mount.lustre** - Lustre-specific helper for mount(8).
- **mfks.lustre** - Tool to format Lustre target disks.

1.2.3 Other Required Software

Although CFS provides some tools and utilities, Lustre also requires several separate software tools to be installed.

1.2.3.1 Core-Required Tools

- **e2fsprogs:** Lustre requires very modern e2fsprogs that understand extents—use e2fsprogs-1.38-cfs1 or later, available at:

  ftp://ftp.lustre.org/pub/lustre/other/e2fsprogs/

  NOTE:
  You might have to install e2fsprogs with rpm -ivh --force to override any dependency issues of your distribution.

- **Perl:** Various userspace utilities are written in Perl. Any modern Perl should work with Lustre.
- **build tools:** If you are not installing Lustre from RPMs, normally you can use a GCC compiler to build Lustre. Use GCC 3.0 or later.

1.2.3.2 High-Availability Software

If you plan to enable failover server functionality with Lustre (either on an OSS or an MDS), high-availability software must be added to your cluster software. Heartbeat is one of the better known high-availability software packages.

Linux-HA (Heartbeat) supports a redundant system with access to the Shared (Common) Storage with dedicated connectivity; it can determine the system's general state. For more information, see Failover on page 59.

1.2.3.3 Debugging Tools

Things inevitably go wrong—disks fail, packets get dropped, software has bugs, and when they do it is useful to have debugging tools on hand to help figure out how and why a problem occurred.

In this regard, the most useful tool is GDB, coupled with crash. You can use these tools to investigate live systems and kernel core dumps. There are also useful kernel patches/ modules, such as netconsole and netdump, that allow core dumps to be made across the network.

For more information about these tools, see the following websites:

Tool	URL
GDB	http://www.gnu.org/software/gdb/gdb.html
crash	http://oss.missioncriticallinux.com/projects/crash/
netconsole	http://lwn.net/2001/0927/a/netconsole.php3
netdump	http://www.redhat.com/support/wpapers/redhat/netdump/

1.3 Environmental Requirements

When preparing to install Lustre, make sure the following environmental requirements are met.

1.3.1 SSH Access

Although it is not strictly required, in many cases it is very helpful to have remote SSH[1] access to all the nodes in a cluster. Some Lustre configuration and monitoring scripts depend on SSH (or Pdsh[2]) access, although these are not required for running Lustre.

1.3.2 Consistent Clocks

Lustre always uses the client clock for timestamps. If the machine clocks across the cluster are not in sync, Lustre should not break. However, the unsynchronized clocks in a cluster will always be a headache as it is very difficult to debug any multi-node issue, or otherwise correlate logs. For this reason, CFS recommends that you keep machine clocks in sync as much as possible. The standard way to accomplish this is by using the Network Time Protocol (NTP). All machines in your cluster should synchronize their time from a local time server (or servers) at a suitable time interval.

For more information about NTP, see: http://www.ntp.org/

1.3.3 Universal UID/GID

To maintain uniform file access permissions on all nodes in your cluster, use the same user IDs (UID) and group IDs (GID) on all clients. Like most cluster usage, Lustre uses a common UID/GID on all cluster nodes.

1.3.4 Choosing a Proper Kernel I/O Scheduler

One of the many functions of the Linux kernel (indeed of any OS kernel), is to provide access to disk storage. The algorithm which decides how the kernel provides disk access is known as the "I/O Scheduler," or "Elevator." In the 2.6 kernel series**,** there are four interchangeable schedulers:

Scheduler	Description
cfq	"Completely Fair Queuing" makes a good default for most workloads on general-purpose servers. It is not a good choice for Lustre OSS nodes, however, as it introduces overhead and I/O latency.
as	"Anticipatory Scheduler" is best for workstations and other systems with slow, single-spindle storage. It is not at all good for OSS nodes, as it attempts to aggregate or batch requests in order to improve performance for slow disks.
deadline	“Deadline” is a relatively simple scheduler which tries to minimize I/O latency by re-ordering requests to improve performance. Best for OSS nodes with "simple" storage, that is software RAID, JBOD, LVM, and so on.
noop	“NOOP” is the most simple scheduler of all, and is really just a single FIFO queue. It does not attempt to optimize I/O at all, and is best for OSS nodes that have high-performance storage, that is DDN, Engenio, and so on. This scheduler may yield the best I/O performance if the storage controller has been carefully tuned for the I/O patterns of Lustre

1. Secure SHell (SSH)
2. Parallel Distributed SHell (Pdsh)

The above observations on the schedulers are just our best advice. CFS strongly suggests that you conduct local testing to ensure high performance with Lustre. Also, note that most distributions ship with either “cfq” or “as” configured as the default scheduler. Choosing an alternate scheduler is an absolutely necessary step to optimally configure Lustre for the best performance. The “cfq” and “as” schedulers should never be used for server platform.

For more in-depth discussion on choosing an I/O scheduler algorithm for Linux, see:

- http://www.redhat.com/magazine/008jun05/features/schedulers
- http://www.novell.com/brainshare/europe/05_presentations/tut303.pdf
- http://kerneltrap.org/node/3851

1.3.5 Changing the I/O Scheduler

There are two ways to change the I/O scheduler—at boot time or with new kernels at runtime. For all Linux kernels, appending 'elevator={noop|deadline}' to the kernel boot string sets the I/O elevator.

With LILO, you can use the 'append' keyword:

```
image=/boot/vmlinuz-2.6.14.2
label=14.2
append="elevator=deadline"
read-only
optional
```

With GRUB, append the string to the end of the kernel command:

```
title Fedora Core (2.6.9-5.0.3.EL_lustre.1.4.2custom)
root (hd0,0)
kernel /vmlinuz-2.6.9-5.0.3.EL_lustre.1.4.2custom ro
root=/dev/VolGroup00/LogVol00 rhgb noapic quiet elevator=deadline
```

With newer Linux kernels[1] one can change the scheduler while running. If the file /sys/block/<*DEVICE*>/queue/scheduler exists (where <*DEVICE*> is the block device you wish to affect), it contains a list of available schedulers and can be used to switch the schedulers.

(hda is the <*disk*>):

```
[root@cfs2]# cat /sys/block/hda/queue/scheduler
noop [anticipatory] deadline cfq
[root@cfs2 ~]# echo deadline > /sys/block/hda/queue/scheduler
[root@cfs2 ~]# cat /sys/block/hda/queue/scheduler
noop anticipatory [deadline] cfq
```

For desktop use, the other schedulers (anticipatory and cfq) are better suited.

1. Red Hat Enterprise Linux v3 Update 3 does not have this feature. It is present in the main Linux tree as of 2.6.15.

1.4 Memory Requirements

This section describes the memory requirements of Lustre.

1.4.1 Determining MDS Memory

Use the following factors to determine the MDS memory:

- Number of clients
- Size of the directories
- Extent of load.

If the number of clients accessing the network at any point of time is very high, you must configure large number of locks on the scale of the entire cluster. You can tune this down. However, any client can hold very little metadata as it can hold very few locks. Therefore, decreasing the number of clients cannot significantly add to the MDS memory.

If there are directories containing 1 million or more files, you may benefit significantly from having more memory. For example, in an environment where clients randomly access one of 10 million files, having extra memory for the cache significantly improves performance.

Chapter II - 2. Lustre Installation

This chapter describes how to install Lustre and includes the following sections:

- Installing Lustre
- Quick Configuration of Lustre
- Building from Source
- Building RPMs

Currently, all Lustre installations run the ext3 file system internally on service nodes. Lustre servers run on top of the ext3 file system internally. The ext3 creates a journal for efficient recovery after a system crash or power outages. For maximum performance on a very large file system, Lustre creates a very large journal, up to 400 MB per target. If your file system runs on 100 OSTs, a total of 40 GB of space is used for the journals.

2.1 Installing Lustre

Use this procedure to install Lustre.

1. Install the Linux base OS per your requirements and installation prerequisites like GCC and Perl, discussed in Prerequisites on page 7.
2. Install the RPMs (described in Using a Pre-packaged Lustre Release on page 8). The preferred installation order is:
   - Lustre-patched version of the linux kernel (kernel-*)
   - Lustre modules for that kernel (lustre-modules-*)
   - Lustre userspace programs (lustre-*). Other packages (optional).
3. Verify that all cluster networking is correct. This may include /etc/hosts or DNS. Set the correct networking options for Lustre in /etc/modprobe.conf. See Modprobe.conf on page 55.)

TIP:
When installing Lustre with InfiniBand, keep the ibhost, kernel and Lustre all on the same revision. To do this:

1. Install the kernel source (Lustre-patched).
2. Install the Lustre source and the ibhost source.
3. Compile the ibhost against your kernel.
4. Compile the Linux kernel.
5. Compile Lustre against the ibhost source --with-vib=<*path to ibhost*>.

Now you can use the RPMs created by the above steps.

2.1.1 MountConf

MountConf is shorthand for Mount Configuration. The Lustre cluster is configured only by the mkfs.lustre and mount commands. There are no more lconf, lmc, xml as in previous versions of Lustre. The MountConf system is one of the important new features of Lustre 1.6.0.

MountConf involves userspace utilities (mkfs.lustre, tunefs.lustre, mount.lustre, lctl) and two new OBD types, the MGC and MGS. The MGS is a configuration management server, which compiles configuration information about all Lustre file systems running at a site. There should be one MGS per site, not one MGS per file system. The MGS requires its own disk for storage. However, there is a provision to allow the MGS to share a disk ("co-locate") with an MDT of one file system.

You must start the MGS first as it manages the configurations. Beyond this, there are no ordering requirements to when a Target (MDT or OST) can be added to a file system. (However, there should be no client I/O at addition time, also known as "quiescent ost addition.")

For example, consider the following order of starting the servers.

1. Start the MGS - start mgs
2. Mount OST 1 - mkfs, mount ost #1
3. Mount the MDT - mkfs, mount mdt
4. Mount OST 2 - mkfs, mount ost #2
5. Mount the client - mount client
6. Mount OST 3 - mkfs, mount ost #3

The clients and the MDT are notified that there is a new OST on-line and they can use it immediately.

NOTE:
The MGS must be running before any new servers are added to a file system. After the servers start the first time, they cache a local copy of their startup logs so that they can restart with or without the MGS.

Currently, there is nothing actually visible on a server mount point (but 'df' will show free space). Eventually, the mount point will probably look like Lustre client.

2.2 Quick Configuration of Lustre

As already discussed, Lustre consists of four types of subsystems – a Management Server (MGS), a Meta Data Target (MDT), Object Storage Targets (OSTs) and clients. All of these can co-exist on a single system or can run on different systems. Together the OSSs and MDS together present a Logical Object Volume (LOV) which is an abstraction that appears in the configuration.

It is possible to set up the Lustre system with many different configurations by using the administrative utilities provided with Lustre. CFS includes some sample scripts in the directory where Lustre is installed. If you have installed the source code, the scripts are located in the lustre/tests subdirectory. These scripts enable quick setup of some simple, standard configurations.

The next section describes how to use these scripts to install a simple Lustre setup.

2.2.1 Simple Configurations

The procedures in this section describe how to set up simple Lustre configurations.

2.2.1.1 Module Setup

Make sure the modules (like LNET) are installed in the appropriate /lib/modules directory. The mkfs.lustre and mount.lustre utilities automatically load the correct modules.

1 Set up module options for networking should first be set up by adding the following line in /etc/modprobe.conf –

```
# Networking options, see /sys/module/lnet/parameters NO \
../lnet/parameters dir
```

2 Add the following line.

```
options lnet networks=tcp
# alias lustre llite -- remove this line from existing modprobe.conf
#(the llite module has been renamed to lustre)
# end Lustre modules
```

The clients and the MDT are notified that there is a new OST on-line and immediately are able to use it.

NOTE:
For a detailed information on formatting an MDS or OST, see Options for Formatting MDS and OST on page 167.

2.2.1.2 Making and Starting a File System

Starting Lustre on MGS and MDT Node “mds16”

First, create an MDT for the "spfs" file system that uses the /dev/sda disk. This MDT also acts as the MGS for the site.

```
$ mkfs.lustre --fsname spfs --mdt --mgs /dev/sda

   Permanent disk data:

Target:spfs-MDTffff

Index:unassigned

Lustre FS:spfs

Mount type:ldiskfs

Flags:0x75

(MDT MGS needs_index first_time update)

Persistent mount opts: errors=remount-\
ro,iopen_nopriv,user_xattr

Parameters:

checking for existing Lustre data: not found

device size = 4096MB

formatting backing filesystem ldiskfs on /dev/sda

target name  spfs-MDTffff

4k blocks0

options-J size=160 -i 4096 -I 512 -q -O dir_index -F

mkfs_cmd = mkfs.ext2 -j -b 4096 -L spfs-MDTffff  -J \
size=160  -i 4096 -I 512 -q -O dir_index -F /dev/sda

Writing CONFIGS/mountdata


$ mkdir -p /mnt/test/mdt

$ mount -t lustre /dev/sda /mnt/test/mdt

$ cat /proc/fs/lustre/devices

0 UP mgs MGS MGS 5

1 UP mgc MGC192.168.16.21@tcp bf0619d6-57e9-865c-551c- \
06cc28f3806c 5

2 UP mdt MDS MDS_uuid 3

3 UP lov spfs-mdtlov spfs-mdtlov_UUID 4

4 UP mds spfs-MDT0000 spfs-MDT0000_UUID 3
```

Starting Lustre on any OST Node

Give OSTs the location of the MGS with the --mgsnode parameter.

```
$ mkfs.lustre --fsname spfs --ost --mgsnode=mds16@tcp0 /dev/sda

Permanent disk data:
Target:spfs-OSTffff
Index:unassigned
Lustre FS:spfs
Mount type:ldiskfs
Flags:0x72
(OST needs_index first_time update)
Persistent mount opts: errors=remount-ro,extents,mballoc
Parameters: mgsnode=192.168.16.21@tcp

device size = 4096MB
formatting backing filesystem ldiskfs on /dev/sda
target namespfs-OSTffff
4k blocks0
options -J size=160 -i 16384 -I 256 -q -O dir_index -F
mkfs_cmd = mkfs.ext2 -j -b 4096 -L spfs-OSTffff  -J \
size=160 -i 16384 -I 256 -q -O dir_index -F /dev/sda
Writing CONFIGS/mountdata
$ mkdir -p /mnt/test/ost0
$ mount -t lustre /dev/sda /mnt/test/ost0
$ cat /proc/fs/lustre/devices
0 UP mgc MGC192.168.16.21@tcp 7ed113fe-dd48-8518-a387- \ 5c34eec6fbf4 5
1 UP ost OSS OSS_uuid 3
2 UP obdfilter spfs-OST0000 spfs-OST0000_UUID 5
```

Mounting Lustre on a client node

```
$ mkdir -p /mnt/testfs
$ mount -t lustre cfs21@tcp:0:/testfs /mnt/testfs
```

The MGS and the MDT can be run on separate devices. With the MGS on node 'mgs16':

```
$ mkfs.lustre --mgs /dev/sda1
$ mkdir -p /mnt/mgs
$ mount -t lustre /dev/sda1 /mnt/mgs
$ mkfs.lustre --fsname=spfs --mdt --mgsnode=mgs16@tcp0 /dev/sda2
$ mkdir -p /mnt/test/mdt
$ mount -t lustre /dev/sda1 /mnt/test/mdt
```

If the MGS node has multiple interfaces (for example, mgs16 and 1@elan), only the client mount command has to change. The MGS NID specifier must be an appropriate nettype for the client (for instance, TCP client could use uml1@tcp0 and Elan client could use 1@elan). Alternatively, a list of all MGS NIDs can be provided and the client chooses the correct one.

```
$ mount -t lustre mgs16@tcp0,1@elan:/spfs /mnt/spfs
```

Reformat a device that has already been formatted with mkfs.lustre

```
$ mkfs.lustre --fsname=spfs --mdt --mgs --reformat /dev/sda1
```

2.2.1.3 File System Name

The file system name is limited to 8 characters. CFS has encoded the file system and target information in the disk label, so that you can mount by label. This allows system administrators to move disks around without worrying about issues such as SCSI disk reordering or getting the /dev/device wrong for a shared target. Soon, CFS will make file system naming as fail-safe as possible. Currently, Linux disk labels are limited to 16 characters. CFS will reserve 8 of those characters to identify the target within the file system, leaving 8 characters for the file system name:

```
myfsname-MDT0000 or myfsname-OST0a19
```

An example of mount-by-label:

```
$ mount -t lustre -L testfs-MDT0000 /mnt/mdt
```

Although the file system name is internally limited to 8 characters, you can mount the clients at any mount point, so file system users are never subjected to short names:

```
mount -t lustre uml1@tcp0:/shortfs /mnt/my-long-filesystem-name
```

2.2.1.4 Starting a Server Automatically

Starting Lustre only involves the mount command, Lustre servers can be added to /etc/fstab:

```
$ mount -l -t lustre
/dev/sda1 on /mnt/test/mdt type lustre (rw) [testfs-MDT0000]
/dev/sda2 on /mnt/test/ost0 type lustre (rw) [testfs-OST0000]
192.168.0.21@tcp:/testfs on /mnt/testfs type lustre (rw)
```

Add to /etc/fstab:

```
LABEL=testfs-MDT0000 /mnt/test/mdt lustre defaults,_netdev,noauto  \ 0 0
LABEL=testfs-OST0000 /mnt/test/ost0 lustre defaults,_netdev,noauto \ 0 0
```

In general, it is wise to specify noauto and let your high-availability (HA) package manage when to mount the device. If you are not using failover, ensure that networking has been started before mounting a Lustre server. RedHat, SuSe, Debian (maybe others) use the "_netdev" flag to ensure that these disks are mounted after the network is up.

We are mounting by disk label here -- the label of a device can be read with e2label. The label of a newly-formatted Lustre server ends in FFFF, meaning that it has yet to be assigned. The assignment takes place when the server is first started, and the disk label is updated.

2.2.1.5 Stopping a Server

To stop a server:

```
$ umount -f /mnt/test/ost0
```

The '-f' flag means "force"; force the server to stop WITHOUT RECOVERY (equivalent to the old lconf –force). Without the '-f' flag, "failover" is implied, meaning the next time the server is started it goes through the recovery procedure (equivalent to the old lconf --failover).

NOTE:
If you are using loopback devices, use the '-d' flag. This flag cleans up loop devices and can always be safely specified.

2.2.2 More Complex Configurations

In case of NID/node specification, note that a node is a server box; it may have multiple NIDs if it has multiple network interfaces. When a node is specified, generally all of its NIDs are required to be listed (delimited by commas ','), so that other nodes can choose the NID appropriate to their own network interfaces. When multiple nodes are specified, they are delimited by a colon (':') or by repeating a keyword (--mgsnode= or --failnode=). To obtain all the NIDs from a node (while LNET is running), execute this command –

```
lctl list_nids
```

2.2.2.1 Failover

This example has a combined MGS/MDT failover pair on uml1 and uml2, and a OST failover pair on uml3 and uml4. There are corresponding Elan addresses on uml1 and uml2.

```
uml1> mkfs.lustre --fsname=testfs --mdt --mgs \
--failnode=uml2,2@elan /dev/sda1
uml1> mount -t lustre /dev/sda1 /mnt/test/mdt
uml3> mkfs.lustre --fsname=testfs --ost --failnode=uml4 \
--mgsnode=uml1,1@elan --mgsnode=uml2,2@elan /dev/sdb
uml3> mount -t lustre /dev/sdb /mnt/test/ost0
client> mount -t lustre uml1,1@elan:uml2,2@elan:/testfs\  /mnt/testfs
uml1> umount /mnt/mdt
uml2> mount -t lustre /dev/sda1 /mnt/test/mdt
uml2> cat /proc/fs/lustre/mds/testfs-MDT0000/recovery_status
```

Where multiple NIDs are specified, comma-separation (for example, uml2,2@elan) means that the two NIDs refer to the same host, and that Lustre needs to choose the "best" one for communication. Colon-separation (for example, uml1:uml2) means that the two NIDs refer to two different hosts, and should be treated as failover locations (Lustre tries the first one, and if that fails, it tries the second one.)

2.2.2.2 Mount with Inactive OSTs

Mounting a client or MDT with known down OSTs (specified targets are treated as "inactive")

```
client> mount -o exclude=testfs-OST0000 -t lustre uml1:/testfs\
/mnt/testfs
client> cat /proc/fs/lustre/lov/testfs-clilov-*/target_obd
```

To reactivate an inactive OST on a live client or MDT, use lctl activate on the OSC device, For example: lctl --device 7 activate.

NOTE:
A colon-separated list can also be specified. For example, exclude=testfs-OST0000:testfs-OST0001.

2.2.2.3 Without Lustre Service

Only start the MGS or MGC. Do not start the target server (for example, if you do not want to start the MDT for a combined MGS/MDT)

```
$ mount -t lustre -L testfs-MDT0000 -o nosvc /mnt/test/mdt
```

2.2.2.4 Failout

Designate an OST as a "failout", so clients receive errors after a timeout instead of waiting for recovery:

```
$ mkfs.lustre --fsname=testfs --ost --mgsnode=uml1 \
-- param="failover.mode=failout" /dev/sdb
```

2.2.2.5 Running Multiple Lustres

The default file system name created by mkfs.lustre is "lustre." For a different file system name, specify "mkfs.lustre --fsname=foo". The MDT, OSTs and clients that comprise a single file system must share the same name. For example:

```
foo-MDT0000

foo-OST0000

foo-OST0001

client mount command: mount -t lustre mgsnode:/foo /mnt/mountpoint
```

The maximum length of the file system name is 8 characters.

The MGS is universal; there is only one MGS per installation, not per file system. An installation with two file systems could look like this:

```
mgsnode# mkfs.lustre --mgs /dev/sda

mdtfoonode# mkfs.lustre --fsname=foo --mdt \
--mgsnode=mgsnode@tcp0 /dev/sda

ossfoonode# mkfs.lustre --fsname=foo --ost \
--mgsnode=mgsnode@tcp0 /dev/sda

ossfoonode# mkfs.lustre --fsname=foo --ost \
--mgsnode=mgsnode@tcp0 /dev/sdb

mdtbarnode# mkfs.lustre --fsname=bar --mdt \
--mgsnode=mgsnode@tcp0 /dev/sda

ossbarnode# mkfs.lustre --fsname=bar --ost \
--mgsnode=mgsnode@tcp0 /dev/sda

ossbarnode# mkfs.lustre --fsname=bar --ost \
--mgsnode=mgsnode@tcp0 /dev/sdb
```

Client mount for foo:

```
mount -t lustre mgsnode@tcp0:/foo /mnt/work
```

Client mount for bar:

```
mount -t lustre mgsnode@tcp0:/bar /mnt/scratch
```

2.2.3 Other Configuration Tasks

This section describes other Lustre configuration tasks.

2.2.3.1 Removing an OST Permanently

In Lustre 1.6, an OST can be permanently removed from a file system. Any files that have stripes on the removed OST will, in the future, return EIO.

```
$ mgs> lctl conf_param testfs-OST0001.osc.active=0
```

This tells any clients of the OST that it should not be contacted; the OSTs current state is irrelevant.

To restore the OST:

1. Make sure the OST is running.
2. Run the following command:

```
$ mgs> lctl conf_param testfs-OST0001.osc.active=1
```

2.2.3.2 Writeconf

Run writeconf, first remove all existing config files for a file system. Use the writeconf command on an MDT to erase all the configuration logs for the file system. The logs are regenerated only as servers restart; therefore all servers must be restarted before clients can access file system data. The logs are regenerated as in a new file system; old settings from lctl conf_param are lost, and current server NIDs are used. Only use this command if:

- The config logs are into a state where the file system cannot start; or
- You are changing the NIDs of one of the servers.

To run writeconf:

1. Unmount all the clients and servers.
2. With every server disk, run:

```
$ mdt> tunefs.lustre --writeconf /dev/sda1
```

3. Remount all servers. You must mount the ***MDT first***.

2.2.3.3 Changing a Server NID

To change a server NID:

1. Update the LNET configuration in /etc/modprobe.conf so the lctl list_nids is correct.
2. Regenerate the configuration logs for every affected file system using the --writeconf flag to tunefs.lustre, as shown in the 2nd step of the Writeconf section.
3. If the MGS NID is also changing, communicate the new MGS location to each server. Type:

```
tunefs.lustre --erase-param --mgsnode=<new_nid(s)> --writeconf \
/dev/...
```

2.2.3.4 Abort Recovery

When starting a target, abort the recovery process. Type:

```
$ mount -t lustre -L testfs-MDT0000 -o abort_recov /mnt/test/mdt
```

NOTE:
The recovery process is blocked until all OSTs are available.

2.3 Building from Source

This section describes how to build Lustre from source code.

2.3.1 Building Your Own Kernel

If you are using non-standard hardware or CFS support has asked you to apply a patch, you will need to build your own kernel. Lustre requires some changes to the core Linux kernel. These changes are organized in a set of patches in the kernel_patches directory of the Lustre repository in CVS. If you are building your kernel from the source code, then you need to apply the appropriate patches.

Managing patches for the kernels is a very involved process, because most patches are intended to work with several kernels. To facilitate support, CFS maintains tested versions on our FTP site as some versions may not work properly with CFS patches. CFS recommends that you use the Quilt package developed by Andreas Gruenbacher, as it simplifies the process considerably. Patch management with Quilt works as follows:

1. A series file lists a collection of patches.
2. The patches in a series form a stack
3. Using Quilt, you push and pop the patches.
4. You then edit and refresh (update) the patches in the stack that is being managed with Quilt.
5. You can then revert inadvertent changes and fork or clone the patches and conveniently show the difference in work (before and after).

2.3.1.1 Selecting a Patch Series

Depending on the kernel being used, a different series of patches needs to be applied. CFS maintains a collection of different patch series files for the various supported kernels in this directory: lustre/kernel_patches/series/. This directory is in the Lustre tarball distributed by CFS.

For example, the lustre/kernel_patches/series/rh-2.4.20 file lists all patches that should be applied to the Red Hat 2.4.20 kernel to build a Lustre-compatible kernel.

The current set of all the supported kernels and their corresponding patch series can always be found in the lustre/kernel_patches/which_patch file.

2.3.1.2 Installing Quilt

A variety of Quilt packages (RPMs, SRPMs and tarballs) are available from various sources. CFS recommend that you use a recent version of Quilt (version 0.29 or later). If possible, use a Quilt package from your distribution vendor. If this is not possible, you may download a package from CFS's FTP site:

ftp://ftp.clusterfs.com/pub/quilt/

If you cannot find an appropriate Quilt package or fulfill its dependencies, CFS suggests building Quilt from the tarball. You can download the tarball from the main Quilt website:

http://savannah.nongnu.org/projects/quilt

2.3.1.3 Preparing the Kernel Tree Using Quilt

To prepare the kernel tree to use Quilt:

1. After acquiring the Lustre source (CVS or tarball) and choosing a series file to match your kernel sources, choose a kernel config file.

   The supported kernel ".config" files are in the lustre/kernel_patches/kernel_configs folder, and are named in such a way as to indicate which kernel and architecture with which they are associated. For example, kernel-2.6.9-2.6-rhel4-x86_64-smp.config is a config file for the 2.6.9 kernel shipped with RHEL 4 suitable for x86_64 SMP systems.

2. Unpack the appropriate kernel source tree.

   For the purposes of illustration, this documentation assumes that the resulting source tree is in /tmp/kernels/linux-2.6.9, we will refer to this as the destination tree.

   You are ready to use Quilt to manage the patching process for your kernel.

3. Perform the following set of commands to set up the necessary symlinks between the Lustre kernel patches and your kernel sources (assuming the Lustre sources are unpacked under /tmp/lustre-1.4.7.3 and you have chosen the 2.6-rhel4 series):

   ```
   $ cd /tmp/kernels/linux-2.6.9

   $ rm -f patches series

   $ ln -s /tmp/lustre-1.5.97/lustre/kernel_patches/series/2.6-\
   rhel4.series ./series

   $ ln -s /tmp/lustre-1.5.97/lustre/kernel_patches/patches .
   ```

4. You can now use Quilt to apply all patches in the chosen series to your kernel sources by using the following commands:

   ```
   $ cd /tmp/kernels/linux-2.6.9

   $ quilt push -av
   ```

If the right series files are chosen, and the patches and the kernel sources are up-to-date, the patched destination Linux tree should be able to act as a base Linux source tree for Lustre.

You do not need to compile the patched Linux source in order to build Lustre from it. However, you must compile the same Lustre-patched kernel and then boot it on any node on which you intend to run the version of Lustre being built using this patched kernel source.

2.3.2 Building Lustre

You can obtain Lustre source code by registering at CFS's download site:

http://www.clusterfs.com/download.html

Once registered, you will receive an email with a download link.

The following set of packages are available for each supported Linux distribution and architecture. The files employ the following naming convention:

kernel-smp-<*kernel version*>_lustre.<*lustre version*>.<*arch*>.rpm

This is an example of **binary packages** for version 1.5.97:

- kernel-lustre-smp-2.6.9-42.0.3.EL_lustre.1.5.97.i686.rpm contains patched kernel
- lustre-1.5.97-2.6.9_42.0.3.EL_lustre.1.5.97smp.i686.rpm contains Lustre userspace files and utilities
- lustre-modules-1.5.97-2.6.9_42.0.3.EL_lustre.1.5.97smp.i686.rpm contains Lustre modules (kernel/fs/lustre and kernel/net/lustre).

Use standard RPM commands to install the binary packages:

```
$ rpm -ivh kernel-lustre-smp-2.6.9-42.0.3.EL_lustre.1.5.97.i686.rpm
$ rpm -ivh lustre-1.5.97-2.6.9_42.0.3.EL_lustre.1.5.97smp.i686.rpm
$ rpm -ivh lustre-modules-1.5.97-\
2.6.9_42.0.3.EL_lustre.1.5.97smp.i686.rpm
```

This is an example of **Source** packages:

- kernel-lustre-source-2.6.9-42.0.3.EL_lustre.1.5.97.i686.rpm contains source for the patched kernel
- lustre-source-1.5.97-2.6.9_42.0.3.EL_lustre.1.5.97smp.i686.rpm contains source for Lustre modules and userspace utilities.

NOTE:
The kernel-source and lustre-source packages are provided in case you need to build external kernel modules or use additional network types. They are not required to run Lustre.

Once you have your Lustre source tree run these commands to build Lustre:

```
$ cd <path to kernel tree>
$ cp /boot/config-'uname -r' .config
$ make oldconfig || make menuconfig
```

- For 2.6 kernels, run these commands:

```
$ make include/asm
$ make include/linux/version.h
$ make SUBDIRS=scripts
```

- For 2.4 kernels, run:

```
$ make dep
```

To configure Lustre and to build Lustre RPMs, go into the Lustre source directory and run these commands:

```
$ ./configure --with-linux=<path to kernel tree>
$ make rpms
```

This creates a set of .rpms in /usr/src/redhat/RPMS/<arch> with a date-stamp appended (the SUSE path is /usr/src/packages).

Example:

```
lustre-1.5.97-\
2.6.9_42.xx.xx.EL_lustre.1.5.97.custom_200609072009.i686.rpm
lustre-debuginfo-1.5.97-\
2.6.9_42.xx.xx.EL_lustre.1.5.97.custom_200609072009.i686.rpm
lustre-modules-1.5.97-\
2.6.9_42.xx.xxEL_lustre.1.5.97.custom_200609072009.i686.rpm
lustre-source-1.5.97-\
2.6.9_42.xx.xx.EL_lustre.1.5.97.custom_200609072009.i686.rpm
```

Change directory (cd) into the kernel source directory and run:

```
$ make rpm
```

This creates a kernel RPM suitable for the installation.

Example:

kernel-2.6.95.0.3.EL_lustre.1.5.97custom-1.i386.rpm

2.3.2.1 Configuration Options

Lustre supports several different features and packages that extend the core functionality of Lustre. These features/packages can be enabled at the build time by issuing appropriate arguments to the configure command. A complete list of supported features and packages can be obtained by issuing the command "./configure –help" in the Lustre source directory. The config files matching the kernel version are in the configs/ directory of the kernel source. Copy one to .config at the root of the kernel tree.

2.3.2.2 Liblustre

The Lustre library client, liblustre, relies on libsysio, which is a library that provides POSIX-like file and name space support for remote file systems from the application program address space. Libsysio can be obtained at the SourceForge website:

http://sourceforge.net/projects/libsysio/

WARNING:
Remember that liblustre is not for general use. It was created to work with specific hardware (Cray) and should NEVER be used with other hardware.

Development of libsysio has continued ever since it was first targeted for use with Lustre. First, check out the b_lustre branch from the libsysio repository on CVS. This gives the version of libsysio compatible with Lustre.

- To build libsysio, run:

```
$ sh autogen.sh
$ ./configure --with-sockets
$ make
```

- To build liblustre, run:

```
$ ./configure --with-lib -with-sysio=/path/to/libsysio/source
$ make
```

Compiler Choice

The compiler must be greater than GCC version 3.3.4. Currently, GCC v4.0 is not supported. GCC v3.3.4 has been used to successfully compile all of the pre-packaged releases made available by CFS, and it is the only officially-supported compiler. Your mileage may vary with other compilers, or even with other versions of GCC.

NOTE:
GCC v3.3.4 was used to build 2.6 series kernels.

2.3.3 Building From Source

Currently, the kernels distributed by CFS do not include third-party InfiniBand modules. Lustre packages cannot include IB network drivers for Lustre, however, Lustre does distribute the source code. Build your InfiniBand software stack against the CFS kernel, and then build new Lustre packages. This includes following procedures.

InfiniBand

To build Lustre with Voltaire InfiniBand sources, add:

```
--with-vib=<path-to-voltaire-sources>
```

as an argument to the configure script.

To configure Lustre, use:

```
--nettype vib --nid <IPoIB address>
```

OpenIB generation 1 / Mellanox Gold

To build Lustre with OpenIB InfiniBand sources, add:

```
--with-openib=<path_to_openib sources>
```

as an argument to the configure script.

To configure Lustre, use:

```
--nettype openib --nid <IPoIB address>
```

Silverstorm

To build Silverstorm with Lustre, configure Lustre with:

```
--iib=<path to silverstorm sources>
```

OpenIB 1.0

NOTE:
Currently (v1.4.5), the Voltaire IB module (kvibnal) does not work on the Altix system. This is due to hardware differences in the Altix system.

2.4 Building RPMs

This section describes how to build RPMs.

2.4.1 Tarball to RPMs

To build a proper Lustre source tarball from the Lustre source RPM:

1. Install the RPM.
2. Configure the resulting Lustre tree.
3. Run 'make dist'

This produces a proper Lustre tarball. Untar it and name the resulting directory: 'lustre-<extraversion>'

The lbuild script requires a working directory. This directory must be empty prior to starting lbuild. If the build fails, clean out the working directory before attempting to restart.

Here is an example of a local build with no downloading. The 'target' (Kernel Version) name must match one of the files found in lustre/kernel_patches/targets. If you do not specify --target-arch (Hardware Platform), all the archs will be built.

The example is for RHEL 2.6 kernel.

```
$ lustre/build/lbuild --extraversion=1.4.9 \
                      --target=2.6-rhel4 \
                      --target-archs=i686 \
                      --release \
                      --kerneldir=/path_to_tarball/ \
                      --stage=/path_to_working_dir/ \
                      --lustre=/path_to_lustre_tarball/ \
                      --nodownload
```

2.4.1.1 RPMs from CVS

The following example assumes we have CVS access, and are building additional network drivers (gm and vib). You must properly configure the network driver tree prior to starting lbuild. The network drivers are compiled as part of the lustre build, options after the '--' separator are passed directly to Lustre. Execute the ./configure script below.

./configure script

Replace CVSROOT by the proper CVS string. (CVS access is not generally available; contact CFS for more information.)

--tag is the CVS tag for the version you are building.

```
$ lustre/build/lbuild --extraversion=1.4.7.1 --target=2.6-rhel4
                --target-archs=i686 --release --kerneldir=/path_to_tarball/
\
                     --stage=/path_to_working_dir/ -d:ext:$CVSROOT
                     --tag=b_release_1_4_7 --disable-datestamp \
                     -- /* following options will be passed to lustre */ \
                     --with-gm=/path_to_gm/gm-2.1.23_Linux \
                     --with-vib=/path_to_vib/ibhost-3.5.0_13
```

Chapter II - 3. Configuring the Lustre Network

This chapter describes how to configure Lustre and includes the following sections:

3.1 Designing Your Lustre Network

Before you configure Lustre, it is essential to have a clear understanding of the Lustre network topologies.

3.1.1 Identify All Lustre Networks

A network is a group of nodes that communicate directly with one another. As previously mentioned in this manual, Lustre supports a variety of network types and hardware, including TCP/IP, Elan, varieties of InfiniBand, Myrinet and others. The normal rules for specifying networks apply to Lustre networks. For example, two TCP networks on two different subnets (tcp0 and tcp1) would be considered two different Lustre networks.

3.1.2 Identify Nodes to Route Between Networks

Any node with appropriate interfaces can route LNET between different networks—the node may be a server, a client, or a standalone router. LNET can route across different network types (such as TCP-to-Elan) or across different topologies (such as bridging two InfiniBand or TCP/IP networks).

3.1.3 Identify Network Interfaces to Include/Exclude from LNET

By default, LNET uses all interfaces for a given network type. If there are interfaces it should not use, (such as administrative networks, IP over IB, and so on), then the included interfaces should be explicitly listed.

3.1.4 Determine Cluster-wide Module Configuration

The LNET configuration is managed via module options, typically specified in /etc/modprobe.conf or /etc/modprobe.conf.local (depending on the distribution). To help ease the maintenance of large clusters, it is possible to configure the networking setup for all nodes through a single, unified set of options in the modprobe.conf file on each node. For more information, see the ip2nets option in Modprobe.conf on page 55.

Users of liblustre should set the accept=all parameter. For details, see Module Parameters on page 37.

3.1.5 Determine Appropriate Mount Parameters for Clients

In their mount commands, clients use the NID of the MDS host to retrieve their configuration information. Since an MDS may have more than one NID, a client should use the appropriate NID for its local network. If you are unsure which NID to use, there is a **lctl** command that can help.

MDS

On the MDS, run:

```
lctl list_nids
```

This displays the server's NIDs.

Client

On a client, run:

```
lctl which_nid <NID list>
```

This displays the closest NID for the client.

Client with SSH Access

From a client with SSH access to the MDS, run these commands:

```
mds_nids=`ssh the_mds lctl list_nids`
lctl which_nid $mds_nids
```

This displays, generally, the correct NID to use for the MDS in the mount command.

3.2 Configuring Your Lustre Network

This section describes how to configure your Lustre network.

NOTE:
CFS recommends using dotted-quad IP addressing rather than host names. We have found this aids in reading debug logs, and helps greatly when debugging configurations with multiple interfaces.

3.2.1 Module Parameters

LNET network hardware and routing are now configured via module parameters of the LNET and LND-specific modules. Parameters should be specified in the /etc/modprobe.conf or /etc/modules.conf file, for example:

```
options lnet networks=tcp0,elan0
```

This specifies that this node should use all available TCP and Elan interfaces.

- Under Linux 2.6, the LNET configuration parameters can be viewed under /sys/module/; generic and acceptor parameters under **lnet** and LND-specific parameters under the corresponding LND's name.
- Under Linux 2.4, sysfs is not available, but the LND-specific parameters are accessible via equivalent paths under /proc.

NOTE:
Depending on the Linux distribution, options with included commas may need to be escaped by using single and/or double quotes. Worst-case quotes look like this:

```
options lnet 'networks="tcp0,elan0"' 'routes="tcp [2,10]@elan0"'
```

But the additional quotes may confuse some distributions. Check for messages such as:

```
lnet: Unknown parameter ''networks'
```

After modprobe LNET, the additional single quotes should be removed from modprobe.conf in this case. Additionally, the message "refusing connection - no matching NID" generally points to an error in the LNET module configuration

NOTE:
By default, Lustre ignores the loopback (lo0) interface. Lustre does not ignore IP addresses aliased to the loopback. In this case, specify all Lustre networks.

The liblustre network parameters may be set by exporting the environment variables LNET_NETWORKS, LNET_IP2NETS and LNET_ROUTES. Each of these variables uses the same parameters as the corresponding modprobe option.

Note, it is very important that a liblustre client includes ALL the routers in its setting of LNET_ROUTES. A liblustre client cannot accept connections, it can only create connections. If a server sends remote procedure call (RPC) replies via a router to which the liblustre client has not already connected, then these RPC replies are lost.

NOTE:
liblustre is not for general use. It was created to work with specific hardware (Cray) and should never be used with other hardware.

3.2.1.1 SilverStorm InfiniBand Options

For the SilverStorm/Infinicon InfiniBand LND (iiblnd), the network and HCA may be specified, as in this example:

```
options lnet networks="iib3(2)"
```

This says that this node is on iib network number 3, using HCA[2] == ib3.

3.2.1.2 Setting Up the Default Debug Level

If you are using zeroconf (mount -t lustre), add a line to your modules.conf as follows:

```
post-install portals sysctl -w portals.debug=0x3f0400
```

This sets the debug level to the value you specify, whenever the portals module is loaded.

NOTE:
The value above is the default value in Lustre, as it provides useful information for diagnosing problems without materially impairing the performance.

3.2.2 Module Parameters - Routing

The following parameter specifies a colon-separated list of router definitions. Each route is defined as a network type, followed by a list of routers.

```
route=<net type> <router NID(s)>
```

Examples:

```
options lnet ’networks="tcp0, elan0"' 'routes="tcp[2,10]@elan0"'
```

This identifies the Elan NIDs 2@elan0 and 10@elan0 as routers for the TCP network.

This is a more complicated example:

```
options lnet 'ip2nets="tcp0 192.168.0.*; elan0 132.6.1.*"' \
'routes="tcp [2,10]@elan0; elan 192.168.0.[2,10]@tcp0"
```

This specifies bi-directional routing - Elan clients can reach Lustre resources on the TCP networks and TCP clients can access the Elan networks. (For more information on *ip2nets*, see Modprobe.conf on page 55.)

Here is a very complex, routed configuration with Voltaire InfiniBand and Myrinet (GM) systems, with four systems configured as routers:

```
options lnet\
   ip2nets="gm10.10.3.*# aa*-i0;\
      vib10.10.131.[11-18]# aa[11-18]-ipoib0;\
      vib10.10.132.*# cc*-ipoib0;"\
   routes="gm10.10.131.[11-18]@vib# vib->gm via aa[11-13];\
      vib0xdd7f813b@gm# gm->vib via aa11;\
      vib0xdd7f81c7@gm# gm->vib via aa12;\
      vib0xdd7f81c2@gm# gm->vib via aa13"
```

live_router_check_interval, dead_router_check_interval, auto_down, check_routers_before_use and **router_ping_timeout**

In a routed Lustre setup with nodes on different networks such as TCP/IP and Elan, the router checker checks the status of a router. Currently, only the clients using the sock LND and Elan LND avoid failed routers. CFS is working on extending this behavior to include all types of LNDs. The **auto_down** parameter enables/disables (1/0) the automatic marking of router state.

The parameter **live_router_check_interval** specifies a time interval in seconds after which the router checker will ping the live routers.

In the same way, you can set the parameter **dead_router_check_interval** for checking dead routers.

You can set the timeout for the router checker to check the live or dead routers by setting the parameter **router_ping_timeout**. The Router pinger sends a ping message to a dead/live router once every **dead/live_router_check_interval** seconds, and if it does not get a reply message from the router within **router_ping_timeout** seconds, it believes the router is down.

The last parameter is **check_routers_before_use**, which is off by default. If it is turned on, you must also give **dead_router_check_interval** a positive integer value.

The router checker gets the following variables for each router:

- Last time that it was disabled
- Duration of time for which it is disabled

The initial time to disable a router should be one minute (enough to plug in a cable after removing it). If the router is administratively marked as "up", then the router checker clears the timeout. When a route is disabled (and possibly new), the "sent packets" counter is set to 0. When the route is first re-used (that is an elapsed disable time is found), the sent packets counter is incremented to 1, and incremented for all further uses of the route. If the route has been used for 100 packets successfully, then the sent-packets counter should be with a value of 100. Set the timeout to 0, so future errors no longer double the timeout.

NOTE:
The **router_ping_timeout** is consistent with the default LND timeouts. You may have to increase it on very large clusters if the LND timeout is also increased. For larger clusters, CFS suggests increasing the check interval.

3.2.3 Downed Routers

There are two mechanisms to update the health status of a peer or a router:

- LNET can actively check health status of all routers and mark them as dead or alive automatically. By default, this is off. To enable it set **auto_down** and if desired **check_routers_before_use**. This initial check may cause a pause equal to **router_ping_timeout** at system startup, if there are dead routers in the system.
- When there is a communication error, all LNDs notify LNET that the peer (not necessarily a router) is down. This mechanism is always on, and there is no parameter to turn it off. However, if you set the LNET module parameter **auto_down** to 0, LNET ignores all such peer-down notifications.

Several key differences in both mechanisms:

- The router pinger only checks routers for their health, while LNDs notices all dead peers, regardless of whether they are a router or not.
- The router pinger actively checks the router health by sending pings, but LNDs only notice a dead peer when there is network traffic going on.
- The router pinger can bring a router from alive to dead or vice versa, but LNDs can only bring a peer down.

3.3 Starting and Stopping LNET

Lustre automatically starts and stops LNET, but it can also be manually started in a standalone manner. This is particularly useful to verify that your networking setup is working correctly before you attempt to start Lustre.

3.3.1 Starting LNET

To start LNET, run:

```
$ modeprob lnet
$ lctl network up
```

To see the list of local NIDs, run:

```
$ lctl list_nids
```

This command tells you if the local node's networks are set up correctly.

If the networks are not correctly setup, see the modules.conf "networks=" line and make sure the network layer modules are correctly installed and configured.

To get the best remote NID, run:

```
$ lctl which_nid
```

This takes the "best" NID from a list of the NIDs of a remote host. The "best" NID is the one that the local node uses when trying to communicate with the remote node.

3.3.1.1 Starting Clients

To start a TCP client, run:

```
mount -t lustre mdsnode:/mdsA/client /mnt/lustre/
```

To start an Elan client, run:

```
mount -t lustre 2@elan0:/mdsA/client /mnt/lustre
```

3.3.2 Stopping LNET

Before the LNET modules can be removed, LNET references must be removed. In general, these references are removed automatically during Lustre shutdown, but for standalone routers, an explicit step is necessary to stop LNET. Run this command:

```
lctl network unconfigure
```

NOTE:
Attempting to remove the Lustre modules prior to stopping the network may result in a crash, or an LNET hang. If this occurs, the node must be rebooted (in most cases). Be certain the Lustre network and Lustre are stopped prior to module unloading. Be extremely careful using *rmmod -f*

To unconfigure the lctl network, run:

```
modprobe -r <any lnd and the lnet modules>
```

TIP:
To remove all the Lustre modules, run:

```
$ lctl modules | awk '{print $2}' | xargs rmmod
```

Chapter II - 4. Configuring Lustre - Examples

This chapter provides configuration examples and includes the following section:

4.1 Simple TCP Network

This chapter presents several examples of Lustre configurations on a simple TCP network.

4.1.1 Lustre with Combined MGS/MDT

Below is an example is of a Lustre setup “datafs” having combined MDT/MGS with four OSTs and a number of Lustre clients.

4.1.1.1 Installation Summary

- Combined (co-located) MDT/MGS
- Four OSTs
- Any number of Lustre clients

4.1.1.2 Configuration Generation and Application

1 Install the Lustre RPMS (per Installing Lustre on page 16) on all nodes that are going to be a part of the Lustre file system. Boot the nodes in Lustre kernel, including the clients.

2 Change modprobe.conf by adding the following line to it.

```
options lnet networks=tcp
```

3 Configuring Lustre on MGS and MDT node.

```
$ mkfs.lustre --fsname datafs --mdt --mgs /dev/sda
```

4 Make a mount point on MDT/MGS for the file system and mount it.

```
$ mkdir -p /mnt/data/mdt
$ mount -t lustre /dev/sda /mnt/data/mdt
```

5 Configuring Lustre on all four OSTs.

```
mkfs.lustre --fsname datafs --ost --mgsnode=mds16@tcp0 /dev/sda
mkfs.lustre --fsname datafs --ost --mgsnode=mds16@tcp1 /dev/sdd
mkfs.lustre --fsname datafs --ost --mgsnode=mds16@tcp2 /dev/sda1
mkfs.lustre --fsname datafs --ost --mgsnode=mds16@tcp3 /dev/sdb
```

6 Make a mount point on all the OSTs for the file system and mount it.

```
$ mkdir -p /mnt/data/ost0
$ mount -t lustre /dev/sda /mnt/data/ost0


$ mkdir -p /mnt/data/ost1
$ mount -t lustre /dev/sdd /mnt/data/ost1


$ mkdir -p /mnt/data/ost2
$ mount -t lustre /dev/sda1 /mnt/data/ost2


$ mkdir -p /mnt/data/ost3
$ mount -t lustre /dev/sdb /mnt/data/ost3


$ mount -t lustre mdt16@tcp0:/datafs /mnt/datafs
```

4.1.2 Lustre with Separate MGS and MDT

The following example describes a Lustre file system “datafs” having an MGS and an MDT on separate nodes, four OSTs, and a number of Lustre clients.

4.1.2.1 Installation Summary

- One MGS
- One MDT
- Four OSTs
- Any number of Lustre clients

4.1.2.2 Configuration Generation and Application

1. Install the Lustre RPMs (per Installing Lustre on page 16) on all the nodes that are going to be a part of the Lustre file system. Boot the nodes in the Lustre kernel, including the clients.
2. Change the modprobe.conf by adding the following line to it.

   ```
   options lnet networks=tcp
   ```

3. Start Lustre on the MGS node.

   ```
   $ mkfs.lustre --mgs /dev/sda
   ```

4. Make a mount point on MGS for the file system and mount it.

   ```
   $ mkdir -p /mnt/mgs
   $ mount -t lustre /dev/sda1 /mnt/mgs
   ```

5. Start Lustre on the MDT node.

   ```
   $ mkfs.lustre --fsname=datafs --mdt --mgsnode=mgsnode@tcp0 \
   /dev/sda2
   ```

6. Make a mount point on MDT/MGS for the file system and mount it.

   ```
   $ mkdir -p /mnt/data/mdt
   $ mount -t lustre /dev/sda /mnt/data/mdt
   ```

7 Start Lustre on all the four OSTs.

```
mkfs.lustre --fsname datafs --ost --mgsnode=mds16@tcp0 /dev/sda
mkfs.lustre --fsname datafs --ost --mgsnode=mds16@tcp1 /dev/sdd
mkfs.lustre --fsname datafs --ost --mgsnode=mds16@tcp2 /dev/sda1
mkfs.lustre --fsname datafs --ost --mgsnode=mds16@tcp3 /dev/sdb
```

8 Make a mount point on all the OSTs for the file system and mount it

```
$ mkdir -p /mnt/data/ost0
$ mount -t lustre /dev/sda /mnt/data/ost0


$ mkdir -p /mnt/data/ost1
$ mount -t lustre /dev/sdd /mnt/data/ost1


$ mkdir -p /mnt/data/ost2
$ mount -t lustre /dev/sda1 /mnt/data/ost2


$ mkdir -p /mnt/data/ost3
$ mount -t lustre /dev/sdb /mnt/data/ost3


$ mount -t lustre mdsnode@tcp0:/datafs /mnt/datafs
```

4.1.2.3 Configuring Lustre with a CSV File

You can configure Lustre 1.6 with a new utility (script) - **/usr/sbin/lustre_config**. This script enables you to automate the formatting and setup of disks on multiple nodes.

Describe your entire installation in a Comma Separated Values (CSV) file and pass it to the script. The script contacts multiple Lustre targets simultaneously, formats the drives, updates modprobe.conf, and produces HA configuration files using definitions in the CSV file. (The **lustre_config -h** option shows several samples of CSV files.)

NOTE:
The CSV file format is a file type that stores tabular data. Many popular spreadsheet programs, such as Microsoft Excel, can read/write CSV files.

How lustre_config Works

The **lustre_config** script parses each line of the CSV file and executes remote commands like **mkfs.lustre** to format every Lustre target that is a part of your Lustre cluster.

Optionally, the lustre_config script can also:

- Verify network connectivity and hostnames in the cluster
- Configure Linux MD/LVM devices
- Modify /etc/modprobe.conf to add Lustre networking information
- Add the Lustre server information to /etc/fstab
- Produce configurations for Heartbeat or CluManager

How to Create a CSV File

Five different types of line formats are available to create a CSV file. Each line format represents a target. The list of targets with the respective line formats are described below:

Linux MD device

The CSV line format is:

hostname, *MD*, *md name*, *operation mode*, *options*, *raid level*, *component devices*

Where:

Variable	Description
hostname	Hostname of the node in the cluster
MD	Marker of the MD device line
md name	MD device name, for example: /dev/md0
operation mode	Create or remove. Default is create
options	A "catchall" for other mdadm options, for example: "-c 128"
raid level	RAID level: 0,1,4,5,6,10, linear and multipath
component devices	Block devices to be combined into the MD device. Multiple devices are separated by space or by using shell expansions, for example: "/dev/sd{a,b,c}"

Linux LVM PV (Physical Volume)

The CSV line format is:

hostname, *PV*, *pv names*, *operation mode*, *options*

Where:

Variable	**Description**
hostname	Hostname of the node in the cluster
PV	Marker of the PV line
pv names	Devices or loopback files to be initialized for later use by LVM or to wipe the label, for example: /dev/sda Multiple devices or files are separated by space or by using shell expansions, for example: "/dev/sd{a,b,c}"
operation mode	Create or remove. Default is create
options	A "catchall" for other pvcreate/pvremove options, for example: "-vv"

Linux LVM VG (Volume Group)

The CSV line format is:

hostname, *VG*, *vg name*, *operation mode*, *options, pv paths*

Where:

Variable	**Description**
hostname	Hostname of the node in the cluster
VG	Marker of the VG line
vg name	Name of the volume group, for example: ost_vg
operation mode	Create or remove. Default is create
options	A "catchall" for other vgcreate/vgremove options, for example: "-s 32M"
pv paths	Physical volumes to construct this VG, required by the create mode; multiple PVs are separated by space or by using shell expansions, for example: "/dev/sd[k-m]1"

Linux LVM LV (Logical Volume)

The CSV line format is:

hostname, *LV*, *lv name*, *operation mode*, *options, lv size, vg name*

Where:

Variable	Description
hostname	Hostname of the node in the cluster
LV	Marker of the LV line
lv name	Name of the logical volume to be created (optional) or path of the logical volume to be removed (required by the remove mode)
operation mode	Create or remove. Default is create
options	A "catchall" for other lvcreate/lvremove options, for example: "-i 2 -I 128"
lv size	Size [kKmMgGtT] to be allocated for the new LV. Default is megabytes (MBs)
vg name	Name of the VG in which the new LV is created

Lustre target

The CSV line format is:

hostname, *module_opts*, *device name*, *mount point*, *device type, fsname, mgs nids, index, format options, mkfs options, mount options, failover nids*

Where:

Variable	Description
hostname	Hostname of the node in the cluster. It must match "uname -n"
module_opts	Lustre networking module options. Use the newline character (\n) to delimit multiple options.
device name	Lustre target (block device or loopback file)
mount point	Lustre target mount point
device type	Lustre target type (mgs, mdt, ost, mgs|mdt, mdt|mgs)
fsname	Lustre file system name (limit to 8 characters)
mgs nids	NID(s) of the remote mgs node, required for mdt and ost targets; if this item is not given for an mdt, it is assumed that the mdt is also an mgs, according to mkfs.lustre
Index	Lustre target index
format options	A "catchall" contains options to be passed to mkfs.lustre. For example: "--device-size", "--param", and so on
mkfs options	Format options to be wrapped with --mkfsoptions="" and passed to mkfs.lustre
mount options	If this script is invoked with "-m" option, then the value of this item is wrapped with --mountfsoptions="" and passed to mkfs.lustre; otherwise, the value is added into /etc/fstab
failover nids	NID(s) of the failover partner node

NOTE:
In one node, all NIDs are delimited by commas (','). To use comma-separated NIDs in a CSV file, they must be enclosed in quotation marks, for example: "lustre-mgs2,2@elan"

When multiple nodes are specified, they are delimited by a colon (':').

NOTE:
If you leave an item blank, it is set to default.

The lustre_config.csv file looks like:

```
{mdtname}.{domainname},options lnet networks=tcp,/dev/sdb,/mnt/mdt,mgs|mdt

{ost2name}.{domainname},options lnet networks=tcp,/dev/sda,/mnt/
ost1,ost,,192.168.16.34@tcp0

{ost1name}.{domainname},options lnet networks=tcp,/dev/sda,/mnt/
ost0,ost,,192.168.16.34@tcp0
```

NOTE:
Provide a Fully Qualified Domain Name (FQDN) for all nodes that are a part of the file system in the first parameter of all the rows starting in a new line. For example, mdt1.clusterfs.com,options lnet networks=tcp,/dev/sdb,/mnt/mdt,mgs|mdt

- AND -

ost1.clusterfs.com,options lnet\ networks=tcp,/dev/sda,/mnt/
ost1,ost,,192.168.16.34@tcp0

Using CSV with lustre_config

Once you created the CSV file, you can start to configure the file system by using the lustre_config script.

1 List the available parameters. At the command prompt. Type:

```
$ lustre_config


lustre_config: Missing csv file!
Usage:  lustre_config [options] <csv file>
   This script is used to format and set up multiple lustre servers from a
   csv file.
    Options:
    -h          help and examples
    -a          select all the nodes from the csv file to operate on
    -w          hostname,hostname,...
                select the specified list of nodes (separated by commas) to
                operate on rather than all the nodes in the csv file
    -x          hostname,hostname,... exclude the specified list of nodes
                (separated by commas)
    -t          HAtype produce High-Availability software configurations
                The argument following -t is used to indicate the High-
                Availability software type. The HA software types which are
                currently supported are: hbv1 (Heartbeat version 1) and hbv2
                (Heartbeat version 2).
    -n          no net - don't verify network connectivity and hostnames in
                the cluster
    -d          configure Linux MD/LVM devices before formatting the Lustre
                targets
    -f          force-format the Lustre targets using --reformat option OR you
                can specify --reformat in the ninth field of the target line
                in the csv file
    -m          no fstab change - don't modify /etc/fstab to add the new
                Lustre targets. If using this option, then the value of "mount
                options" item in the csv file will be passed to mkfs.lustre,
                else the value will be added into the /etc/fstab.
    -v          verbose mode
   csv file is a spreadsheet that contains configuration parameters
   (separated by commas) for each target in a Lustre cluster
```

Example 1: Simple Lustre configuration with CSV (use the following command):

```
$ lustre_config -v -a -f lustre_config.csv
```

This command starts the execution and configuration on the nodes or targets in lustre_config.csv, prompting you for the password to log in with root access to the nodes. To avoid this prompt, configure a shell like pdsh or ssh.

After completing the above steps, the script makes Lustre target entries in the /etc/fstab file on Lustre server nodes, such as:

```
/dev/sdb          /mnt/mdtlustre  defaults        0 0
/dev/sda          /mnt/ostlustre  defaults        0 0
```

2 Run "mount /dev/sdb" and "mount /dev/sda" to start the Lustre services.

NOTE:
You can use a script, /usr/sbin/lustre_createcsv, to collect the information on Lustre targets from a running Lustre cluster and generating a CSV file. It is a reverse utility as compared to lustre_config and should be run on the MGS node.

Example 2: More complicated Lustre configuration with CSV (use the following command):

For RAID and LVM-based configuration, the lustre_config.csv file looks like this:

```
# Configuring RAID 5 on mds16.clusterfs.com
mds16.clusterfs.com,MD,/dev/md0,,-c 128,5,/dev/sdb /dev/sdc /dev/sdd


# configuring multiple RAID5 on oss161.clusterfs.com
oss161.clusterfs.com,MD,/dev/md0,,-c 128,5,/dev/sdb /dev/sdc /dev/sdd
oss161.clusterfs.com,MD,/dev/md1,,-c 128,5,/dev/sde /dev/sdf /dev/sdg
# configuring LVM2-PV from the RAID5 from the above steps on
oss161.clusterfs.com
oss161.clusterfs.com,PV,/dev/md0 /dev/md1
# configuring LVM2-VG from the PV and RAID5 from the above steps on
oss161.clusterfs.com
oss161.clusterfs.com,VG,oss_data,,-s 32M,/dev/md0 /dev/md1
# configuring LVM2-LV from the VG, PV and RAID5 from the above steps on
oss161.clusterfs.com
oss161.clusterfs.com,LV,ost0,,-i 2 -I 128,2G,oss_data
oss161.clusterfs.com,LV,ost1,,-i 2 -I 128,2G,oss_data


# configuring LVM2-PV on oss162.clusterfs.com
oss162.clusterfs.com,PV, /dev/sdb /dev/sdc /dev/sdd /dev/sde /dev/sdf /dev/
sdg
# configuring LVM2-VG from the PV from the above steps on
oss162.clusterfs.com
oss162.clusterfs.com,VG,vg_oss1,,-s 32M,/dev/sdb /dev/sdc /dev/sdd
oss162.clusterfs.com,VG,vg_oss2,,-s 32M,/dev/sde /dev/sdf /dev/sdg
# configuring LVM2-LV from the VG and PV from the above steps on
oss162.clusterfs.com
oss162.clusterfs.com,LV,ost3,,-i 3 -I 64,1G,vg_oss2
```

```
oss162.clusterfs.com,LV,ost2,,-i 3 -I 64,1G,vg_oss1

#configuring Lustre File System on MDS/MGS, OSS and OST with RAID and LVM
created above

mds16.clusterfs.com,options lnet networks=tcp,/dev/md0,/mnt/
mdt,mgs|mdt,,,,,,,

oss161.clusterfs.com,options lnet networks=tcp,/dev/oss_data/ost0,/mnt/
ost0,ost,,192.168.16.34@tcp0,,,,

oss161.clusterfs.com,options lnet networks=tcp,/dev/oss_data/ost1,/mnt/
ost1,ost,,192.168.16.34@tcp0,,,,

oss162.clusterfs.com,options lnet networks=tcp,/dev/pv_oss1/ost2,/mnt/
ost2,ost,,192.168.16.34@tcp0,,,,

oss162.clusterfs.com,options lnet networks=tcp,/dev/pv_oss2/ost3,/mnt/
ost3,ost,,192.168.16.34@tcp0,,,,

$ lustre_config -v -a -d -f lustre_config.csv
```

This command creates RAID and LVM, and then configures Lustre on the nodes or targets specified in lustre_config.csv. The script prompts you for the password to log in with root access to the nodes.

After completing the above steps, the script makes Lustre target entries in the /etc/fstab file on Lustre server nodes, such as:

For MDS | MDT:

```
/dev/md0 /mnt/mdt                lustre  defaults        0 0
```

For OSS:

```
/pv_oss1/ost2 /mnt/ost2          lustre  defaults        0 0
```

3 Run "mount /dev/sdb" and "mount /dev/sda" to start the Lustre services.

Chapter II - 5. More Complicated Configurations

This chapter describes more complicated Lustre configurations and includes the following sections:

- Multihomed Servers
- Elan to TCP Routing

5.1 Multihomed Servers

Servers megan and oscar each have three TCP NICs (eth0, eth1, and eth2) and an Elan NIC. The eth2 NIC is used for management purposes and should not be used by LNET. TCP clients have a single TCP interface and Elan clients have a single Elan interface.

5.1.1 Modprobe.conf

Options under modprobe.conf are used to specify the networks available to a node. You have the choice of two different options – the networks option, which explicitly lists the networks available and the ip2nets option, which provides a list-matching lookup. Only one option can be used at any one time. The order of LNET lines in modprobe.conf is important when configuring multi-homed servers. If a server node can be reached using more than one network, the first network specified in modprobe.conf will be used.

Networks

On the servers:

```
options lnet 'networks="tcp0(eth0,eth1),elan0"'
```

Elan-only clients:

```
options lnet networks=elan0
```

TCP-only clients:

```
options lnet networks=tcp0
```

IB-only clients:

```
options lnet networks="iib0"
options kiiblnd ipif_basename=ib0
```

NOTE:
In the case of TCP-only clients, all available IP interfaces are used for tcp0 since the interfaces are not specified. If there is more than one, the IP of the first one found is used to construct the tcp0 NID.

ip2nets

The *ip2nets* option is typically used to provide a single, universal modprobe.conf file that can be run on all servers and clients. An individual node identifies the locally available networks based on the listed IP address patterns that match the node's local IP addresses. Note that the IP address patterns listed in this option (ip2nets) are only used to identify the networks that an individual node should instantiate. They are not used by LNET for any other communications purpose. The servers megan and oscar have eth0 IP addresses 192.168.0.2 and .4. They also have IP over Elan (eip) addresses of 132.6.1.2 and .4. TCP clients have IP addresses 192.168.0.5-255. Elan clients have eip addresses of 132.6.[2-3].2, .4, .6, .8.

Modprobe.conf is identical on all nodes:

```
options lnet 'ip2nets="tcp0(eth0,eth1)192.168.0.[2,4]; tcp0 \
192.168.0.*; elan0 132.6.[1-3].[2-8/2]"'
```

NOTE:
LNET lines in modprobe.conf are used by the local node only to determine what to call its interfaces. They are not used for routing decisions.

Because megan and oscar match the first rule, LNET uses eth0 and eth1 for tcp0 on those machines. Although they also match the second rule, it is the first matching rule for a particular network that is used. The servers also match the (only) Elan rule. The [2-8/2] format matches the range 2-8 stepping by 2; that is 2,4,6,8. For example, clients at 132.6.3.5 would not find a matching Elan network.

5.1.2 Start Servers

For the combined MGS/MDT with TCP network, run these commands:

```
$ mkfs.lustre --fsname spfs --mdt --mgs /dev/sda
$ mkdir -p /mnt/test/mdt
$ mount -t lustre /dev/sda /mnt/test/mdt
```

- OR -

For the MGS on the separate node with TCP network, run these commands:

```
$ mkfs.lustre --mgs /dev/sda
$ mkdir -p /mnt/mgs
$ mount -t lustre /dev/sda /mnt/mgs
```

For starting the MDT on node mds16 with MGS on node mgs16, run these commands:

```
$ mkfs.lustre --fsname=spfs --mdt --mgsnode=mgs16@tcp0 /dev/sda
$ mkdir -p /mnt/test/mdt
$ mount -t lustre /dev/sda2 /mnt/test/mdt
```

For starting the OST on TCP-based network, run these commands:

```
$ mkfs.lustre --fsname spfs --ost --mgsnode=mgs16@tcp0 /dev/sda$
$ mkdir -p /mnt/test/ost0
$ mount -t lustre /dev/sda /mnt/test/ost0
```

5.1.3 Start Clients

TCP clients can use the host name or IP address of the MDS, run:

```
mount –t lustre megan@tcp0:/mdsA/client /mnt/lustre
```

Use this command to start the Elan clients:

```
mount –t lustre 2@elan0:/mdsA/client /mnt/lustre
```

NOTE:
If the MGS node has multiple interfaces (for instance, cfs21 and 1@elan), only the client mount command has to change. The MGS NID specifier must be an appropriate nettype for the client (for example, TCP client could use uml1@tcp0, and Elan client could use 1@elan). Alternatively, a list of all MGS NIDs can be given, and the client chooses the correct one. For example:

```
$ mount -t lustre mgs16@tcp0,1@elan:/testfs /mnt/testfs
```

5.2 Elan to TCP Routing

Servers megan and oscar are on the Elan network with eip addresses 132.6.1.2 and .4. Megan is also on the TCP network at 192.168.0.2 and routes between TCP and Elan. There is also a standalone router, router1, at Elan 132.6.1.10 and TCP 192.168.0.10. Clients are on either Elan or TCP.

5.2.1 Modprobe.conf

Modprobe.conf is identical on all nodes, run:

```
options lnet 'ip2nets="tcp0 192.168.0.*; elan0 132.6.1.*"' \
'routes="tcp [2,10]@elan0; elan 192.168.0.[2,10]@tcp0"'
```

5.2.2 Start servers

To start router1, run:

```
modprobe lnet
lctl network configure
```

To start megan and oscar, run:

```
FIXME
```

5.2.3 Start clients

For the TCP client, run:

```
mount -t lustre megan:/mdsA/client /mnt/lustre/
```

For the Elan client, run:

```
mount -t lustre 2@elan0:/mdsA/client /mnt/lustre
```

Chapter II - 6. Failover

This chapter describes failover in a Lustre system and includes the following sections:

6.1 What is Failover?

We say a computer system is **Highly Available** when the services it provides are available with minimum downtime. In a highly-available system, if a failure condition occurs, such as loss of a server or a network or software fault, the services provided remain unaffected. Generally, we measure availability by the percentage of time the system is required to be available.

Availability is accomplished by providing replicated hardware and/or software, so failure of the system will be covered by a paired system. The concept of “failover” is the method of switching an application and its resources to a standby server when the primary system fails or is unavailable. Failover should be automatic and, in most cases, completely application-transparent.

Lustre failover requires two nodes (a failover pair), which must be connected to a shared storage device. Lustre supports failover for both metadata and object storage servers.

The Lustre file system supports failover at the server level. Lustre does not provide the tool set for system-level components that is needed for a complete failover solution (node failure detection, power control, and so on)[1]. CFS does provide the necessary scripts to interact with these packages, and exposes health information for system monitoring. The recommended choice is the Heartbeat package (from www.linux-ha.org). Heartbeat is responsible for detecting failure of the primary server node and controlling the failover. Lustre works with any HA software that supports resource (I/O) fencing.

1. This functionality has been available for some time in third-party tools.

The hardware setup requires a pair of servers with a shared connection to a physical storage (like SAN, NAS, hardware RAID, SCSI and FC). The method of sharing storage should be essentially transparent at the device level, that is, the same physical LUN should be visible from both nodes. To ensure high availability at the level of physical storage, we encourage the use of RAID arrays to protect against drive-level failures.

To have a fully-automated, highly-available Lustre system, you need power management software and HA software, which must provide the following -

- **Resource fencing** - Physical storage must be protected from simultaneous access by two nodes.
- **Resource control** - Starting and stopping the Lustre processes as a part of failover, maintaining the cluster state, and so on.
- **Health monitoring** - Verifying the availability of hardware and network resources, responding to health indications given by Lustre.

For proper resource fencing, the Heartbeat software must be able to completely power off the server or disconnect it from the shared storage device. It is absolutely vital that no two active nodes access the same partition, at the risk of severely corrupting data. When Heartbeat detects a server failure, it calls a process (STONITH) to power off the failed node; and then starts Lustre on the secondary node. HA software controls the Lustre resources with a service script. CFS provides /etc/init.d/lustre for this purpose.

Servers providing Lustre resources are configured in primary/secondary pairs for the purpose of failover. When a server “umount” command is issued, the disk device is set read-only. This allows the second node to start service using that same disk, after the command completes. This is known as a **soft** failover, in which case both the servers can be running and connected to the net. Powering off the node is known as a **hard** failover.

6.1.1 The Power Management Software

The Linux-HA package includes a set of power management tools, known as STONITH (Shoot The Other Node In The Head). STONITH has native support for many power control devices, and is extensible. It uses expect scripts to automate control. PowerMan, by the Lawrence Livermore National Laboratory (LLNL), is a tool for manipulating remote power control (RPC) devices from a central location. Several RPC varieties are supported natively by PowerMan. The latest version is available at:

http://www.llnl.gov/linux/powerman/

6.1.2 Power Equipment

A multi-port, Ethernet addressable RPC is relatively inexpensive. For recommended products, refer to the list of supported hardware on the PowerMan site. Linux Network Iceboxes are also very good tools. They combine the remote power control and the remote serial console into a single unit.

6.1.3 Heartbeat

The Heartbeat package is one of the core components of the Linux-HA project. Heartbeat is highly-portable, and runs on every known Linux platform, as well as FreeBSD and Solaris. For more information, see:

http://linux-ha.org/HeartbeatProgram

To download Linux-HA, go to:

http://linux-ha.org/download

CFS supports both Heartbeat V1 and Heartbeat V2. V1 has a simpler configuration and works very well. V2 adds monitoring and supports more complex cluster topologies. CFS recommends that you refer to the Linux-HA website for additional information.

6.1.4 Connection Handling During Failover

A connection is alive when it is active and in operation. While sending a new request this type of connection, the connection does not develop until either the reply arrives or the connection becomes disconnected or failed. If there is no traffic on a given connection, you should check the connection periodically to ensure its status.

If an active connection disconnects, then it leads to at least one timed-out request. New and old requests alike are in sleep until:

- The reply arrives (in case of reactivation of the connection and during the re-send request asynchronously).
- The application gets a signal (such as TERM or KILL).
- The server evicts the client (which gives -EIO for these requests) or the connection becomes "failed."

Therefore, the timeout is effectively infinite. Lustre waits as long as it needs to and avoids giving the application an -EIO error.

Finally, if a connection goes to "failed" condition, which happens immediately in the "failout" OST mode, new and old requests receive -EIO immediately. In non-failout mode, a connection can only get into this state by using "lctl deactivate", which is the only option for the client in the event of an OST failure.

6.1.5 Roles of Nodes in a Failover

A failover pair of nodes can be configured in two ways – **active / active** and **active / passive**. An active node actively serves data while a passive node is idle, standing by to take over in the event of a failure. In the following example, using two OSTs (both of which are attached to the same shared disk device), the following failover configurations are possible:

- **active / passive** - This configuration has two nodes out of which only one is actively serving data all the time. In case of a failure, the other node takes over.

  If the active node fails, the OST in use by the active node will be taken over by the passive node, which now becomes active. This node serves most of the services that were on the failed node.

- **active / active** - This configuration has two nodes actively serving data all the time. In case of a failure, one node takes over for the other.

  To configure this with respect to the shared disk, the shared disk needs to provide multiple partitions, and each OST is the primary server for one partition and the *secondary* server for the other partition. The active / passive configuration doubles the hardware cost without improving performance, and is seldom used for OST servers.

6.2 OST Failover Review

The OST has two operating modes: **failover** and **failout**. The default mode is **failover**. In this mode, the clients reconnect after a failure, and the transactions, which were in progress, are completed. Data on the OST is written synchronously, and the client replays uncommitted transactions after the failure.

In the failout mode, when any communication error occurs, the client attempts to reconnect, but is unable to continue with the transactions that were in progress during the failure. Also, if the OST actually fails, data that has not been written to the disk (still cached on the client) is lost. Applications usually see an -EIO for operations done on that OST until the connection is reestablished. However, the LOV layer on the client avoids using that OST. Hence, the operations such as file creates and fsstat still succeed. The failover mode is the current default, while the failout mode is seldom used.

6.3 MDS Failover Review

The MDS has only one failover mode: active / passive, as only one MDS may be active at a given time.

6.4 Configuring MDS and OSTs for Failover

6.4.1 Starting / Stopping a Resource

You can start a resource with the “mount” command and stop it with the “umount” command. For details, see Stopping a Server on page 22.

6.4.2 Active / Active Failover Configuration

With OST servers it is possible to have a load-balanced active / active configuration. Each node is the primary node for a group of OSTs, and the failover node for other groups. To expand the simple two-node example, we add ost2 which is primary on nodeB, and is on the LUNs nodeB:/dev/sdc1 and nodeA:/dev/sdd1. This demonstrates that the /dev/ identify can differ between nodes, but both devices must map to the same physical LUN.

For an active / active configuration, mount one OST on one node and another OST on the other node. You can format them from either node.

6.4.3 Hardware Requirements for Failover

This section describes hardware requirements that must be met to configure Lustre for failover.

6.4.3.1 Hardware Preconditions

- The setup must consist of a failover pair where each node of the pair has access to shared storage. If possible, the storage paths should be identical (nodeA:/dev/sda == nodeB:/dev/sda).
- Shared storage can be arranged in an active / passive (MDS, OSS) or active / active (OSS only) configuration. Each shared resource has a primary (default) node. Heartbeat assumes that the non-primary node is secondary for that resource.
- The two nodes must have one or more communication paths for Heartbeat traffic. A communication path can be:
  - Dedicated Ethernet
  - Serial live (serial crossover cable)

  Failure of all Heartbeat communication is not good. This condition is called “split-brain”. The Heartbeat software resolves this situation by powering down one node.
- The two nodes must have a method to control one another's state; RPC hardware is the best choice. There must be a script to start and stop a given node from the other node. STONITH provides soft power control methods (SSH, meatware), but these cannot be used in a production situation.
- Heartbeat provides a remote ping service that is used to monitor the health of the external network. If you wish to use the ipfail service, then you must have a very reliable external address to use as the ping target. Typically, this is a firewall route or another very reliable network endpoint external to the cluster.

6.5 Setting Up Failover with Heartbeat V1

This section describes how to set up failover with Heartbeat V1.

6.5.1 Installing the Software

1. Install Lustre (see Lustre Installation on page 15).
2. Install the RPMs that are required to configure Heartbeat.

   The following packages are needed for Heartbeat V1. CFS used the 1.2.3-1 version. RedHat supplies v1.2.3-2. Heartbeat is available as an RPM or source.

   These are the Heartbeat packages, in order:

   - heartbeat-stonith -> heartbeat-stonith-1.2.3-1.i586.rpm
   - heartbeat-pils -> heartbeat-pils-1.2.3-1.i586.rpm
   - heartbeat itself -> heartbeat-1.2.3-1.i586.rpm

   You can find the above RPMs at:

   http://linux-ha.org/download/index.html#1.2.3
3. Satisfy the installation prerequisites.

   Heartbeat 1.2.3 installation requires following:

   - python
   - openssl
   - libnet-> libnet-1.1.2.1-19.i586.rpm
   - libpopt -> popt-1.7-274.i586.rpm
   - librpm -> rpm-4.1.1-222.i586.rpm
   - glib -> glib-2.6.1-2.i586.rpm
   - glib-devel -> glib-devel-2.6.1-2.i586.rpm

6.5.1.1 Configuring Heartbeat

This section describes basic configuration of Heartbeat with and without STONITH.

Basic Configuration - Without STONITH

The http://linux-ha.org website has several guides covering basic setup and initial testing of Heartbeat; CFS suggests that you read them.

1 Configure and test the Heartbeat setup before adding STONITH.

Let us assume there are two nodes, nodeA and nodeB. nodeA owns ost1 and nodeB owns ost2. Both the nodes are with dedicated Ethernet – eth0 having serial crossover link – /dev/ttySO. Consider that both nodes are pinging to a remote host – 192.168.0.3 for health.

2 Create /etc/ha.d/ha.cf

- This file must be identical on both the nodes.
- Follow the specific order of the directives..
- Sample ha.cf file

```
# Suggested fields - logging
debugfile /var/log/ha-debug
logfile /var/log/ha-log
logfacility local0
#  Required fields - Timing
keepalive 2
deadtime 30
initdead 120
# If using serial Heartbeat
baud 19200
serial  /dev/ttyS0
# For Ethernet broadcast
udpport 694
bcast eth0
# Use manual failback
auto_failback off
# Cluster members - name must match `hostname`
node oss161.clusterfs.com oss162. clusterfs.com
# remote health ping
ping 192.168.16.1
respawn hacluster /usr/lib/heartbeat/ipfail
```

3 Create /etc/ha.d/haresources

- This file must be identical on both the nodes.
- It specifies a virtual IP address and a service.
- Sample haresources

```
oss161.clusterfs.com 192.168.16.35 \
Filesystem::/dev/sda::/ost1::lustre


oss162.clusterfs.com 192.168.16.36 \
Filesystem::/dev/sda::/ost1::lustre
```

4 Create /etc/ha.d/authkeys

- Copy the example from /usr/share/doc/heartbeat-<*version*>.
- chmod the file '0600' – Heartbeat does not start if the permissions on this file are incorrect.
- Sample authkeys files

```
auth 1

1 sha1 PutYourSuperSecretKeyHere
```

a. Start Heartbeat.

```
[root@oss161 ha.d]# service heartbeat start

Starting High-Availability services:
[  OK  ]
```

b. Monitor the syslog on both nodes. After the initial deadtime interval, you should see the nodes discovering each other's state, and then they start the Lustre resources they own. You should see the startup command in the log:

```
Aug  9 09:50:44 oss161 crmd: [4733]: info: update_dc: Set DC to <null>
(<null>)

Aug  9 09:50:44 oss161 crmd: [4733]: info: do_election_count_vote:
Election check: vote from oss162.clusterfs.com

Aug  9 09:50:44 oss161 crmd: [4733]: info: update_dc: Set DC to <null>
(<null>)

Aug  9 09:50:44 oss161 crmd: [4733]: info: do_election_check: Still
waiting on 2 non-votes (2 total)

Aug  9 09:50:44 oss161 crmd: [4733]: info: do_election_count_vote:
Updated voted hash for oss161.clusterfs.com to vote

Aug  9 09:50:44 oss161 crmd: [4733]: info: do_election_count_vote:
Election ignore: our vote (oss161.clusterfs.com)

Aug  9 09:50:44 oss161 crmd: [4733]: info: do_election_check: Still
waiting on 1 non-votes (2 total)

Aug  9 09:50:44 oss161 crmd: [4733]: info: do_state_transition: State
transition S_ELECTION -> S_PENDING [ input=I_PENDING
cause=C_FSA_INTERNAL origin=do_election_count_vote ]

Aug  9 09:50:44 oss161 crmd: [4733]: info: update_dc: Set DC to <null>
(<null>)
```

```
Aug  9 09:50:44 oss161 crmd: [4733]: info: do_dc_release: DC role
released

Aug  9 09:50:45 oss161 crmd: [4733]: info: do_election_count_vote:
Election check: vote from oss162.clusterfs.com

Aug  9 09:50:45 oss161 crmd: [4733]: info: update_dc: Set DC to <null>
(<null>)

Aug  9 09:50:46 oss161 crmd: [4733]: info: update_dc: Set DC to
oss162.clusterfs.com (1.0.9)

Aug  9 09:50:47 oss161 crmd: [4733]: info: update_dc: Set DC to
oss161.clusterfs.com (1.0.9)

Aug  9 09:50:47 oss161 cib: [4729]: info: cib_replace_notify: Local-
only Replace: 0.0.1 from <null>

Aug  9 09:50:47 oss161 crmd: [4733]: info: do_state_transition: State
transition S_PENDING -> S_NOT_DC [ input=I_NOT_DC cause=C_HA_MESSAGE
origin=do_cl_join_finalize_respond ]

Aug  9 09:50:47 oss161 crmd: [4733]: info: populate_cib_nodes:
Requesting the list of configured nodes

Aug  9 09:50:48 oss161 crmd: [4733]: notice: populate_cib_nodes: Node:
oss162.clusterfs.com (uuid: 00e8c292-2a28-4492-bcfc-fb2625ab1c61)

Aug  9 09:50:48 oss161 crmd: [4733]: notice: populate_cib_nodes: Node:
oss161.clusterfs.com (uuid: e370be9a-24f4-46a5-99ac-41a88c5fa344)

Sep 7 10:42:40 d1_q_0 heartbeat: info: Running \

/etc/ha.d/resource.d/ost1 start
```

In this example, 'ost1' is our shared resource. These are common things to watch out for:

- If you configure two nodes as primary for one resource, then you will see both nodes attempt to start it. This is very bad. Shut down immediately and correct your HA resources files.
- If the commutation between nodes is not correct, both nodes may also attempt to mount the same resource, or will attempt to STONITH each other. There should be many error messages in syslog indicating a communication fault.
- When in doubt, you can set a Heartbeat debug level in ha.cf—levels above 5 produce huge volumes of data.

c. Try some manual failover/ failback. Heartbeat provides two tools for this purpose (by default they are installed in /usr/lib/heartbeat) –

- hb_standby [local|foreign] – Causes a node to yield resources to another node—if a resource is running on its primary node it is local, otherwise it is foreign.
- hb_takeover [local|foreign] – Causes a node to grab resources from another node.

Basic Configuration - With STONITH

STONITH automates the process of power control with the expect package. Expect scripts are very dependent on the exact set of commands provided by each hardware vendor, and as a result any change made in the power control hardware/ firmware requires tweaking STONITH.

Much must be deduced by running the STONITH package by hand. STONITH has some supplied packages, but can also run with an external script. There are two STONITH modes:

- Single STONITH command for all nodes found in ha.cf:

```
-------/etc/ha.d/ha.cf-------------------
stonith <type> <config file>
```

- STONITH command per-node:

```
-------/etc/ha.d/ha.cf--------------------
stonith_host <hostfrom> <stonith_type> <params...>
```

You can use an external script to kill each node:

```
stonith_host nodeA external foo /etc/ha.d/reset-nodeB
stonith_host nodeB external foo /etc/ha.d/reset-nodeA
```

Here, foo is a placeholder for an unused parameter.

To get the proper syntax, run:

```
$ stonith -L
```

The above command lists supported models.

To list required parameters and specify the config file name, run:

```
$ stonith -l -t <model>
```

To attempt a test, run:

```
$ stonith -l -t <model> <fake host name>
```

This command also gives data on what is required. To test, use a real hostname. The external STONITH scripts should take the parameters *{start|stop|status}* and return 0 or 1.

STONITH _only happens when the cluster cannot do things in an orderly manner. If two cluster nodes can communicate, they usually shut down properly. This means many tests do not produce a STONITH, for example:

- Calling **init 0** or **shutdown** or **reboot** on a node, orderly halt, no STONITH
- Stopping the heartbeat service on a node, again, orderly halt, no STONITH

You really have to do something drastic (for example, killall -9 heartbeat) like pulling cables, or so on before you trigger STONITH.

Also, the alert script does a software failover, which halts Lustre but does not halt or STONITH the system. To use STONITH, edit the fail_lustre.alert script and add your preferred shutdown command after the line -

`/usr/lib/heartbeat/hb_standby local &`;

A simple method to halt the system is the sysrq method, run:

```
$ !/bin/bash
```

This script forces a boot, run:

```
$ 'echo s' = sync
$ 'echo u' = remount read-only
$ 'echo b' = reboot
$

SYST="/proc/sysrq-trigger"
if [ ! -f $SYST ]; then
echo "$SYST not found!"
exit 1
fi

$ sync, unmount, sync, reboot
echo s > $SYST
echo u > $SYST
echo s > $SYST
echo b > $SYST

exit 0
```

6.5.2 Mon (Status Monitor)

Mon requires two scripts:

- Monitor script (checks a resource for health)
- Alert script (triggered by failure of the monitor)

Mon requires one configuration file:

/etc/mon/mon.cf

We use a trap-based monitor. The trap is set with a time interval. The trap is cleared by checking Lustre health. If the trap is not cleared, mon triggers a failover.

All monitors are configured in one file. Mon is started as a service at boot prior to heartbeat startup. All monitors are disabled at startup and enabled by Heartbeat in conjunction with resource startup / shutdown.

6.5.2.1 Mon Setup and Configuration

This section describes installation prerequisites for Mon and how to install Mon.

Install Prerequisites for Mon

Mon is not required for a basic failover setup. It is not required for Heartbeart V2, as monitoring is included in V2.

The Heartbeat software monitors the health of the node. Adding Mon to the setup allows application health to be monitored (Lustre is the application).

The base package is available from

ftp://ftp.kernel.org/pub/software/admin/

Mon requires following Perl packages:

- Time::Period
- Time::HiRes
- Convert::BER
- Mon::SNMP

As always, CFS recommends using CPAN when installing Perl. The packages are also available as tarballs refer to:

http://www.cpan.org

Install Mon

After installing the Perl packages, obtain the Mon tarball at

ftp://ftp.kernel.org/pub/software/admin/mon/

1 Untar the tarball.

2 Copy the Mon program to a location on the root path.

(*/usr/lib/mon/mon* is default)

3 Install the *moncmd* program.

4 For this setup, CFS has altered the Mon startup a bit. You must patch the S99mon script, and install the result as /etc/init.d/mon – set this routine to start at boot, prior to the Heartbeat startup

```
$ chkconfig --add mon
```

5 Verify that the path for moncmd in the init script matches where you installed moncmd (/usr/local/bin/moncmd is the default).

6 Create a set of Mon directories as specified in /etc/mon/mon.cf

cfbasedir= /etc/mon

alertdir= /usr/local/lib/mon/alert.d

mondir= /usr/local/lib/mon/mon.d

statedir= /usr/local/lib/mon/state.d

logdir= /usr/local/lib/mon/log.d

dtlogfile= /usr/local/lib/mon/log.d/downtime.log

7 Create the /etc/mon/auth.cf file - allow everything in the *command* section change AUTH_ANY to *all*.

8 Create the /etc/mon/mon.cf file. Starting with the provided example:

   a. Verify that the correct paths are set.
   b. For each Lustre object, create two watches:
      - The first watch runs the trap monitor.
      - The second watch receives the trap.
      - Both monitors will attempt to fail Lustre if they fail.
      - The monitor currently hard kills heartbeat to guarantee failover

A CFS user has provided a shell script that will generate a mon.cf file.

9 Copy the supplied trap generator script (mon.trap) to a proper location (/usr/local/lib/mon/)

This Perl script is based on a script found on the Mon mailing list. Other scripts are also available there

10 Copy the provided Lustre monitor script (lustre.mon.trap) to the mon monitor directory (/usr/local/lib/mon/mon.d)

   a. Verify that the location of TRAPPER points at the trap generation script from mon.trap
   b. Verify that the name matches the script specified in /etc/mon/mon.cf
   c. This script is based on /etc/init.d/lustre

11 Copy the provided Lustre alert script to the mon alert directory: /usr/local/lib/mon/alert.d

a. Verify that the name matches script specified in /etc/mon/mon.cf

This is a stock script from the mon package.

b. For the Lustre failover sequence, you are free to choose another method of triggering the transition.

- The script will _not STONITH the node.
- Edit the script to provide hard node power off or reboot (if needed).

Add Mon to the Heartbeat Configuration

1 Copy the lustre-resource-monitor script to the Heartbeat resource directory (/etc/ha.d/resource.d)

2 Give the script a unique name (alpha-mon, beta-mon).

3 Edit the script, and set MONLIST to the service names to be monitored (two services per object as defined in /etc/mon/mon.cf).

4 Edit /etc/ha.d/haresources to add the mon scripts—the mon script will appear on the same line as the Lustre resource.

5 Restart the Heartbeat software.

The trap should appear in syslog:

```
Apr 26 13:45:38 d2_q_0 mon[3000]: trap trap 1 from 192.168.0.150 \
for alpha-ost lustre_a, status 255
```

6.6 Setting Up Failover with Heartbeat V2

This section describes how to set up failover with Heartbeat V2.

6.6.1 Installing the Software

1 Install Lustre (see Lustre Installation on page 15**).**

2 Install RPMs required for configuring Heartbeat.

The following packages are needed for Heartbeat (v2). We used the 2.0.4 version of Heartbeat.

Heartbeat packages, in order:

- heartbeat-stonith -> heartbeat-stonith-2.0.4-1.i586.rpm
- heartbeat-pils -> heartbeat-pils-2.0.4-1.i586.rpm
- heartbeat itself -> heartbeat-2.0.4-1.i586.rpm

You can find all the RPMs at the following location:

http://linux-ha.org/download/index.html#2.0.4

3 Satisfy the installation prerequisites.

To install Heartbeat 2.0.4-1, you require:

- Python
- openssl
- libnet-> libnet-1.1.2.1-19.i586.rpm
- libpopt -> popt-1.7-274.i586.rpm
- librpm -> rpm-4.1.1-222.i586.rpm
- libtld- > libtool-ltdl-1.5.16.multilib2-3.i386.rpm
- lingnutls -> gnutls-1.2.10-1.i386.rpm
- Libzo ->lzo2-2.02-1.1.fc3.rf.i386.rpm
- glib -> glib-2.6.1-2.i586.rpm
- glib-devel -> glib-devel-2.6.1-2.i586.rpm

6.6.2 Configuring the Hardware

Heartbeat v2 runs well with an un-altered v1 configuration. This makes upgrading simple. You can test the basic function and quickly roll back if issues appear. Heartbeat v2 does not require a virtual IP address to be associated with a resource. This is good since we do not use virtual IPs.

Heartbeat v2 supports multi-node clusters (of more than two nodes), though it has not been tested for a multi-node cluster. This section describes only the two-node case. The multi-node setup adds a **score** value to the resource configuration. This value is used to decide the proper node for a resource when failover occurs.

Heartbeat v2 adds a resource manager (crm). The resource configuration is maintained as an XML file. This file is re-written by the cluster frequently. Any alterations to the configuration should be made with the HA tools or when the cluster is stopped.

6.6.2.1 Hardware Preconditions

- The basic cluster assumptions are the same as those for Heartbeat v1. For the sake of clarity, here are the preconditions:
- The setup must consist of a failover pair where each node of the pair has access to shared storage. If possible, the storage paths should be identical (d1_q_0:/dev/sda == d2_q_0:/dev/sda).
- Shared storage can be arranged in an active/passive (MDS,OSS) or active/active (OSS only) configuration. Each shared resource will have a primary (default) node. The secondary node is assumed.
- The two nodes must have one or more communication paths for heartbeat traffic. A communication path can be:
  - Dedicated Ethernet
  - Serial live (serial crossover cable)

  Failure of all heartbeat communication is not good. This condition is called “split-brain” and the heartbeat software will resolve this situation by powering down one node.
- The two nodes must have a method to control each other's state. The **Remote Power Control** hardware is the best. There must be a script to start and stop a given node from the other node. STONITH provides soft power control methods (ssh, meatware) but these cannot be used in a production situation.
- Heartbeat provides a remote ping service that is used to monitor the health of the external network. If you wish to use the ipfail service, you must have a very reliable external address to use as the ping target.

6.6.2.2 Configuring Lustre

Configuring Lustre for Heartbeat V2 is identical to the V1 case.

6.6.2.3 Configuring Heartbeat

For details on all configuration options, refer to the Linux HA website:

http://linux-ha.org/ha.cf

As mentioned earlier, you can run Heartbeat V2 using the V1 configuration. To convert from the V1 configuration to V2, use the **haresources2cib.py** script (typically found in **/usr/lib/heartbeat**).

If you are starting with V2, CFS recommends creating a V1-style configuration and converting it, as the V1 style is human-readable. The heartbeat XML configuration is located at **/var/lib/heartbeat/cib.xml** and the new resource manager is enabled with the **crm yes** directive in **/etc/ha.d/ha.cf**. For additional information on CiB, refer to:

http://linux-ha.org/ClusterInformationBase/UserGuide

Heartbeat log daemon

Heartbeat V2 adds a logging daemon, which manages logging on behalf of cluster clients. The UNIX syslog API makes calls that can block, Heartbeat requires log writes to complete as a sign of health. This daemon prevents a busy syslog from triggering a false failover. The logging configuration has been moved to **/etc/logd.cf**, while the directives are essentially unchanged.

Basic configuration (No STONITH or monitor)

Assuming two nodes, d1_q_0 and d21_q_0:

- d1_q_0 owns ost-alpha
- d2_q_0 owns ost-beta
- dedicated Ethernet - eth0
- serial crossover link - /dev/ttySO
- remote host for health ping - 192.168.0.3

Use this procedure:

1 Create symlinks from /etc/init.d/lustre to /etc/init.d/<resource_name>

  These links must exist before running the conversion script.

  Placing these scripts in /etc/init.d/ causes the conversion script to identify the script as type lsb. This gives us more flexibility for script parameters. Scripts found in /etc/ha.d/resource.d are considered to be of type heartbeat and have more restrictions.

2 Create the basic ha.cf and haresources files

  haresources no longer requires the dummy virtual IP address.

  This is an example of /etc/ha.d/haresouces

```
oss161.clusterfs.com 192.168.16.35 \
Filesystem::/dev/sda::/ost1::lustre


oss162.clusterfs.com 192.168.16.36 \
Filesystem::/dev/sda::/ost1::lustre
```

  Once you have these files created, you can run the conversion tool:

```
$ /usr/lib/heartbeat/haresources2cib.py -c basic.ha.cf \
basic.haresources > basic.cib.xml
```

3 Examine the cib.xml file

The first section in the XML file is <attributes>. The default values should be fine for most installations.

The actual resources are defined in the <primitive> section. The default behavior of Heartbeat is an automatic failback of resources when a server is restored. To avoid this, you must add a parameter to the <primitive> definition. You may also like to reduce the timeouts. In addition, the current version of the script does not correctly name the parameters.

```
<cib generated="true" admin_epoch="0" epoch="0" num_updates="0" \
have_quorum="true" ignore_dtd="false" num_peers="2" ccm_transition="1" cib-
last- \ written="Thu Aug  9 09:50:12 2007">
   <configuration>
     <crm_config/>
     <nodes>
       <node id="00e8c292-2a28-4492-bcfc-fb2625ab1c61" \
uname="oss162.spsoftware.com" type="normal"/>
       <node id="e370be9a-24f4-46a5-99ac-41a88c5fa344" \
uname="oss161.spsoftware.com" type="normal"/>
     </nodes>
     <resources/>
     <constraints/>
   </configuration>
 </cib>
```

a. Copy the modified resource file to /var/lib/heartbeat/crm/cib.xml

b. Start the Heartbeat software.

c. After startup, Heartbeat re-writes the cib.xml, adding a <node> section and status information. Do not alter those fields.

Basic Configuration – Adding STONITH

As per Basic configuration (No STONITH or monitor) on page 74, the best way to do this is to add the STONITH options to ha.cf and run the conversion script. A sample example is in section **6.6.4.1 ha.cf**. See http://linux-ha.org/ExternalStonithPlugins for more information.

6.6.3 Operation

In normal operation, Lustre should be controlled by the Heartbeat software. Start Heartbeat at the boot time. It starts Lustre after the initial dead time.

6.6.3.1 Initial startup

1 Stop the Heartbeat software (if running).

If this is a new Lustre file system:

```
$ mkfs.lustre --fsname=spfs --ost --failnode=oss162 --mgsnode=mds16@tcp0 /
dev/sdb (one)
```

2 mount -t lustre /dev/sdb /mnt/spfs/ost/

3 /etc/init.d/heartbeat start on one node.

4 tail -f /var/log/ha-log to see progress.

5 After initdead, this node should start all Lustre objects.

6 /etc/init.d/heartbeat start on second node.

7 After heartbeat is up on both the nodes, failback the resources to the second node. On the second node, run:

```
$ /usr/lib/heartbeart/hb_takeover local
```

You should see the resources stop on the first node, and start up on the second node

6.6.3.2 Testing

1 Pull power from one node.

2 Pull networking from one node.

3 After Mon is setup, pull the connection between the OST and the backend storage.

6.6.3.3 C. Failback

In normal case, do the failback manually after determining that the failed node is now good. Lustre clients can work during a failback, but block momentarily.

6.7 Considerations with Failover Software and Solutions

The failover mechanisms used by Lustre and tools such as Hearbeat are soft failover mechanisms. They check system and/or application health at a regular interval, typically measured in seconds. This, combined with the data protection mechanisms of Lustre, is usually sufficient for most user applications.

However, these *soft* mechanisms are not perfect. The Heartbeat poll interval is typically 30 seconds. To avoid a false failover, Heartbeat waits for a *deadtime* interval before triggering a failover. In normal case, a user I/O request should block and recover after the failover completes. But this may not always be the case, given the delay imposed by Heartbeat.

Likewise, the Lustre *health_check* mechanism cannot be a perfect protection against any or all failures. It is a sample taken at a time interval, not something that brackets each and every I/O request. This is true for every HA monitor, not just the Lustre *health_check*.

Indeed, there will be cases where a user job will die prior to the HA software triggering a failover. You can certainly shorten timeouts, add monitoring, and take other steps to decrease this probability. But there is a serious trade-off – shortening timeouts increases the probability of false-triggering a busy system. Increasing monitoring takes the system resources, and can likewise cause a false trigger.

Unfortunately, *hard* failover solutions capable of catching failures in the sub-second range generally require special hardware. As a result, they are quite expensive.

Chapter II - 7. Configuring Quotas

This chapter describes how to configure quotas and includes the following section:

7.1 Working with Quotas

Quotas allow a system administrator to limit the maximum amount of disk space a user or group can consume in a directory. Quotas are set by root, and can be specified for individual users and/or groups. Before a file is written to a partition where quotas have been set, the quota of the creator's group is checked. If a quota exists for that group, then the file size is counted towards the group's quota. If no quota exists for that group, then the owner's user quota is checked before the file is written. In a similar manner, inode usage for specific functions can be controlled if a user over-uses the allocated space.

Lustre quota enforcement differs from standard Linux quota support in several ways:

- Quota is administered via the **lfs** command
- Quota is distributed (as Lustre is a distributed file system), which has several ramifications
- Quota is allocated and consumed in a quantized fashion
- Client does not set the *usrquota* or *grpquota* options to **mount**. When a quota is enabled, it is enabled for all clients of the file system and turned on automatically at mount.

7.1.1 Configuring Disk Quotas

Enabling Quotas

1 If you have re-complied your Linux kernel, be sure that CONFIG_QUOTA and CONFIG_QUOTACTL are enabled (quota is enabled in all the Linux 2.6 kernels supplied by CFS).

2 Start the server.

3 Mount the Lustre file system on the client and verify that the lquota module has loaded properly by using the **lsmod** command.

```
$ lsmod
[root@oss161 ~]# lsmod
Module                  Size  Used by
obdfilter             220532  1
fsfilt_ldiskfs         52228  1
ost                    96712  1
mgc                    60384  1
ldiskfs               186896  2 fsfilt_ldiskfs
lustre                401744  0
lov                   289064  1 lustre
lquota                107048  4 obdfilter
mdc                    95016  1 lustre
ksocklnd              111812  1
```

The mount command for Lustre no longer recognizes the *usrquota* and *grpquota* options, please remove them from your /etc/fstab if they were previously specified.

When quota is enabled on the file system, it is automatically enabled for all clients of the file system.

NOTE:
Lustre with Linux kernel 2.4 does not support quotas.

7.1.2 Creating Quota Files and Quota Administration

Once each quota-enabled file system is remounted, it 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 **lfs** command with the `quotacheck` option:

```
#lfs quotacheck -ug /mnt/lustre
```

By default, quota is turned on after `quotacheck` completes. The following options are available:

- **u** — to check the user disk quota information
- **g** — to check the group disk quota information

It also checks all the objects on all OSTs and the MDS to sum up for every UID/GID. It reads all Lustre metadata and recomputes the number of blocks/inodes that each UID/GID has used. If there are many files in Lustre, it may take a long time to complete. If quota breaks for any reason, it brings everything back.

The **lfs** command now includes these other command options for working with quotas:

- **quotaon** — announces to the system that disk quotas should be enabled on one or more file systems. The file system quota files must be present in the root directory of the specified file system.
- **quotaoff** — announces to the system that the specified file systems should have all the disk quotas turned off.
- **setquota** — used to specify the quota limits and tune the grace period. By default the grace period is one week.

Usage:

```
setquota [ -u | -g ] <name> <block-softlimit> <block-hardlimit>
<inode-softlimit> <inode-hardlimit> <filesystem>

setquota -t [ -u | -g ] <block-grace> <inode-grace> <filesystem>

lfs > setquota -u bob 307200 309200 10000 11000 /mnt/lustre
```

Description: sets limits for user "bob". The block hard limit is around 300 MB and the inode hard limit is 1100 MB.

NOTE:
To set grace time, use `lfs setquota -t`

```
$ lfs setquota -t -u 200 2200 /mnt/lustre
```

Quota displays the quota allocated and consumed for each Lustre device. This example shows the result of the previous setquota:

```
# lfs quota -u bob /mnt/lustre Disk quotas for user bob (uid 500):
     Filesystem  blocks   quota   limit   grace   files   quota   limit   grace
    /mnt/lustre       0  307200  309200               0   10000   11000
lustre-MDT0000_UUID 0       0  102400               0       0    5000
lustre-OST0000_UUID 0       0  102400
lustre-OST0001_UUID 0       0  102400
```

7.1.3 Quota Allocation

The Linux kernel sets a default quota size of 1 MB. (For a block, the default is 100 MB. For files, the default is 5000.) Lustre handles quota allocation in a different manner. A quota must be set properly or users may experience unnecessary failures. The file system block quota is divided up among the OSTs within the file system. Each OST requests an allocation which is increased up to the quota limit. The quota allocation is then *quantized* to reduce the number of quota-related request traffic. By default, Lustre will allocate 100 MB per OST. This means the minimum quota that can be assigned is 100 MB multiplied by the number of OSTs in your file system. If you attempt to assign a smaller quota, users maybe unable to create files. The default is established at file system creation time, but can be tuned via /proc values (detailed below). The inode quota is also allocated in a quantized manner on the MDS.

This sets a much smaller granularity. It is specified that we will request new quota in units of 10 MB and 200 inodes respectively. If we look at the example again:

```
# lfs quota -u bob /mnt/lustre
Disk quotas for user bob (uid 500):
    Filesystem  blocks   quota   limit   grace   files   quota     limit  grace
   /mnt/lustre   207432  307200  309200           1041   10000   11000
lustre-MDT0000_UUID 992      0    102400           1041      0       5000
lustre-OST0000_UUID    103204*       0    102400
lustre-OST0001_UUID     103236*       0    102400
```

NOTE:
The values appended with "*" show the limit that has been over-used, then the allowed quota, and receive the message "Disk quota exceeded". Example:

```
$ cp: writing `/mnt/lustre/var/cache/fontconfig/
beeeeb3dfe132a8a0633a017c99ce0c0-x86.cache-2': Disk quota exceeded.
```

We see that the requested quota of 3 GB is divided across the OSTs, each OST with an initial allocation of 10 MB blocks. The MDS line shows the initial 200 inode allocation.

It is very important to note that **the block quota is consumed per OST**. Much like free space, when the quota is consumed on one OST, clients may be unable to create files regardless of the quota available on other OSTs.

Additional information:

Grace period — The period of time within which users are allowed to exceed their soft limit. There are four types of grace period:

- user block soft limit
- user inode soft limit
- group block soft limit
- group inode soft limit

The grace periods are applied to all users. The user block soft limit is for all users who are using a blocks quota.

Soft limit — Once you are beyond the soft limit, the quota module begins to time for you, but you still can write block and inode. When you are always beyond the soft limit and use up your grace time, then you get the same result as the hard limit. For inodes and blocks, it is the same. Usually, the soft limit MUST be less than hard limit; if not, quota module never triggers the timing. If you are not interested in the soft limit, leave it as zero (0).

Hard limit — When you are beyond the hard limit, you get -EQUOTA and cannot write inode/block any more. The hard limit is the absolute limit. When a grace period is set, you can exceed the soft limit within the grace period if are under the hard limits.

Lustre quota allocation is controlled by two values "quota_bunit_sz" and "quota_iunit_sz" referring to KBs and inodes respectively. These values can be accessed on the MDS as /proc/fs/lustre/mds/*/quota_* and on the OST as /proc/fs/lustre/obdfilter/*/quota_*.

The /proc values are bounded by two other variables quota_btune_sz and quota_itune_sz. By default, the *tune_sz variables are set at 1/2 the *unit_sz variables, and you cannot set *tune_sz larger than *unit_sz. You must set bunit_sz first if it is increasing by more than 2x, and btune_sz first if it is decreasing by more than 2x.

Total number of inodes — To know the total number of inodes you can use "lfs df -i" (and also /proc/fs/lustre/*/*/filestotal). But it may report a lower 'total inode count' than the number of inodes actually in the filesystem. If the underlying filesystem has fewer free blocks than inodes, the total inode count for that filesystem reports only as many inodes as there are free blocks.

This is because Lustre may need to store an external attribute for each new inode, and it is better to report a free inode count that is the guaranteed minimum number of inodes that can be created.

Unfortunately, the statfs interface does not report the free inode count directly, but instead reports the total inode and used inode counts. The free inode count is calculated for df as equal to total inodes - used inodes.

It is not very critical to know the total inode count for a file system. Instead you should know accurately the free inode count and the used inode count for a filesystem. Hence, Lustre manipulates the total inode count in order to accurately report the other two values.

The values set for the MDS must match the values set on the OSTs.

The parameter quota_bunit_sz displays bytes, however lfs setquota uses KBs. The parameter quota_bunit_sz must be a multiple of 1024. A proper minimum KB size for lfs setquota can be calculated by

Size in KBs = (quota_bunit_sz * (number of OSTS + 1)) / 1024.

We add one (1) to the number of OSTs as the MDS also consumes KBs. As inodes are only consumed on the MDS, the minimum inode size for lfs setquota is equal to quota_iunit_sz.

NOTE:
Setting the quota below this limit may prevent the user from all the file creation.

To turn on the quotas for a user and a group, run:

```
$ lfs quotaon -ug /mnt/lustre
```

To turn off the quotas for a user and a group, run:

```
$ lfs quotaoff -ug /mnt/lustre
```

To set the quotas for a user as 1 GB block quota and 10,000 file quota, run:

```
$ lfs setquota -u {username} 0 1000000 0 10000 /mnt/lustre
```

To list the quotas of a user, run:

```
$ lfs quota -u {username} /mnt/lustre
```

To see the grace time for quota, run:

```
$ lfs quota -t -{u|g} {quota user|group} /mnt/lustre
```

Chapter II - 8. RAID

This chapter describes RAID storage and Lustre, and includes the following sections:

8.1 Considerations for Backend Storage

Lustre's architecture allows it to use any kind of block device as backend storage. The characteristics of such devices, particularly in the case of failures vary significantly and have an impact on configuration choices.

This section surveys issues and recommendations regarding backend storage.

8.1.1 Reliability

A quick calculation (shown below), makes it clear that without further redundancy, RAID5 is not acceptable for large clusters and RAID6 is a must.

Calculation

Take a 1 PB file system (2000 disks of 500GB capacity). The MTF[1] of a disk is about 1000 days and repair time at 10% of disk bandwidth is close to 1 day (500 GB at 5 MB/sec = 100,000 sec = 1 day). This means that the expected failure rate is 2000 / 1000 = 2 disks per day.

If we have a RAID5 stripe that is ~10 wide, then during 1 day of rebuilding, the chance that a second disk in the same array fails is about 9 / 1000 ~= 1/100. This means that in the expected period of 50 days, a double failure in a RAID5 stripe leads to data loss.

So RAID6 or another double parity algorithm is necessary for OST storage. For the MDS, CFS recommends RAID0+1 storage.

1. Mean Time to Failure

8.1.2 Selecting Storage for the MDS and OSS

The MDS does a large amount of small writes. For this reason, CFS recommends using RAID1 storage. Building RAID1 Linux MD devices and striping over these devices with LVM makes it easy to create an MDS file system of 1-2 TB (for example, with 4 or 8 500 GB disks).

It is considered mandatory that you use disk monitoring software, so rebuilds happen without any delay. CFS recommend backups of the metadata file systems. This can be done with LVM snapshots or using raw partition backups.

We also recommend using a kernel version of 2.6.15 or later with bitmap RAID rebuild features. These reduce RAID recovery time from a rebuild to quick resynchronization.

8.1.3 Understanding Double Failures with Software and Hardware RAID5

Software RAID does not offer the hard consistency guarantees of top-end enterprise RAID arrays. Hardware RAID guarantees that the value of any block is exactly the before or after value and that ordering of writes is preserved. With software RAID, an interrupted write operation that spans multiple blocks can frequently leave a stripe in an inconsistent state that is not restored to either the old or the new value. Such interruptions are normally caused by an abrupt shutdown of the system.

If the array functions without disk failures, but experiences sudden power-down incidents, such interrupted writes on journal file systems, these events can affect file data and data in the journal. Metadata itself is re-written from the journal during recovery and is correct. Because the journal uses a single block to indicate a complete transaction has committed after other journal writes have completed, the journal remains valid. File data can be corrupted when overwriting file data; this is a known problem with incomplete writes and caches. Recovery of the disk file systems with software RAID is similar to recovery without software RAID. Using Lustre servers with disk file systems does not change these guarantees.

Problems can arise if, after an abrupt shutdown, a disk fails on restart. In this case, even single block writes provide no guarantee that (as an example), the journal will not be corrupted. Follow these requirements:

- If a power down is followed by a disk failure, the disk file system needs a file system check.
- If a RAID array dows not guarantee before / after semantics, the same requirement holds.

  CFS considers this to be a requirement for most arrays that are used with Lustre, including the successful and popular DDN arrays.

  CFS will release a modification to the disk file system that eliminates this requirement for a check with a feature called "journal checksums". With RAID6 this check is not required with a single disk failure, but is required with a double failure upon reboot after an abrupt interruption of the system.

8.1.4 Performance Considerations

CFS is currently improving the Linux software RAID code to preserve large I/O which the disk subsystems can do very efficiently. With existing RAID code software, RAID performs equally with all stride sizes, but we expect that fairly large stride sizes will prove advantageous when these fixes are implemented.

8.1.5 Formatting

When formating a file system on a RAID device, it is beneficial to specify additional parameters at the time of formatting. This ensures that the file system is optimized for the underlying disk geometry. Use the **--mkfsoptions** parameter to specify these options in the Lustre configuration.

For RAID5, RAID6, RAID1+0 storage, specifying the **-E stride={stripe_size}** option improves the layout of the file system metadata ensuring that no single disk contains all of the allocation bitmaps. The stripe_size parameter is in units of 4096-byte blocks and represents the amount of contiguous data written to a single disk before moving to the next disk. This is applicable to both MDS and OST file systems.

NOTE:
It is better to have the MDS on RAID1+0 than on RAID5 or RAID6.

For more information on how to override the defaults while formatting MDS or OST file systems, see Options for Formatting MDS and OST on page 167.

8.2 Insights into Disk Performance Measurement

Tips and insights for disk performance measurement are provided below. Some of this information is specific to RAID arrays and/or the Linux RAID implementation.

- Performance is limited by the slowest disk.

  Benchmark all disks individually. CFS has frequently encountered situations where drive performance was not consistent for all devices in the array.

- Verify drive ordering and identification.

  For example, on a test system with a Marvell driver, the disk ordering is not preserved between boots but the controller ordering is. Therefore, CFS ran the sgp_dd survey tool and create arrays without rebooting.

- Disks and arrays are very sensitive to request size.

  To identify the most ideal request size for a given disk, benchmark the disk with different record sizes ranging from 4 KB to 1-2 MB.

- By default, the maximum size of a request is quite small.

  To properly handle I/O request sizes greater than 256 KB, the current Linux kernel needs either a driver patch or several changes in the block layer defaults, namely MAX_SECTORS, MAX_PHYS_SEGMENTS and MAX_HW_SEGMENTS. CFS kernels contain this patch. In the CFS source, see blkdev_tunables-2.6-suse.patch.

- Select the best I/O scheduler for your setup.

  Consider trying different I/O schedulers, because their behavior varies with storage and load. CFS recommends using the deadline or noop schedulers. Benchmark all of the I/O schedules and select the best one for your setup. For further information on I/O schedulers, refer to:

  http://www.linuxjournal.com/article/6931

  http://www.redhat.com/magazine/008jun05/features/schedulers/

- Use the proper block device with sgp_dd (sgX versus sdX)

  ```
  size 1048576K rsz 128 crg 8 thr 32 read 20.02 MB/s
  size 1048576K rsz 128 crg 8 thr 32 read 56.72 MB/s
  ```

  The above outputs were achieved on the same disk with the same parameters for sgp_dd. The only difference between them is that, in the first case, /dev/sda was used; in the second case, /dev/sg0 was used. sgX is a special interface that bypasses the block layer and the I/O scheduler, but sends the SCSI commands directly to a drive. sdX is a regular block device, and the requests go through the block layer and the I/O scheduler. The numbers do not change on testing with different I/O schedulers.

  NOTE:
  The sg device cannot be used by Lustre as it is not a block device - the sg device is used for performance measurement only.

- Requests with partial-stripe write impair RAID5.

  In many cases, RAID5 does a read-modify-write cycle, which is not performant.

  Try to avoid synchronized writes. It is likely that subsequent writes would make the stripe full and no reads will be needed. Try to configure RAID5 and the application in such a manner that most of the writes are full-stripe and stripe-aligned.

- NR_STRIPES in RAID5 (Linux kernel parameter)

  This is the size of the internal cache that RAID5 uses for all the operations. If many processes are doing I/O, CFS suggests that you increase this number. In newer kernels, use a module parameter to tune it.

- Do not put an ext3 journal onto RAID5.

  As journal is written linearly and synchronously, in most cases writes do not fill whole stripes. In this case, RAID5 has to read parities.

- Suggested MD device setups for maximum performance:

  MDT

  RAID1 with internal journal and two disks from different controllers.

  If you need larger MDTs, create two equal-sized RAID0 arrays from multiple disks. Create a RAID1 array from these arrays. Using RAID10 directly requires a newer mdadm[1] than the one shipped with RHEL 4. You can also use LVM instead of RAID0, although this has not been tested.

  OST

  File system: RAID5 with 6 disks, each from a different controller.

  External journal: RAID1 with two partitions of 400 MB (or more), each from disks on different controllers.

  ```
  $ mkfs.lustre ... --mkfsoptions "-j -J device=/dev/mdX"
  ```

  Before running --reformat, set up the journal device (/dev/mdX), run:

  ```
  $ 'mke2fs -O journal_dev -b 4096 /dev/mdX'
  ```

  You can create a root file system, swap, and other system partitions on a RAID1 array with partitions on any two remaining disks. The remaining space on the OST journal disk can be used for this.

1. The tool that administers software RAID on Linux.

CFS has not tested RAID1 of swap.

- rsz in sgp_dd

  It must be equal to the multiplication of <chunksize> and (disks-1).

  You also should pass stripe=N, and extents or mballoc as a mountfs option for OSS. Here N = <chunksize> * (disks-1) / pagesize.

- Run fsck on power failure or disk failure (RAID arrays).

  Run fsck on an array in the event of a power failure and failure of a disk in the array due to potential write consistency issues.

  You can automate this in rc.sysinit by detecting degraded arrays.

8.2.1 Sample Graphs

8.2.1.1 Graphs for Write Performance

Figure 1 Write - RAID0, 64K chunks, 6 spindles

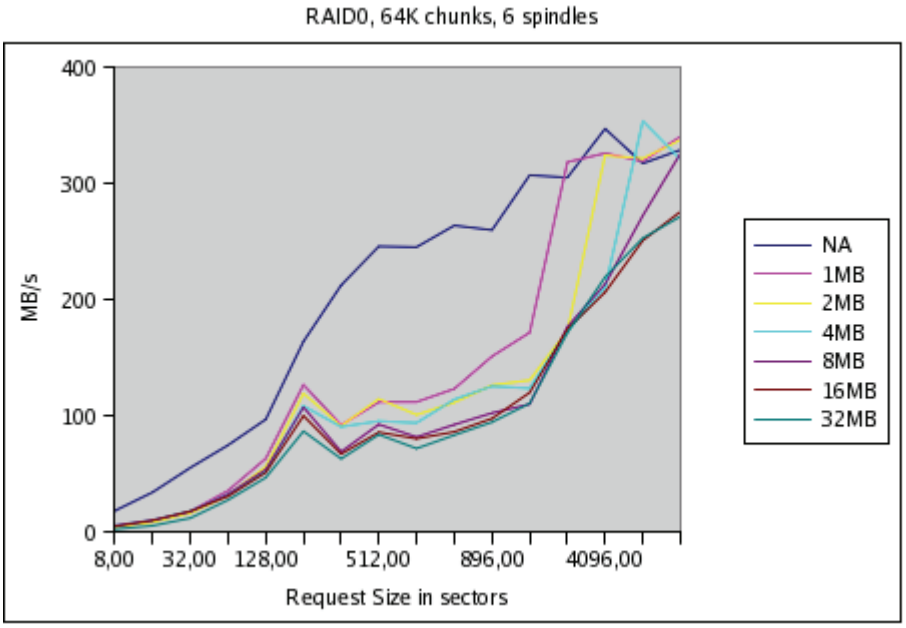
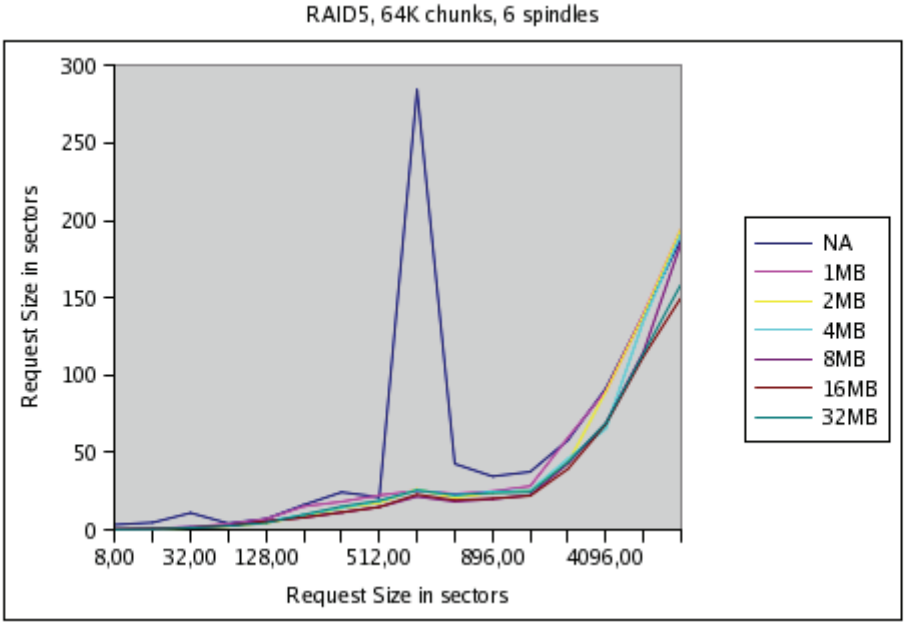


Figure 2 Write - RAID5, 64K chunks, 6 spindles



8.2.1.2 Graphs for Read Performance

Figure 3 Read - RAID0, 64K chunks, 6 spindles

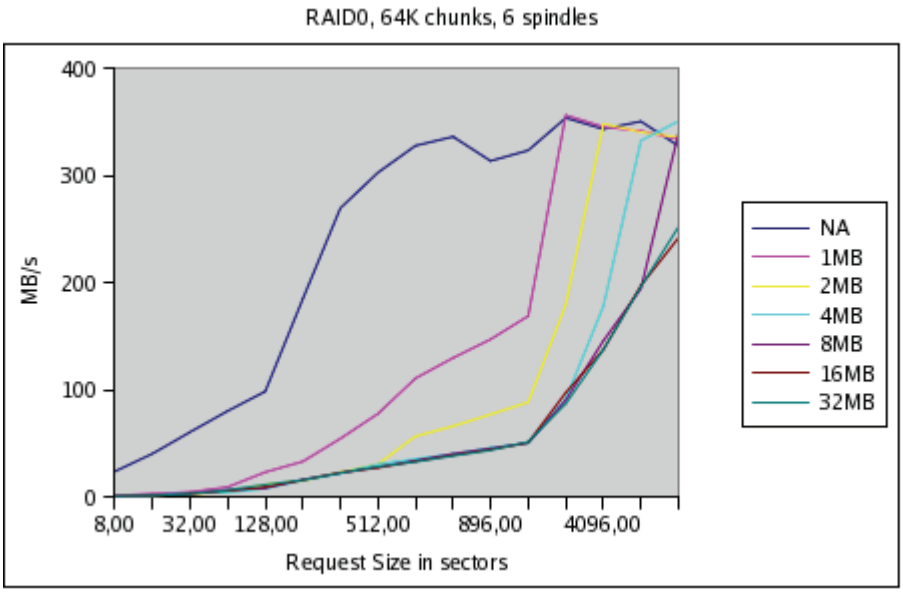
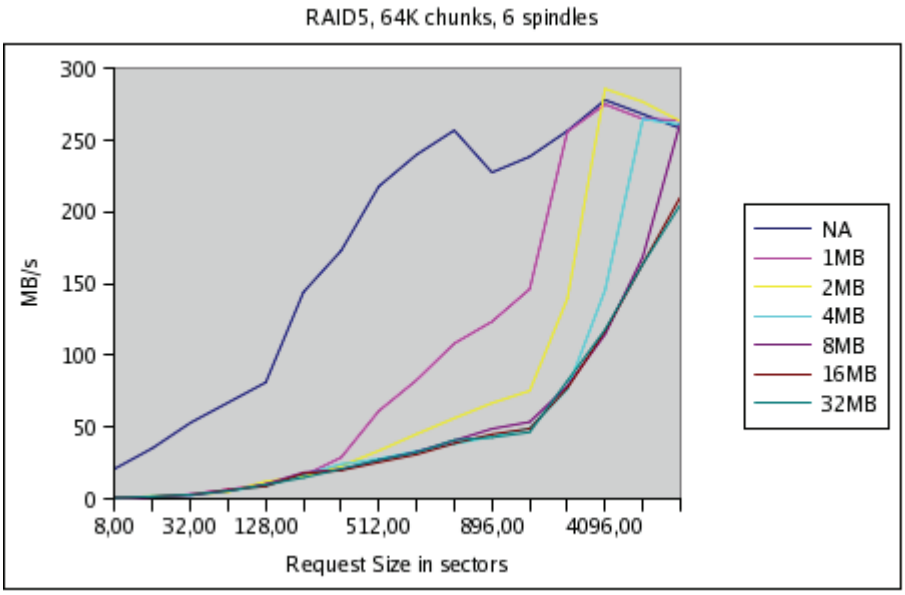


Figure 4 Read - RAID5, 64K chunks, 6 spindles



8.3 Creating an External Journal

To create an external journal:

1 Format the Lustre MDT/MGS to use an external journal device. Format the sdb with:

```
$ mke2fs  -b 4096 -O journal_dev /dev/sdb
```

2 Format a Lustre target sda to use an external journal on sdb.

```
$ mkfs.lustre --mdt --mgs --mkfsoptions="-J device=/dev/sdb" \  /dev/sda
Permanent disk data:
Target:     lustre-MDTffff
Index:      unassigned
Lustre FS:  lustre
Mount type: ldiskfs
Flags:      0x75
(MDT MGS needs_index first_time update )
Persistent mount opts: errors=remount-\ ro,iopen_nopriv,user_xattr
Parameters:

device size = 4096MB
formatting backing filesystem ldiskfs on /dev/sda
target name  lustre-MDTffff
4k blocks     0
options     -J device=/dev/sdb -i 4096 -I 512 -q -O \  dir_index -F
mkfs_cmd = mkfs.ext2 -j -b 4096 -L lustre-MDTffff -J device=/dev/sdb -i \
4096 -I
512 -q -O dir_index -F /dev/sda
Writing CONFIGS/mountdata
```

3 Start the Lustre target, run:

```
$ mkdir -p /mnt/test/mdt
$ mount -t lustre /dev/sda /mnt/mds/
```

4 Format the Lustre OSS to use an external journal device. Format the sdb with:

```
$ mke2fs  -b 4096 -O journal_dev /dev/sdb
```

5 Format a Lustre target sda to use an external journal on sdb.

```
# mkfs.lustre --ost --reformat --mkfsoptions="-J device=/dev/sdb"\ --
mgsnode=mds16@tcp0 /dev/sda

Permanent disk data:

Target:     lustre-OSTffff

Index:      unassigned

Lustre FS:  lustre

Mount type: ldiskfs

Flags:      0x72

(OST needs_index first_time update )

Persistent mount opts: errors=remount-ro,extents,mballoc

Parameters: mgsnode=192.168.16.21@tcp


device size = 4096MB

formatting backing filesystem ldiskfs on /dev/sda

target name lustre-OSTffff

4k blocks   0

options     -J device=/dev/sdb -i 16384 -I 256 -q -O \  dir_index -F

mkfs_cmd = mkfs.ext2 -j -b 4096 -L lustre-OSTffff -J \  device=/dev/sdb -i
16384 -I

256 -q -O dir_index -F /dev/sda

Writing CONFIGS/mountdata
```

6 Mount Lustre on the client, run:

```
$ mkdir -p /mnt/testfs

$ mount -t lustre cfs21@tcp0:/testfs /mnt/testfs
```

Chapter II - 9. Kerberos

This chapter describes how to use Kerberos with Lustre and includes the following sections:

9.1 What is Kerberos?

Kerberos is a mechanism for authenticating all entities (such as users and services) on an “unsafe” network. Users and services, known as "principals", share a secret password (or key) with the Kerberos server. This key enables principals to verify that messages from the Kerberos server are authentic. By trusting the Kerberos server, users and services can authenticate one another.

WARNING
Kerberos is a Lustre 1.8 feature that is not available in version 1.6. Do NOT attempt to use Kerberos with Lustre until version 1.8 is released.

9.2 Lustre Setup with Kerberos

Setting up Lustre with Kerberos can provide advanced security protections for the Lustre network. Broadly, Kerberos offers three types of benefit:

- Allows Lustre connection peers (MDS, OSS and clients) to authenticate one another.
- Protects the integrity of the PTLRPC message from being modified during network transfer.
- Protects the privacy of the PTLRPC message from being eavesdropped during network transfer.

Kerberos uses the “kernel keyring” client upcall mechanism.

9.2.1 Configuring Kerberos for Lustre

This section describes supported Kerberos distributions and how to set up and configure Kerberos on Lustre.

9.2.1.1 Kerberos Distributions Supported on Lustre

Lustre supports the following Kerberos distributions:

- MIT Kerberos 1.3.x
- MIT Kerberos 1.4.x
- MIT Kerberos 1.5.x
- MIT Kerberos 1.6 (not yet verified by CFS)

On a number of operating systems, the Kerberos RPMs are installed when the operating system is first installed. To determine if Kerberos RPMs are installed on your OS, run:

```
# rpm -qa | grep krb
```

If Kerberos is installed, the command returns a list like this:

```
krb5-devel-1.4.3-5.1
krb5-libs-1.4.3-5.1
krb5-workstation-1.4.3-5.1
pam_krb5-2.2.6-2.2
```

NOTE:
The Heimdal implementation of Kerberos is not currently supported on Lustre, although CFS will soon support it. For the latest update, please visit:
www.clusterfs.com

9.2.1.2 Preparing to Set Up Lustre with Kerberos

To set up Lustre with Kerberos:

1. Configure NTP to synchronize time across all machines.
2. Configure DNS with zones.
3. Verify that there are fully-qualified domain names (FQDNs), that are resolvable in both forward and reverse directions for all servers. This is required by Kerberos.
4. On every node, install flowing packages:
   - **libgssapi** (version 0.10 or higher)

     Some newer Linux distributions include libgssapi by default. If you do not have libgssapi, build and install it from source:

     http://www.citi.umich.edu/projects/nfsv4/linux/libgssapi/libgssapi-0.10.tar.gz
   - **keyutils**

9.2.1.3 Configuring Lustre for Kerberos

To configure Lustre for Kerberos:

1 Configure the client nodes. For each client node, create a lustre_root principal, and generate and install the keytab.

```
kadmin> addprinc -randkey lustre_root@REALM
kadmin> ktadd -e des-cbc-md5:normal lustre_root@REALM
```

NOTE:
There is only one security context for each client-OST pair, shared by all users on the client. This protects data written by one user to be passed to an OST by another user due to asynchronous bulk I/O. The client-OST connection only guarantees message integrity or privacy; it does not authenticate users.

2 Configure the MDT nodes. For each MDT node, create a lustre_mds principal, and generate and install the keytab.

```
kadmin> addprinc -randkey lustre_mds/mdthost.domain@REALM
kadmin> ktadd -e des-cbc-md5:normal
lustre_mds/mdthost.domain@REALM
```

3 Configure the OST nodes. For each OST node, create a lustre_oss principal, and generate and install the keytab.

```
kadmin> addprinc -randkey lustre_oss/osthost.domain@REALM
kadmin> ktadd -e des-cbc-md5:normal lustre_oss/osthost.domain@REALM
```

Lustre supports almost all useful encryption types which are supported by MIT Kerberos 5:

- **des-cbc-crc**
- **des-cbc-md5**
- **des3-hmac-sha1**
- **aes128-cts**
- **aes256-cts**
- **arcfour-hmac-md5**

NOTE:
Encryption Type or *enctype* is an identifier that specifies the encryption algorithm, mode and hash algorithms. Keys in Kerberos have an associated *enctype* to identify the cryptographic algorithm and mode to be used when performing cryptographic operations with the key. It is important that the enctypes requested by the client are actually supported on the system hosting the client. This is the case if the defaults that control enctypes are not overridden.

NOTE:
For MIT Kerberos 1.3.x, only **des-cbc-md5** works because of a known issue between libgssapi and the Kerberos library.
The host.domain should be the FQDN in your network; otherwise the server might not recognize the GSS request.

9.2.1.4 Configuring Kerbros

To configure Kerberos to work with Lustre:

1 Modify the files for Kerberos:

```
$ /etc/krb5.conf
[libdefaults]
default_realm = CLUSTERFS.COM

[realms]
CLUSTERFS.COM = {
kdc = mds16.clustrefs.com
admin_server = mds16.clustrefs.com
}

[domain_realm]
.clustrefs.com = CLUSTERFS.COM
clustrefs.com = CLSUTREFS.COM

[logging]
default = FILE:/var/log/kdc.log
```

2 Prepare the Kerberos database.

3 Create service principals so Lustre supports Kerberos authentication.

NOTE:
You can create service principals when configuring your other services to support Kerberos authentication.

4 Configure the client nodes. For each client node:

a. Create a lustre_root principal and generate the keytab:

```
kadmin> addprinc -randkey lustre_root@CLUSTERFS.COM

kadmin> ktadd -e des-cbc-md5:normal lustre_root@ CLUSTERFS.COM
```

This process populates “/etc/krb5.keytab”, which is not human-readable. Use the “ktutil” program to read and modify it.

b. Install the keytab.

NOTE:
There is only one security context for each client-OST pair, shared by all users on the client. This protects data written by one user to be passed to an OST by another user due to asynchronous bulk I/O. The client-OST connection only guarantees message integrity or privacy; it does not authenticate users.

5 Configure the MDT nodes. For each MDT node, create a lustre_mds principal, and generate and install the keytab.

```
kadmin> addprinc -randkey lustre_mds/mdthost.domain@CLUSTERFS.COM
kadmin> ktadd -e des-cbc-md5:normal lustre_mds/mdthost.domain@CLUSTERFS.COM
```

6 Configure the OST nodes. For each OST node, create a lustre_oss principal, and generate and install the keytab.

```
kadmin> addprinc -randkey lustre_oss/osthost.domain@CLUSTERFS.COM
kadmin> ktadd -e des-cbc-md5:normal lustre_oss/osthost.domain@ CLUSTERFS.COM
```

For more detailed information on installing Kerberos, see:

http://web.mit.edu/Kerberos/krb5-1.6/#documentation

9.2.1.5 Setting the Environment

Perform the following steps to configure the system and network to use Kerberos.

System-wide Configuration

1 On each MDT, OST, and client node, add the following line to /etc/fstab to mount them automatically.

```
nfsd       /proc/fs/nfsd       nfsd       defaults    0 0
```

2 On each MDT and client node, dd the following line to /etc/request-key.conf.

```
create lgssc * * /usr/sbin/lgss_keyring %o %k %t %d %c %u %g %T %P %S
```

Networking

If your network is not using SOCKLND or InfiniBand (and uses Quadrics, Elan or Myrinet for example), configure a /etc/lustre/nid2hostname (simple script that translates a NID to a hostname) on each server node (MDT and OST). This is an example on an Elan cluster:

```
#!/bin/bash
set -x
exec 2>/tmp/$(basename $0).debug

# convert a NID for a LND to a hostname, for GSS for example

# called with thre arguments: lnd netid nid
#   $lnd will be string "QSWLND", "GMLND", etc.
#   $netid will be number in hex string format, like "0x16", etc.
#   $nid has the same format as $netid
# output the corresponding hostname, or error message leaded by a '@' for
error logging.

lnd=$1
netid=$2
nid=$3

# uppercase the hex
nid=$(echo $nid | tr '[abcdef]' '[ABCDEF]')
# and convert to decimal
nid=$(echo -e "ibase=16\n${nid/#0x}" | bc)
case $lnd in
     QSWLND)    # simply stick "mtn" on the front
                echo "mtn$nid"
                ;;
     *)         echo "@unknown LND: $lnd"
                ;;
esac
```

9.2.1.6 Building Lustre

If you are compiling the kernel from the source, enable GSS during configuration:

```
# ./configure --with-linux=path_to_linux_source --enable-gss --other-options
```

When you enable Lustre with GSS, the configuration script checks all dependencies, like Kerberos and libgssapi installation, and in-kernel SUNRPC-related facilities. When you install lustre-xxx.rpm on target machines, RPM again checks for dependencies like Kerberos and libgssapi.

9.2.1.7 Running GSS Daemons

If we turn on GSS between MDT-OST or MDT-MDT, GSS treats MDT as a client. Hence, lgssd should be running on MDT.

There are two types of GSS daemons: ***lgssd*** and ***lsvcgssd***. Before starting Lustre, make sure they are running on each node before starting Lustre:

- OST: lsvcgssd
- MDT: lsvcgssd
- CLI: none

NOTE:
CFS is maintaining a patch against nfs-utils, and bringing necessary patched files into the Lustre tree. After a successful build, GSS daemons are built under lustre/utils/gss and are part of lustre-xxxx.rpm.

9.2.2 Types of Lustre-Kerberos Flavors

There are three major flavors in which you can configure Lustre with Kerberos:

- Basic flavor
- Security flavor
- Customized flavor

Select a flavor depending on your priorities and preferences.

9.2.2.1 Basic Flavor

Currently, CFS supports four basic flavors: ***null***, ***plain***, ***krb5i***, and ***krb5p***, described in Table 2

Table 2 Basic Flavors Supported by CFS

Basic Flavor	Authentication	RPC Message Protection	Bulk Data Protection	Remarks
null	N/A	N/A	N/A	Almost no performance overhead. The on-wire RPC data is compatible with old versions of Lustre (1.4.x, 1.6.x).
plain	N/A	null	null	Carries checksum (So only protects data mutating during transfer, does NOT guarantee the genuine author as there is no actual authentication).
krb5i	GSS/Kerberos5	integrity	integrity [SHA1]	RPC message integrity protection algorithm is determined by actual Kerberos algorithms in use; heavy performance overhead.
krb5p	GSS/Kerberos5	privacy	privacy [SHA1/ARC4]	RPC message privacy protection algorithm is determined by actual Kerberos algorithms in use; considerable performance overhead.

9.2.2.2 Security Flavor

Security flavor is a string that describes what kind of security transform is performed on a given PTLRPC connection. It covers two parts of messages: **RPC message** and **BULK data**. You can set any one of the parts in one of the following three modes:

- ***null*** – No protection
- ***integrity*** – Data integrity protection (checksum or signature)
- ***privacy*** – Data privacy protection (encryption)

9.2.2.3 Customized Flavor

Generally, you do not need the customized flavor; basic flavor is sufficient for regular usage. But, you can customize the flavor string to some extent. The usual format of a flavor string is:

```
Qbasic_flavor[-bulk{nip}[:checksum_alg[/encryption_alg]]]
```

Here are some examples of how to use customized flavors:

- *plain-bulki*: Use ***plain*** on RPC message (offering null protection), but add checksum protection on the bulk transfer.
- *krb5i-bulkn*: Use ***krb5i*** on RPC message, but do not protect the bulk transfer.
- *krb5p-bulki*: Use ***krb5p*** on RPC message, but protect data integrity of the bulk transfer.
- *krb5p-bulkp:sha512/arc4*: Use ***krb5p*** on RPC message, and protect data privacy of the bulk transfer by algorithm SHA512 and ARC4.

Currently, Lustre supports following bulk data crypto algorithms:

- Checksum:
  - ocrc32
  - omd5
  - osha1/sha256/sha384/sha512
- Encryption:
  - oarc4

9.2.2.4 Specifying Security Flavors

If you have not specified a security flavor, the CLIENT-MDT connection defaults to ***plain***, and all other connections use ***null***.

Specifying Flavors by Mount Options

When mounting OST or MDT devices, add the mount option (shown below) to specify the security flavor:

```
# mount -t lustre -o sec=plain /dev/sda1 /mnt/mdt/
```

This means all connections to this device will use the ***plain*** flavor. You can split this `sec=flavor` as:

```
# mount -t lustre -o sec_mdt={flavor1},sec_cli={flavor1}/dev/sda /mnt/mdt/
```

This means connections from other MDTs to this device will use flavor1, and connections from all clients to this device will use flavor2.

Specifying Flavors by On-Disk Parameters

You can also specify the security flavors by specifying on-disk parameters on OST and MDT devices:

```
# tune2fs -o security.rpc.mdt=flavor1 -o security.rpc.cli=flavor2 device
```

On-disk parameters are overridden by mount options.

9.2.2.5 Mounting Clients

Root on client node mounts Lustre without any special tricks.

9.2.2.6 Authenticating Normal Users

On client nodes, a non-root user needs ***kinit*** before accessing Lustre, just like other Kerberized applications. You can destroy the established security contexts before logging out by "lfs flushctx":

```
# lfs flushctx [-k]
```

Here `-k` also means destroy the on-disk Kerberos credential cache. It is equivalent to "kdestroy." Otherwise, it only destroys established contexts in Lustre kernel

Chapter II - 10. Bonding

This chapter describes how to set up bonding with Lustre, and includes the following sections:

10.1 Network Bonding

Bonding, also known as link aggregation, trunking and port trunking[1], is a method of aggregating multiple physical network links into a single logical link for increased bandwidth.

Several different types of bonding are supported in Linux. All these types are referred to as “modes,” and use the bonding kernel module.

Modes 0 to 3 provide support for load balancing and fault tolerance by using multiple interfaces. Mode 4 aggregates a group of interfaces into a single virtual interface where all members of the group share the same speed and duplex settings. This mode is described under IEEE spec 802.3ad, and it is referred to as either “mode 4” or “802.3ad.”

(802.3ad refers to mode 4 only. The detail is contained in Clause 43 of the IEEE 8 - the larger 802.3 specification. For more information, consult IEEE.)

1. This manual uses the term ’bonding’.

10.2 Requirements

The most basic requirement for successful bonding is that both endpoints of the connection must support bonding. In a normal case, the non-server endpoint is a switch. (Two systems connected via crossover cables can also use bonding.) Any switch used must explicitly support 802.3ad Dynamic Link Aggregation.

The kernel must also support bonding. All supported Lustre kernels have bonding functionality. The network driver for the interfaces to be bonded must have the ethtool support. To determine slave speed and duplex settings, ethtool support is necessary. All recent network drivers implement it.

To verify that your interface supports ethtool, run:

```
$ which ethtool
$ ethtool eth0
Settings for eth0:
Supported ports: [ MII ]
Supported link modes:   10baseT/Half 10baseT/Full \
100baseT/Half100baseT/Full1000baseT/Half1000baseT/Full
Supports auto-negotiation: Yes
(ethtool will return an error if your card is not supported.)
```

To quickly check whether your kernel supports bonding, run:

```
$ grep ifenslave /sbin/ifup
$ which ifenslave
```

NOTE:
Bonding and ethtool have been available since 2000. All Lustre-supported kernels include this functionality.

10.3 Using Lustre with Multiple NICs versus Bonding NICs

Lustre can use multiple NICs without bonding. There is a difference in performance when Lustre uses multiple NICs versus when it uses bonding NICs.

Whether an aggregated link actually yields a performance improvement proportional to the number of links provided, depends on network traffic patterns and the algorithm used by the devices to distribute frames among aggregated links. Performance with bonding depends on:

- Out-of-order packet delivery

  This can trigger TCP congestion control. To avoid this, some bonding drivers restrict a single TCP conversation to a single adapter within the bonded group.

- Load balancing between devices in the bonded group.

  Consider a scenario with a two CPU node with two NICs. If the NICs are bonded, Lustre establishes a single bundle of sockets to each peer. Since ksocklnd bind sockets to CPUs, only one CPU moves data in and out of the socket for a uni-directional data flow to each peer. If the NICs are not bonded, Lustre establishes two bundles of sockets to the peer. Since ksocklnd spreads traffic between sockets, and sockets between CPUs, both CPUs move data.

10.4 Bonding Module Parameters

Bonding module parameters control various aspects of bonding.

Outgoing traffic is mapped across the slave interfaces according to the transmit hash policy. For Lustre, CFS recommends setting the xmit_hash_policy option to the layer3+4 option for bonding. This policy uses upper layer protocol information if available to generate the hash. This allows traffic to a particular network peer to span multiple slaves, although a single connection does not span multiple slaves.

```
$ xmit_hash_policy=layer3+4
```

The *miimon* option enables users to monitor the link status. (The parameter is a time interval in milliseconds.) It makes an interface failure transparent to avoid serious network degradation during link failures. A reasonable default setting is 100 milliseconds; run:

```
$ miimon=100
```

For a busy network, increase the timeout.

10.5 Setting Up Bonding

To set up bonding:

1. Create a virtual 'bond' interface.
2. Assign an IP address to the 'bond' interface.
3. Attach one or more **slave** interfaces to the **bond** interface. Typically, the MAC address of the first slave interface becomes the MAC address of the bond.
4. Set up the bond interface and its options in /etc/modprobe.conf. Start the slave interfaces by your normal network method.

   NOTE:
   You must modprobe the bonding module for each bonded interface. If you wish to create bond0 and bond1, two entries in modprobe.conf are required.

   The examples below are from RedHat systems, and use /etc/sysconfig/networking-scripts/ifcfg-* for setup. The OSDL website referenced below includes detailed instructions for other configuration methods, instructions to use DHCP with bonding, and other setup details. CFS strongly recommends using this website.

   http://linux-net.osdl.org/index.php/Bonding
5. Check /proc/net/bonding to determine status on bonding. There should be a file there for each bond interface.
6. Check the interface state with ethtool or ifconfig. ifconfig lists the first bonded interface as “bond0.”

10.5.1 Examples

This is an example of modprobe.conf for bonding ethernet interfaces eth1 and eth2 to bond0:

```
install bond0 /sbin/modprobe -a eth1 eth2 && /sbin/modprobe bonding \
miimon=100 mode=802.3ad xmit_hash_policy=layer3+4

alias bond0 bonding
```

ifcfg-bond0:

```
DEVICE=bond0

BOOTPROTO=static

IPADDR=###.###.##.##

(Assign here the IP of the bonded interface.)

NETMASK=255.255.255.0

ONBOOT=yes
```

ifcfg-eth1 (eth2 is a duplicate):

```
DEVICE=eth1 # Change to match device
MASTER=bond0
SLAVE=yes
BOOTPROTO=none
ONBOOT=yes
TYPE=Ethernet
```

From linux-net.osdl.org:

```
For example, the content of /proc/net/bonding/bond0 after the driver\ is
loaded with parameters of mode=0 and miimon=1000 is generally as \ follows:
Ethernet Channel Bonding Driver: 2.6.1 (October 29, 2004)
Bonding Mode: load balancing (round-robin)
Currently Active Slave: eth0
MII Status: up
MII Polling Interval (ms): 1000
Up Delay (ms): 0
Down Delay (ms): 0

Slave Interface: eth1
MII Status: up
Link Failure Count: 1

Slave Interface: eth0
MII Status: up
Link Failure Count: 1
```

In the following example, the bond0 interface is the master (MASTER) while eth0 and eth1 are slaves (SLAVE).

NOTE:
All slaves of bond0 have the same MAC address (Hwaddr) – bond0. All modes, except TLB and ALB, have this MAC address. TLB and ALB require a unique MAC address for each slave.

```
$ /sbin/ifconfig

bond0Link encap:EthernetHwaddr 00:C0:F0:1F:37:B4

inet addr:XXX.XXX.XXX.YYY Bcast:XXX.XXX.XXX.255 \
Mask:255.255.252.0

UP BROADCAST RUNNING MASTER MULTICAST MTU:1500  Metric:1

RX packets:7224794 errors:0 dropped:0 overruns:0 frame:0

TX packets:3286647 errors:1 dropped:0 overruns:1 carrier:0

collisions:0 txqueuelen:0


eth0Link encap:EthernetHwaddr 00:C0:F0:1F:37:B4

inet addr:XXX.XXX.XXX.YYY Bcast:XXX.XXX.XXX.255 \
Mask:255.255.252.0

UP BROADCAST RUNNING SLAVE MULTICAST MTU:1500  Metric:1

RX packets:3573025 errors:0 dropped:0 overruns:0 frame:0

TX packets:1643167 errors:1 dropped:0 overruns:1 carrier:0

collisions:0 txqueuelen:100

Interrupt:10 Base address:0x1080


eth1Link encap:EthernetHwaddr 00:C0:F0:1F:37:B4

inet addr:XXX.XXX.XXX.YYY Bcast:XXX.XXX.XXX.255 \
Mask:255.255.252.0

UP BROADCAST RUNNING SLAVE MULTICAST MTU:1500  Metric:1

RX packets:3651769 errors:0 dropped:0 overruns:0 frame:0

TX packets:1643480 errors:0 dropped:0 overruns:0 carrier:0

collisions:0 txqueuelen:100

Interrupt:9 Base address:0x1400
```

10.6 Configuring Lustre with Bonding

Lustre uses the IP address of the bonded interfaces and requires no special configuration. It treats the bonded interface as a regular TCP/IP interface. If necessary, specify “bond0” using the Lustre *networks* parameter:

```
options lnet networks=tcp(bond0)
```

10.7 Bonding References

CFS recommends the following bonding references:

- In the Linux kernel source tree, see documentation/networking/bonding.txt:

  http://linux-ip.net/html/ether-bonding.html

  http://www.sourceforge.net/projects/bonding

- This is the bonding SourceForge website:

  http://linux-net.osdl.org/index.php/Bonding

  This is the most exhaustive reference and CFS highly recommends it. This website includes explanations of more complicated setups, including the use of DHCP with bonding.

Chapter II - 11. Upgrading Lustre

The chapter describes how to upgrade and downgrade Lustre versions and includes the following sections:

- Upgrading from Version 1.4.6 and later to Version 1.6
- Downgrading Lustre from Version 1.6 to Version 1.4.6/7

11.1 Upgrading from Version 1.4.6 and later to Version 1.6

Use the procedures in this chapter to upgrade Lustre 1.4.6 and later to version 1.6.

11.1.1 Upgrade Requirements

Remember the following important points before upgrading Lustre.

Upgrade MDT before OSTs. The upgrade procedure is:

1. Shut down lconf failover.
2. Install the new modules.
3. Run tunefs.lustre.
4. Mount startup.

Upgrade can be done across a failover pair, in which case the upgrade procedure is:

1. On the backup server, install the new modules.
2. Shut down lconf failover.
3. On the new server, run tunefs.lustre.
4. On the new server, mount startup.
5. On the primary server, install the new modules.

   The file system name must be less than or equal to 8 characters (so it fits on the disk label).

11.1.2 Supported Upgrade Paths

The following Lustre upgrade paths are supported.

Entire file system or individual servers / clients

- Servers can undergo a "rolling upgrade", in which individual servers (or their failover partners) and clients are upgraded one at a time and restarted, so that the file system never goes down. This type of upgrade limits your ability to change certain parameters.
- The entire file system can be shut down, and all servers and clients upgraded at once.
- Any combination of the above two paths.

Interoperability between the nodes

This describes the interoperability between clients, OSTs, and MDTs.

Clients

- Old live clients can continue to communicate with old/new/mixed servers.
- Old clients can start up using old/new/mixed servers.
- New clients can start up using old/new/mixed servers (use old mount format for old MDT).

OSTs

- New clients/MDTs can continue to communicate with old OSTs.
- New OSTs can only be started after the MGS has been started (typically this means "after the MDT has been upgraded.")

MDTs

- New clients can communicate with old MDTs.
- New co-located MGS/MDTs can be started at any point.
- New non-MGS MDTs can be started after the MGS starts.

11.1.3 Starting Clients

You can start *a new client with an old MDT* by using the old format of the client mount command:

```
client# mount -t lustre <mdtnid>:/<mdtname>/client <mountpoint>
```

You can start *a new client with an upgraded MDT* by using the new format and pointing it at the MGS, not the MDT (for co-located MDT/MGS, this is the same):

```
client# mount -t lustre <mgsnid>:/<fsname> <mountpoint>
```

Old clients always use the old format of the mount command, regardless of whether the MDT has been upgraded or not.

11.1.4 Upgrading a Single File System

tunefs.lustre will find the old client log on an 1.4.x MDT that is being upgraded to 1.6. (If the name of the client log is not "client", use the lustre_up14.sh script, described in Step 2 to Step 4.)

1 Shut down the MDT.

```
mdt1# lconf --failover --cleanup config.xml
```

2 Install the new version of Lustre.

3 Run tunefs.lustre to upgrade the old configuration. There are two options here:

4 Rolling upgrade keeps a copy of the original configuration log, allowing immediate reintegration into a live file system, but prevents OSC parameter and failover NID changes. (The writeconf procedure can be performed later to eliminate these restrictions. For details, see Writeconf on page 25.)

```
mdt1# tunefs.lustre --mgs --mdt --fsname=testfs /dev/sda1
```

i.--writeconf begins a new configuration log, allowing permanent modification of all parameters (see Changing Parameters on page 177), but requiring all other servers and clients to be stopped at this point. No clients can be started until all OSTs are upgraded.

```
mdt1# tunefs.lustre --writeconf --mgs --mdt -fsname=testfs \
/dev/sda1
```

5 Start the upgraded MDT.

```
mdt1# mount -t lustre /dev/sda1 /mnt/test/mdt
```

6 OSTs for this file system can now be upgraded and started in a similar manner, except they need the address of the MGS. Very old installations may also need to specify the OST index (for instance, --index=5).

```
ost1# tunefs.lustre --ost --fsname=testfs --mgsnode=mdt1 /dev/sdb
```

11.1.5 Upgrading Multiple File Systems with a Shared MGS

The upgrade order is: MGS first, then for any single file system the MDT must be upgraded and mounted, and then the OSTs for that file system. If the MGS is co-located with the MDT, then the old config logs stored on the MDT are automatically transferred to the MGS. If the MGS is not co-located with the MDT (for a site with multiple file systems), then the old config logs must be transferred to the MGS manually.

1 Format the MGS node, but do not start it.

```
mgsnode# mkfs.lustre --mgs /dev/sda1
```

2 Mount the MGS disk as type ldiskfs.

```
mgsnode# mount -t ldiskfs /dev/sda1 /mnt/mgs
```

3 For each MDT, copy the MDT and client startup logs from the MDT to the MGS, renaming them as needed. There is a script that helps automate this process—lustre_up14.sh

```
mdt1# sh lustre_up14.sh /dev/sdb testfs
debugfs 1.35 (28-Feb-2004)
/dev/sda1: catastrophic mode - not reading inode or group bitmaps
Copying log mds1 to testfs-MDT0000. Okay [y/n]?y
Copying log cfs21 to testfs-client. Okay [y/n]?y
Copying log client to testfs-client. Okay [y/n]?y
ls -l /tmp/logs
total 24
-rw-r--r--  1 root root 9408 Jun  9 15:20 testfs-client
-rw-r--r--  1 root root 9064 Jun  9 15:20 testfs-MDT0000
mdt1# scp /tmp/logs/* mgsnode:/mnt/mgs/CONFIGS/
```

4 Unmount the MGS ldiskfs mount.

```
mgsnode# umount /mnt/mgs
```

5 Start the MGS.

```
mgsnode# mount -t lustre /dev/sda1 /mnt/mgs
```

6 Shut down one of the old MDTs.

```
mdt1# lconf --failover --cleanup config.xml
```

7 Upgrade the old MDT.

```
install new Lustre 1.6
mdt1# tunefs.lustre --mdt --nomgs --fsname=testfs \
--mgsnode=mgsnode@tcp0 /dev/sdb
```

(--nomgs is *required* to upgrade a non-co-located MDT.)

8 Start the upgraded MDT.

```
mdt1# mount -t lustre /dev/sdb /mnt/test/mdt
```

9 Upgrade and start OSTs for this file system.

```
ost1# lconf --failover --cleanup config.xml
install new Lustre 1.6
ost1# tunefs.lustre --ost --fsname=testfs \
--mgsnode=mgsnode@tcp0 /dev/sdc
ost1# mount -t lustre /dev/sdc /mnt/test/ost1
```

10 Upgrade other MDTs in a similar manner. Keep in mind:

- The MGS must **NOT** be running (mounted) when the backing disk is mounted as ldiskfs.
- The MGS **MUST** be running when first starting a newly-upgraded server (MDT or OST).

11.2 Downgrading Lustre from Version 1.6 to Version 1.4.6/7

This section describes how to downgrade Lustre version 1.6 to version 1.4.6 or 1.4.7.

11.2.1 Downgrade Requirements

- The file system must have been upgraded from 1.4.x. In other words, a file system created or reformatted under 1.6 cannot be downgraded.
- Any new OSTs that were dynamically added to the file system will be unknown in version 1.4.x. It is possible to add them back using lconf --write-conf, but you must be careful to use the correct UUID of the new OSTs.
- Downgrading an MDS that is also acting as an MGS prevents access to all other file systems that the MGS serves.

11.2.2 Downgrading a File System

To downgrade a file system:

1 Shut down all clients.

2 Shut down all servers.

3 Install Lustre 1.4.x on the client and server nodes.

4 Restart the servers (OSTs, then MDT) and clients.

WARNING:
When you downgrade Lustre, all OST additions and parameter changes made since the file system was upgraded are lost.

Chapter II - 12. Lustre SNMP Module

The Lustre SNMP module reports information about Lustre components and system status, and generates traps if an LBUG occurs. The Lustre SNMP module works with the net-snmp. The module consists of a plug-in (lustresnmp.so), which is loaded by the snmpd daemon, and a MIB file (Lustre-MIB.txt).

This chapter describes how to install and use the Lustre SNMP module, and includes the following sections:

12.1 Installing the Lustre SNMP Module

To install the Lustre SNMP module:

1. Locate the SNMP plug-in (lustresnmp.so), in the base Lustre RPM and install it.

   ```
   /usr/lib/lustre/snmp/lustresnmp.so
   ```

2. Locate the MIB (Lustre-MIB.txt) in `/usr/share/lustre/snmp/mibs/Lustre-MIB.txt` and append the following line to snmpd.con.

   ```
   dlmod lustresnmp /usr/lib/lustre/snmp/lustresnmp.so
   ```

3. You may need to copy Lustre-MIB.txt to a different location to use few tools. For this, use either of these commands.

   ```
   ~/.snmp/mibs
   ```

   ```
   /usr/local/share/snmp/mibs
   ```

12.2 Building the Lustre SNMP Module

To build the Lustre SNMP module, you need the net-snmp-devel package. The default net-snmp install includes an snmpd.conf file.

1 Complete the net-snmp setup by checking and editing the snmpd.conf file, located in `/etc/snmp`

`/etc/snmp/snmpd.conf`

2 Build the Lustre SNMP module from the Lustre src.rpm

- Install the Lustre source
- Run ./configure
- Add the **--enable-snmp** option

12.3 Using the Lustre SNMP Module

Once the Lustre SNMP module in installed and built, use can use it for the following purposes:

- For all Lustre components, the SNMP module reports a number and total and free capacity (usually in bytes).
- Depending on the component type, SNMP also reports total or free numbers for objects like OSD and OSC or other files (LOV, MDC, and so on).
- The Lustre SNMP module provides one read/write variable, sysStatus, which starts and stops Lustre.
- The sysHealthCheck object reports status either as healthy' or 'not healthy' and provides information for the failure.
- The Lustre SNMP module generates traps on the detection of LBUG (lustrePortalsCatastropeTrap), and detection of various OBD-specific healthchecks (lustreOBDUnhealthyTrap).

Chapter II - 13. Backup and Restore

This chapter describes how to perform backup and restore on Lustre, and includes the following sections:

13.1 Lustre Backups

Lustre provides file system backups at several levels.

13.1.1 Client Filesystem-level Backups

It is possible to get a backup of Lustre file systems from a client (or many clients working parallel in different directories) with the help of user-level backup tools tar, cpio, amanda, and many other enterprise-level backup utilities. Using normal, file backup tools remains the easiest, recommended method to back up and restore data.

However, due to the large size of most Lustre file systems, it is not always possible to get a complete backup. CFS recommends that you back up subsets of a file system. This includes subdirectories of the entire directory, filesets for a single user, files incremented by date, and so on.

13.1.2 Performing Device-level Backups

In some situations, you may need a full, device-level backup of an individual MDS or OST storage device (before replacing hardware, performing maintenance, etc.). A full device-level backup is the easiest backup method and it ensures preservation of the original data.

In case of hardware replacement, if the spare storage device is available, then it is possible to take a raw copy of the MDS or OST from one block device to the other, as long as the new device is at least as large as the original device. To do this, run:

```
dd if=/dev/{original} of=/dev/{new} bs=1M
```

If there are problems while reading the data on the original device due to hardware errors, then run the following command to read the data and skip sections with errors. Run:

```
dd if=/dev/{original} of=/dev/{new} bs=4k conv=sync,noerror
```

In spite of hardware errors, the ext3 file system is very robust and it may be possible to recover the file system data after running e2fsck on the new device.

13.1.3 Performing File-level Backups

In some situations, you may want to back up data from a single file on the MDS or an OST file system, rather than back up the entire device. This may be a preferable backup strategy if the storage device is large, but has relatively little data, parameter configurations on the ext3 file system need to be changed, or to use less space for backup.

You can mount the ext3 file system directly from the storage device and do a file-level backup. However you **MUST STOP** Lustre on that node.

To do this, back up the Extended Attributes (EAs) stored in the file system. As the current backup tools do not properly save this data, perform the following procedure.

13.1.3.1 Backing Up an MDS File

To back up a file on the MDS:

1 Make a mount point for the filesystem "mkdir /mnt/mds" and mount the filesystem at that location.

- For 2.4 kernels, run:

  ```
  mount -t ext3 {dev} /mnt/mds
  ```

- For 2.6 kernels, run:

  ```
  mount -t ldiskfs {dev} /mnt/mds
  ```

2 Change to the mount point being backed up "cd /mnt/mds".

3 Back up the EAs, run:

```
getfattr -R -d -m '.*' -P . > ea.bak
```

NOTE:
The getfattr command is part of the "attr" package in most distributions. If the getfattr command returns errors like "Operation not supported" then the kernel does not correctly support EAs. STOP and use a different backup method or contact CFS for assistance.

4 Verify that the ea.bak file has properly backed up the EA data on the MDS. Without this EA data, the backup is not useful. Look at this file with "more" or a text editor. It should have an item for each file like:

```
# file: ROOT/mds_md5sum3.txt
trusted.lov=0s0AvRCwEAAABXoKUCAAAAAAAAAAAAAAAAAAAAAQAAEAAADD5QoAAAAAAAAAAAAAA
AAAAAAAAAEAAAA=
```

5 Back up all file system data, run:

```
tar czvf {backup file}.tgz
```

6 Change directory out of the mounted files ystem, run:

```
cd -
```

7 Unmount the files system, run:

```
umount /mnt/mds
```

13.1.3.2 Backing Up an OST File

Follow the same procedure as Backing Up an MDS File, except skip Step 4 and, for each OST device file system, replace `mds` with `ost` in the commands.

13.2 Restoring from a File-level Backup

To restore data from a file-level backup, you need to format the device, restore the file data and then restore the EA data.

1 Format the device. To get the optimal ext3 parameters, run:

```
$ mkfs.lustre --fsname {fsname} --reformat --mgs|mdt|ost /dev/sda
```

WARNING:
Only reformat the node which is being restored. If there are multiple services on the node, do not perform this step as it can cause all devices on the node to be reformatted. In that situation, use these steps:

For MDS file systems, run:

```
mke2fs -j -J size=400 -I {inode_size} -i 4096 {dev}
```

where {inode_size} is at least 512 and possibly larger if the default stripe count is > 10 (inode_size = power_of_2_>=_than(384 + stripe_count * 24)).

For OST file systems, run:

```
mke2fs -j -J size=400 -I 256 -i 16384 {dev}"
```

2 Enable ext3 file system directory indexing.

```
tune2fs -O dir_index {dev}
```

3 Mount the file system.

- For 2.4 kernels, run:

```
mount -t ext3 {dev} /mnt/mds
```

- For 2.6 kernels, run:

```
mount -t ldiskfs {dev} /mnt/mds
```

4 Change to the new file system mount point, run:

```
cd /mnt/mds
```

5 Restore the file system backup, run:

```
tar xzvpf {backup file}
```

6 Restore the file system EAs, run:

`setfattr --restore=ea.bak` (not required for OST devices)

7 Remove the recovery logs (now invalid), run:

```
rm OBJECTS/* CATALOGS
```

NOTE:
If the file system is in use during the restore process, then run the **lfsck** tool (part of the CFS e2fsprogs) to ensure that the file system is coherent.

It is not necessary to run this tool if the backup of all device file systems occurs at the same time after stopping the entire Lustre file system. After completing the file system should be immediately usable without running **lfsck**. There may be few I/O errors reading from files that are present on the MDS, but not on the OSTs. However, the files that are created after the MDS backup are not visible or accessible.

Chapter II - 14. POSIX

This chapter describes POSIX and includes the following sections:

Portable Operating System Interface (POSIX) is a set of standard, operating system interfaces based on the Unix OS. POSIX defines file system behavior on single Unix node. It is not a standard for clusters.

POSIX specifies the user and software interfaces to the OS. Required program-level services include basic I/O (file, terminal, and network) services. POSIX also defines a standard threading library API which is supported by most modern operating systems.

POSIX in a cluster means that most of the operations are atomic. Clients can not see the metadata. POSIX offers strict mandatory locking which gives guarantee of semantics. Users do not have control on these locks.

The current Lustre POSIX is comparable with NFS. Lustre 1.8 promises strong security with features like GSS / Kerberos 5. This enables graceful handling of users from multiple realms which, in turn, introduce multiple UID & GID databases.

Note
Advisory fcntl/flock/lockf locks will be available in Lustre 1.8.

Note
Although used mainly with UNIX systems, the POSIX standard can apply to any operating system.

14.1 Installing POSIX

To install POSIX (used for testing Lustre):

1 Download all POSIX files from ftp://ftp.lustre.org:/pub/benchmarks/posix/tet_vsxgen_2.0.tgz

lts_vsx-pcts-1.0.1.2.tgz

install.sh

myscen.bld

myscen.exec

WARNING:
Do NOT configure or mount a Lustre file system yet.

2 Run the install.sh script and select /home/tet for the root directory for the test suite installation.

3 Install users and groups. Accept the defaults for the packages to be installed.

4 To avoid a bug in the installation scripts where the test directory is not created properly, create a temporary directory to hold the POSIX tests when they are built.

```
$ mkdir -p /mnt/lustre/TESTROOT;chown vsx0.vsxg0
```

5 Log in as the test user: `su - vsx0`

6 Run ../setup.sh to build the test suite. Most of the defaults are correct, except the root directory from which to run the test sets. For this setting, specify /mnt/lustre/TESTROOT. Do NOT install pseudo languages.

7 When the system displays this prompt:

```
Install scripts into TESTROOT/BIN..?
```

Do not immediately repond. Using another terminal (as stopping the script does not work), replace the files /home/tet/test_sets/scen.exec and /home/tet/test_sets/scen.bld with myscen.exec and myscen.bld (downloaded earlier).

```
$ cp .../myscen.bld  /home/tet/test_sets/scen.bld
$ cp .../myscen.exec /home/tet/test_sets/scen.exec
```

This limits the tests run only to the relevant file systems and avoids additional hours of other tests on sockets, math, stdio, libc, shell, and so on.

8 Continue with the installation.

a. Build the test sets. It proceeds to build and install all of the file system tests.

b. Run the test sets. Even though it is running them on a local file system, this is a valuable baseline for comparison with the behavior of Lustre. It should put the results into /home/tet/test_sets/results/0002e/journal. Rename or symlink this directory to /home/tet/test_sets/results/ext3/journal (or to the name of the local file system on which the test was run).

Running the full test takes approximately five minutes. Do not re-run the failed tests. The results are in a very lengthy table in /home/tet/test_sets/results/report.

9 Save the test suite to run further tests on a Lustre file system. Tar up the tests, so that you do not have to rebuild each time.

14.2 Running the Test Suite Against Lustre

To run the POSIX tests against Lustre:

1. As root, set up your Lustre file system, mounted on /mnt/lustre (for instance, sh llmount.sh) and untar the POSIX tests back to their home.

   ```
   $ tar --same-owner -xzpvf /path/to/tarball/TESTROOT.tgz -C \  /mnt/lustre
   ```

   As the vsx0 user, you can re-run the tests as many times as you want. If you are newly logged in as the vsx0 user, you need to source the environment with '. profile' so that your path and environment is set up correctly.

2. Run the POSIX tests.

   ```
   $ . /home/tet/profile
   $ tcc -e -s scen.exec -a /mnt/lustre/TESTROOT -p
   ```

   Each new result is placed in a new directory under /home/tet/test_sets/results and is given a directory name similar to 0004e (an incrementing number which ends with **e** (for test execution) or **b** (for building tests).

3. To look at a formatted report:

   ```
   $ vrpt results/0004e/journal | less
   ```

   Some tests are "**Unsupported**", "**Untested**" or "**Not In Use**", which does not necessarily indicate a problem.

4. To compare two test results, use the command:

   ```
   $ vrptm results/ext3/journal results/0004e/journal | less
   ```

   This is more interesting than looking at the result of a single test as it helps to find test failures that are specific to the file system, instead of the Linux VFS or kernel. Up to six test results can be compared at one time. It is often useful to rename the results directory to have more interesting names so that they are meaningful in the future.

14.3 Isolating and Debugging Failures

In the case of Lustre failures, you need to capture information about what is happening at runtime. For example some tests may cause kernel panics, depending on your Lustre configuration. By default, debugging is not enabled in the POSIX suite. You need to turn on the VSX debugging options. There are two debug options of note in the config file tetexec.cfg, under the TESTROOT directory:

VSX_DBUG_FILE=output_file - If you are running the test under UML with hostfs support, use a file on the hostfs as the debug output file. In the case of a crash, the debug output can be safely written to the debug file.

Note
The default value for this option puts the debug log under your test directory in /mnt/lustre/TESTROOT, which is not useful in case of kernel panic and Lustre (or your machine) crashes.

VSX_DBUG_FLAGS=xxxxx - The following example makes VSX output all debug messages:

VSX_DBUG_FLAGS=t:d:n:f:F:L:l,2:p:P

VSX is based on the TET framework which provides common libraries for VSX. You can also have TET print out verbose debug messages by inserting the **-T** option when running the tests. For example:

```
$  tcc -Tall5 -e -s scen.exec -a /mnt/lustre/TESTROOT -p 2>&1 | tee /tmp/
POSIX-command-line-output.log
```

VSX prints out detailed messages in the report for failed tests. This includes the test strategy, operations done by the test suite, and the failures. Each subtest (for instance, 'access', 'create') usually contains many single tests. The report shows exactly which single testing fails. In this case, you can find more information directly from the VSX source code.

For example, if the fifth single test of subtest chmod failed; you could look at the source:

```
$ /home/tet/test_sets/tset/POSIX.os/files/chmod/chmod.c
```

Which contains a single test array:

```
public  struct tet_testlist tet_testlist[] = {
test1, 1,
test2, 2,
test3, 3,
test4, 4,
test5, 5,
test6, 6,
test7, 7,
test8, 8,
test9, 9,
test10, 10,
test11, 11,
test12, 12,
test13, 13,
test14, 14,
test15, 15,
test16, 16,
test17, 17,
test18, 18,
test19, 19,
test20, 20,
test21, 21,
test22, 22,
test23, 23,
NULL, 0
};
```

If this single test is causing problems (as in the case of a kernel panic) or if you are trying to isolate a single failure, it may be useful to narrow the tet_testlist array down to the single test in question and then recompile the test suite. Then, you can create a new tarball of the resulting TESTROOT directory, with an appropriate name (like TESTROOT-chmod-5-only.tgz) and re-run the POSIX suite. It may also be helpful to edit the scen.exec file to run only test set in question.

```
 "total tests in POSIX.os 1"
/tset/POSIX.os/files/chmod/T.chmod
```

Note
Rebuilding individual POSIX tests is not straightforward due to the reliance on tcc. You may have to substitute the edited source files into the source tree (following the installation described above) and letting the existing POSIX install scripts do the work. The installation scripts (specifically, /home/tet/test_sets/run_testsets.sh) contain relevant commands to build the test suite, similar to tcc -p -b -s $HOME/scen.bld $*
but it does not work outside the script.

Chapter II - 15. Benchmarking

This chapter describes benchmark suites to test Lustre, and includes the following sections:

- Bonnie++ Benchmark
- IOR Benchmark
- IOzone Benchmark

The benchmarking process involves identifying the highest standard of excellence and performance, learning and understanding these standards, and finally adapting and applying them to improve the performance. Benchmarks are most often used to provide an idea of how fast any software or hardware runs.

Complex interactions between I/O devices, caches, kernel daemons, and other OS components result in behavior that is rather difficult to analyze. Moreover, systems have different features and optimizations, so no single benchmark is always suitable. The variety of workloads that these systems experience also adds in to this difficulty. One of the most widely researched areas in storage subsystem is filesystem design, implementation, and performance.

15.1 Bonnie++ Benchmark

Bonnie++[1] is a benchmark tool that test hard drive and file system performance by sequential I/O and random seeks. Bonnie++ tests file system activity that has been known to cause bottlenecks in I/O-intensive applications.

To install and run the Bonnie++ benchmark:

1 Download the most recent version of the Bonnie++ software:

http://www.coker.com.au/bonnie++/

2 Install and run the Bonnie++ software (per the ReadMe file accompanying the software).

Sample output:

Version 1.03 ------Sequential Output------ --Sequential Input- --Random-

```
                    -Per Chr- --Block-- -Rewrite- -Per Chr- --Block-- --Seeks--
Machine        Size K/sec %CP K/sec %CP K/sec %CP K/sec %CP K/sec %CP  /sec %CP
mds              2G           38118  22 21245  10           51967  10  90.0   0
```

------Sequential Create------ --------Random Create--------

```
                    -Create-- --Read--- -Delete-- -Create-- --Read--- -Delete--
               files  /sec %CP  /sec %CP  /sec %CP  /sec %CP  /sec %CP  /sec %CP
                  16   510   0 +++++ +++   283   1   465   0 +++++ +++   291   1
mds,2G,,,38118,22,21245,10,,,51967,10,90.0,0,16,510,0,+++++,+++,283,1,465,0
,+++++,+++,291,1
```

Version 1.03 ------Sequential Output------ --Sequential Input- --Random-

```
                    -Per Chr- --Block-- -Rewrite- -Per Chr- --Block-- --Seeks--
Machine        Size K/sec %CP K/sec %CP K/sec %CP K/sec %CP K/sec %CP  /sec %CP
mds              2G 27460  92 41450  25 21474  10 19673  60 52871  10  88.0   0
```

------Sequential Create------ --------Random Create--------

```
                    -Create-- --Read--- -Delete-- -Create-- --Read--- -Delete--
               files  /sec %CP  /sec %CP  /sec %CP  /sec %CP  /sec %CP  /sec %CP
                  16 29681  99 +++++ +++ 30412  90 29568  99 +++++ +++ 28077  82
mds,2G,27460,92,41450,25,21474,10,19673,60,52871,10,88.0,0,16,29681,99,++++
+,+++,30412,90,29568,99,+++++,+++,28077,82
```

1. Bonnie++ is baesd on Bonnie code.

15.2 IOR Benchmark

The IOR benchmark, developed by LLNL, tests system performance by focusing on parallel/sequential read/write operations that are typical of scientific applications.

To install and run the IOR benchmark:

1. Satisfy the prerequisites to run IOR.
   a. Download lam 7.0.6 (local area multi-computer):

      http://www.lam-mpi.org/7.0/download.php

   b. Obtain a Fortran compiler for the Fedora Core 4 operating system.
   c. Download the most recent version of the IOR software:

      ftp://ftp.llnl.gov/pub/siop/ior/

2. Install the IOR software (per the ReadMe file and User Guide accompanying the software).
3. Run the IOR software. In user mode, use the lamboot command to start the lam service and use appropriate Lustre-specific commands to run IOR (described in the IOR User Guide).

   Sample Output

```
IOR-2.9.0: MPI Coordinated Test of Parallel I/O
Run began: Fri Sep 29 11:43:56 2006
Command line used: ./IOR -w -r -k -O lustrestripecount 10 -o test
Machine: Linux mds
Summary:
api                = POSIX
test filename      = test
access             = single-shared-file
clients            = 1 (1 per node)
repetitions        = 1
xfersize           = 262144 bytes
blocksize          = 1 MiB
aggregate filesize = 1 MiB

access    bw(MiB/s)  block(KiB) xfer(KiB)  open(s)    wr/rd(s)   close(s)
iter
------    ---------  ---------- ---------  --------   --------   --------
write     173.89     1024.00    256.00     0.000030   0.005701   0.000016   0
read      278.49     1024.00    256.00     0.000009   0.003566   0.000012   0

Max Write: 173.89 MiB/sec (182.33 MB/sec)
Max Read:  278.49 MiB/sec (292.02 MB/sec)

Run finished: Fri Sep 29 11:43:56 2006
```

15.3 IOzone Benchmark

The IOzone benchmark tests file I/O performance for the following operations: read, write, re-read, re-write, read backwards, read strided, fread, fwrite, random read/write, pread/pwrite variants, aio_read, aio_write, and mmap.

To install and run the IOzone benchmark:

1 Download the most recent version of the IOZone software from this location:

www.iozone.org

2 Install the IOZone software (per the ReadMe file accompanying the IOZone software).

3 Run the IOZone software (per the ReadMe file accompanied with the IOZone software).

Sample Output

```
Iozone: Performance Test of File I/O
        Version $Revision: 3.263 $
Compiled for 32 bit mode.
Build: linux
Contributors:William Norcott, Don Capps, Isom Crawford, Kirby Collins
             Al Slater, Scott Rhine, Mike Wisner, Ken Goss
             Steve Landherr, Brad Smith, Mark Kelly, Dr. Alain CYR,
             Randy Dunlap, Mark Montague, Dan Million,
             Jean-Marc Zucconi, Jeff Blomberg,
             Erik Habbinga, Kris Strecker, Walter Wong.

Run began: Fri Sep 29 15:37:07 2006
Network distribution mode enabled.
Command line used: ./iozone -+m test.txt
Output is in Kbytes/sec
Time Resolution = 0.000001 seconds.
Processor cache size set to 1024 Kbytes.
Processor cache line size set to 32 bytes.
File stride size set to 17 * record size.
                                                              random  random
bkwd  record  stride
             KB  reclen   write rewrite    read    reread    read   write
read rewrite    read   fwrite frewrite   fread  freread
            512       4  194309  406651   728276   792701  715002  498592
638351  700365  587235   190554   378448  686267   765201

iozone test complete.
```

Chapter II - 16. Lustre Recovery

This chapter describes how to recover Lustre, and includes the following sections:

Lustre offers substantial recovery support to deal with node or network failure, and returns the cluster to a reliable, functional state. When Lustre is in recovery mode, it means that the servers (MDS/OSS), judge there is a stop of file system in an unclean state. In other words, unsaved data may be in the client cache. To save this data, the file system re-starts in recovery mode and makes the clients write the data to disk.

16.1 Recovering Lustre

In Lustre recovery mode, the servers attempt to contact all of the clients and request that they replay their transactions.

- If all clients are contacted and they are in a recoverable state (they have not rebooted), then recovery proceeds and the file system comes back with the cached client-side data safely saved to disk.
- If one or more clients are not able to reconnect (due to hardware failures or client reboots), then the recovery process times out, which causes all clients to be expelled. In this case, if there is any unsaved data in the client cache, it is not saved to disk and is lost. This is an unfortunate side effect of allowing Lustre to keep data consistent on disk.

16.2 Types of Failure

Different types of failure can cause Lustre to enter recovery mode:

- Client (compute node) failure
- MDS failure (and failover)
- OST failure
- Transient network partition
- Network failure
- Disk state loss
- Down node

- Disk state of multiple, out-of-sync systems

Currently, all failure and recovery operations are based on the notion of connection failure. All imports or exports associated with a given connection are considered as failed if any of them do.

16.2.1 Client Failure

Lustre supports for recovery from client failure based on the revocation of locks and other resources, so surviving clients can continue their work uninterrupted. If a client fails to timely respond to a blocking AST from the Distributed Lock Manager or a bulk data operation times out, the system removes the client from the cluster. This action allows other clients to acquire locks blocked by the dead client, and it also frees resources (such as file handles and export data) associated with the client. This scenario can be caused by a client node system failure or a network partition.

16.2.2 MDS Failure (and Failover)

Reliable Lustre operation requires that the MDS have a peer configured for failover, including the use of a shared storage device for the MDS backing file system. When a client detects an MDS failure, it connects to the new MDS and launches the MetadataReplay function. MetadataReplay ensures that the replacement MDS re-accumulates the state resulting from transactions whose effects were visible to clients, but which were not committed to disk. Transaction numbers ensure that the operations replay occurs in the same order as the original intergration. Additionally, clients inform the new server of their existing lock state (including locks that have not yet beem granted). All metadata and lock replay must complete before new, non-recovery operations are permitted. During the recovery window, only clients that were connected at the time of MDS failure are permitted to reconnect.

ClientUpcall, a user-space policy program, manages the re-connection to a new or rebooted MDS. ClientUpcall is responsible to set up necessary portals, routes and connections, and indicates which connection UUID should replace the failed one.

16.2.3 OST Failure

When an OST fails or is severed from the client, Lustre marks the corresponding OSC as inactive, and the LogicalObjectVolume avoids making stripes for new files on that OST. Operations that operate on the "whole file", such as determining file size or unlinking, skips inactive OSCs (and OSCs that become inactive during the operation). Attempts to read from or write to an inactive stripe result in an -EIO error being returned to the client.

As with the MDS failover case, Lustre invokes the ClientUpcall when it detects an OST failure. If and when the upcall indicates that the OST is functioning again, Lustre reactivates an OSC in question and makes file data from stripes on the newly-returned OST available for reading and writing.

16.2.4 Network Partition

The partition can be transient. Lustre recovery occurs in following sequence:

- Clients can detect "harmless partition" upon reconnecting. Dropped-reply cases require ReplyReconstruction
- Servers evict clients.
- ClientUpcall may try other routers. The arbitrary configuration change is possible the message ’Failed Recovery - ENOTCONN’ is given for evicted clients.
- Process invalidates all entries and locks. Eventually, the file system finishes recovering and returns to normal operation. You may check the progress of Lustre recovery by looking at the recovery_status proc entry for each device on the OSSs, for example: cat /proc/fs/lustre/obdfilter/ost1/recovery_status

The file system may get stuck in recovery if any servers are down or if any of servers have thrown a Lustre bug (LBUG); check /proc/fs/lustre/health_check.

Chapter III - 1. Lustre I/O Kit

This chapter describes the Lustre I/O kit and kit tools, and includes the following sections:

1.1 Lustre I/O Kit Description and Prerequisites

The Lustre I/O kit is a collection of benchmark tools for a Lustre cluster. The I/O kit can be used to validate the performance of the various hardware and software layers in the cluster and also as a way to find and troubleshoot I/O issues.

The I/O kit contains three tests. The first surveys basic performance of the device and bypasses the kernel block device layers, buffer cache and file system. The subsequent tests survey progressively higher layers of the Lustre stack. Typically with these tests, Lustre should deliver 85-90% of the raw device performance.

It is very important to establish performance from the “bottom up” perspective. First, the performance of a single raw device should be verified. Once this is complete, verify that performance is stable within a larger number of devices. Frequently, while troubleshooting such performance issues, we find that array performance with all LUNs loaded does not always match the performance of a single LUN when tested in isolation. After the raw performance has been established, other software layers can be added and tested in an incremental manner.

1.1.1 Downloading an I/O Kit

You can download the I/O kits from:

https://downloads.clusterfs.com/customer/lustre-iokit/

In this directory, you will find two packages:

- **lustre-iokit** consists of a set of scripts developed and supported by CFS.
- **scali-lustre-iokit** is a Python tool maintained by the kind team at Scali, and is not discussed in this version of the manual.

1.1.2 Prerequisites to Using an I/O Kit

The following prerequisites must be met to use the Lustre I/O kit from CFS:

- password-free remote access to nodes in the system (normally obtained via ssh or rsh)
- Lustre file system software
- sg3_utils for the sgp_dd utility

1.2 Running I/O Kit Tests

As mentioned above, the I/O kit contains these test tools:

- sgpdd_survey
- obdfilter_survey
- ost_survey

1.2.1 sgpdd_survey

Use sgpdd_survey tool to test **bare metal** performance, while bypassing as much of the kernel as possible. This script requires the sgp_dd package, although it does not require Lustre software. This survey may be used to characterize the performance of a SCSI device by simulating an OST serving multiple stripe files. The data gathered by this survey can help set expectations for the performance of a Lustre OST exporting the device.

The script uses sgp_dd to carry out raw sequential disk I/O. It runs with variable numbers of sgp_dd threads to show how performance varies with different request queue depths.

The script spawns variable numbers of sgp_dd instances, each reading or writing a separate area of the disk to demonstrate performance variance within a number of concurrent stripe files.

The device(s) used must meet one of the two tests described below:

SCSI device:

- Must appear in the output of **sg_map** (make sure the kernel module "sg" is loaded)

Raw device:

- Must appear in the output of **raw -qa**

If you need to create raw devices in order to use the sgpdd_survey tool, note that raw device 0 cannot be used due to a bug in certain versions of the "raw" utility (including that shipped with RHEL4U4.)

You may not mix raw and SCSI devices in the test specification.

WARNING:
The sgpdd_survey script overwrites the device being tested, which results in the LOSS OF ALL DATA on that device. Exercise caution when selecting the device to be tested.

The sgpdd_survey script must be customized according to the particular device being tested and also according to the location where it should keep its working files. Customization variables are described explicitly at the start of the script.

When the sgpdd_survey script runs, it creates a number of working files and a pair of result files. All files start with the prefix given by the script variable ${rslt}.

```
${rslt}_<date/time>.summary same as stdout
${rslt}_<date/time>_* tmp files
${rslt}_<date/time>.detail collected tmp files for post-mortem
```

The summary file and stdout should contain lines like this:

```
total_size 8388608K rsz 1024 thr 1 crg 1 180.45 MB/s 1 x 180.50 \
=/ 180.50 MB/s
```

The number immediately before the first MB/s is bandwidth, computed by measuring total data and elapsed time. The remaining numbers are a check on the bandwidths reported by the individual sgp_dd instances.

If there are so many threads that the sgp_dd script is unlikely to be able to allocate input/output buffers, then "ENOMEM" is printed.

If one or more sgp_dd instances do not successfully report a bandwidth number, then "failed" is printed.

1.2.2 obdfilter_survey

The obdfilter_survey script processes sequential input/output with varying numbers of threads and objects (files) by using lctl::test_brw to drive the echo_client connected to local or remote obdfilter instances, or remote obdecho instances. It can be used to characterize the performance of the following Lustre components:

Stripe F/S

Here, the script directly exercises one or more instances of obdfilter. The script may be running on one or more nodes, for example, when the nodes are all attached to the same multi-ported disk subsystem.

You need to tell the script the names of all obdfilter instances, which should already be up and running. If some instances are on different nodes, then you also need to specify their hostnames, for example, node1:ost1. All the obdfilter instances are driven directly. The script automatically loads the obdecho module (if required) and creates one instance of echo_client for each obdfilter instance.

Network

Here, the script drives one or more instances of obdecho via instances of echo_client running on one or more nodes. You need to tell the script the names of all echo_client instances, which should already be up and running. If some instances are on different nodes, then you also need to specify their hostnames, for example, node1:ECHO_node1.

Stripe F/S over the network

Here, the script drives one or more instances of obdfilter via instances of echo_client running on one or more nodes. As noted above, you need to tell the script the names of all echo_client instances, which should already be up and running. Note that the script is **not** scalable to hundreds of nodes since it is only intended to measure individual servers, not the scalability of the system as a whole.

Script

The script must be customized according to the components being tested and the location where it should keep its working files. Customization variables are clearly described at the beginning of the script.

1.2.2.1 Running obdfilter_survey Against a Local Disk

To run the obdfilter_survey script against a local disk:

1. Create a Lustre configuration shell script and XML, using your normal methods. You do not need to specify an MDS or LOV, but you do need to list all OSTs that you wish to test.
2. On all OSS machines, run:

   ```
   $ mkfs.lustre --fsname spfs --mdt --mgs /dev/sda
   ```

   Remember, write tests are destructive. This test should be run prior to startup of your actual Lustre file system. If you do this, you will **not** need to reformat to restart Lustre. However, if the test is terminated before completion, you may have to remove objects from the disk.
3. Determine the obdfilter instance names on all clients. The names appear as the 4th column of **lctl dl**. For example:

   ```
   $ pdsh -w oss[01-02] lctl dl |grep obdfilter |sort

   oss01:   0 UP obdfilter oss01-sdb oss01-sdb_UUID 3
   oss01:   2 UP obdfilter oss01-sdd oss01-sdd_UUID 3
   oss02:   0 UP obdfilter oss02-sdi oss02-sdi_UUID 3
   ```

   Here the obdfilter instance names are **oss01-sdb**, **oss01-sdd**, **oss02-sdi**. Since you are driving obdfilter instances directly, set the shell array variable, *ost_names*, to the names of the obdfilter instances and leave *client_names* variable undefined. For example:

   ```
   ost_names_str='oss01:oss01-sdb oss01:oss01-sdd oss02:oss02-sdi' \
   ./obdfilter-survey
   ```

1.2.2.2 Running obdfilter_survey Against a Network

If you are driving obdfilter or obdecho instances over the network, then you must instantiate the echo_clients. Set the shell array variable client_names to the names of the echo_client instances and leave *ost_names* variable undefined.

Optionally, you can prefix any name in *ost_names* or *client_names* with the hostname that it runs on, for example, *remote_node:ost4*. If you are running remote nodes, make sure these requirements are met:

- The custom_remote_shell() works on your cluster.
- All pathnames that you specify in the script are mounted on the node from which obdfilter_survey is started and on all remote nodes.
- The obdfilter_survey script is installed on clients at the same location as the master node.

To run the obdfilter_survey script against a network:

1 Bring up obdecho instances on the servers and echo_client instances on the clients, and run the included echo.sh on a node that has Lustre installed. Shell variables:

- *SERVERS*: set this to a list of server hostnames or *hostname* of the current node is used. This may be the wrong interface, so be sure to check it.

NOTE:
echo.sh could probably be smarter about this.

- *NETS*: set this if you are using a network type other than TCP.

For example:

```
SERVERS=oss01-eth2 sh echo.sh
```

2 On the servers, start the obdecho server and verify that it is up, run:

```
$ lctl dl
0 UP obdecho ost_oss01.local ost_oss01.local_UUID 3
1 UP ost OSS OSS_UUID 3
```

3 On the clients, start the other side of the echo connection, run:

```
$ lctl dl
0 UP osc OSC_xfer01.local_ost_oss01.local_ECHO_client \
6bc9b_ECHO_client_2a8a2cb3dd 5
1 UP echo_client ECHO_client 6bc9b_ECHO_client_2a8a2cb3dd 3
```

4 Verify connectivity from a client, run:

```
$ lctl ping SERVER_NID
```

5 Run the script on the master node, specifying the client names in an environment variable.

For example, run:

```
$ client_names_str='xfer01:ECHO_client xfer02:ECHO_client
xfer03:ECHO_client xfer04:ECHO_client xfer05:ECHO_client
xfer06:ECHO_client xfer07:ECHO_client xfer08:ECHO_client
xfer09:ECHO_client xfer10:ECHO_client xfer11:ECHO_client
xfer12:ECHO_client' ./obdfilter-survey
```

6 When aborting, run killall vmstat on clients:

```
pdsh -w (clients) killall vmstat
```

Use *lctl device_list* to verify the obdfilter / echo_client instance names. For example, when the script runs, it creates a number of working files and a pair of result files. All files start with the prefix given by ${rslt}.

```
${rslt}.summary      same as stdout
${rslt}.script_*     per-host test script files
${rslt}.detail_tmp*  per-ost result files
${rslt}.detail       collected result files for
                     post-mortem
```

The script iterates over the given numbers of threads and objects performing all specified tests and checking that all test processes completed successfully.

Note that the script does **not** clean up properly if it is aborted or if it encounters an unrecoverable error. In this case, manual cleanup may be required, possibly including killing any running instances of **lctl** (local or remote), removing echo_client instances created by the script, and unloading obdecho.

1.2.2.3 Output of the sbdfilter_survey Script

The summary file and stdout contain lines like:

```
ost 8 sz 67108864K rsz 1024 obj8 thr8 write613.54 \
[ 64.00, 82.00]
```

Where:

Variable	Description
ost8	Total number of OSTs under test
sz 67108864K	Total amount of data read or written (in KB)
rsz 1024	Record size (size of each echo_client input/output
obj 8	Total number of objects over all OSTs
thr 8	Total number of threads over all OSTs and objects
write	Test name; if more tests have been specified, they all appear on the same line.
613.54	Aggregate bandwidth over all OSTs (measured by dividing the total number of MBs by the elapsed time)
[64.00, 82.00]	Minimum and maximum instantaneous bandwidths seen on any individual OST

NOTE:
Although the numbers of threads and objects are specified per-OST in the customization section of the script, results are reported aggregated over all OSTs.

1.2.2.4 Visualizing Results

It is useful to import the summary data (its fixed width) into Excel (or any graphing package) and graph the bandwidth against the number of threads for varying numbers of concurrent regions. This shows how the OSS performs for a given number of concurrently-accessed objects (files) with varying numbers of inputs / outputs in flight.

It is also useful to record average disk I/O sizes during each test. These numbers help find pathologies in the system when the file system block allocator or the block device elevator fragment I/O requests.

The obparse.pl script (included) is an example of processing the output files to a .csv format.

1.2.3 ost_survey

The ost_survey tool is a shell script that uses lfs setstripe to perform I/O against a single OST. The script writes a file (currently using dd) to each OST in the Lustre file system, and compares read and write speeds. The ost_survey tool is used to detect misbehaving disk subsystems.

NOTE:
CFS has frequently discovered wide performance variations across all LUNs in a cluster.

To run the ost_survey script, supply a file size (in KB) and the Lustre mount point. For example, run:

```
$ ./ost-survey.sh 10 /mnt/lustre
Average read Speed:         6.73
Average write Speed:        5.41
read - Worst OST indx 0     5.84 MB/s
write - Worst OST indx 0    3.77 MB/s
read - Best OST indx 1      7.38 MB/s
write - Best OST indx 1     6.31 MB/s
3 OST devices found
Ost index 0 Read speed5.84 Write speed 3.77
Ost index 0 Read time0.17 Write time   0.27
Ost index 1 Read speed7.38 Write speed 6.31
Ost index 1 Read time0.14 Write time   0.16
Ost index 2 Read speed6.98 Write speed 6.16
Ost index 2 Read time0.14 Write time   0.16
```

Chapter III - 2. LustreProc

This chapter describes Lustre /proc entries and includes the following sections:

2.1 Introduction

The proc file system acts as an interface to internal data structures in the kernel. It can be used to obtain information about the system and to change certain kernel parameters at runtime (sysctl).

The Lustre file system provides several proc file system variables that control aspects of Lustre performance and provide information.

The proc variables are classified based on the subsystem they affect.

2.1.1 /proc Entries for Lustre

This section includes /proc entries for Lustre.

2.1.1.1 Finding Lustre

By using the proc files on the MGS, you can see the following:

- All known file systems

```
# cat /proc/fs/lustre/mgs/MGS/filesystems
spfs
lustre
```

- The server names participating in a file system (for each file system that has at least one server running)

```
# cat /proc/fs/lustre/mgs/MGS/live/spfs
fsname: spfs
flags: 0x0     gen: 7
spfs-MDT0000
spfs-OST0000
```

All servers are named according to this convention: <*fsname*>-<*MDT*|*OST*><*XXXX*>. This can be shown for live servers under /proc/fs/lustre/devices:

```
# cat /proc/fs/lustre/devices
  0 UP mgs MGS MGS 11
  1 UP mgc MGC192.168.10.34@tcp 1f45bb57-d9be-2ddb-c0b0-5431a4922670 5
  2 UP mdt MDS MDS_uuid 3
  3 UP lov lustre-mdtlov lustre-mdtlov_UUID 4
  4 UP mds lustre-MDT0000 lustre-MDT0000_UUID 7
  5 UP osc lustre-OST0000-osc lustre-mdtlov_UUID 5
  6 UP osc lustre-OST0001-osc lustre-mdtlov_UUID 5
  7 UP lov lustre-clilov-ce63ca00 08ac6584-6c4a-3536-2c6d-b36cf9cbdaa0 4
  8 UP mdc lustre-MDT0000-mdc-ce63ca00 08ac6584-6c4a-3536-2c6d-b36cf9cbdaa05
  9 UP osc lustre-OST0000-osc-ce63ca00 08ac6584-6c4a-3536-2c6d-b36cf9cbdaa05
 10 UP osc lustre-OST0001-osc-ce63ca00 08ac6584-6c4a-3536-2c6d-b36cf9cbdaa05
```

Or from the device label at any time:

```
# e2label /dev/sda
lustre-MDT0000
```

2.1.1.2 Lustre Timeouts/ Debugging

/proc/sys/lustre/timeout

This is the time period that a client waits for a server to complete an RPC (default 100s). Servers wait half of this time for a normal client RPC to complete and a quarter of this time for a single bulk request (read or write of up to 1 MB) to complete. The client pings recoverable targets (MDS and OSTs) at one quarter of the timeout, and the server waits one and a half times the timeout before evicting a client for being "stale."

/proc/sys/lustre/ldlm_timeout

This is the time period for which a server will wait for a client to reply to an initial AST (lock cancellation request) where default is 20s for an OST and 6s for an MDS. If the client replies to the AST, the server will give it a normal timeout (half of the client timeout) to flush any dirty data and release the lock.

/proc/sys/lustre/fail_loc

This is the internal debugging failure hook.

See lustre/include/linux/obd_support.h for the definitions of individual failure locations. The default value is 0 (zero).

```
sysctl -w lustre.fail_loc=0x80000122 # drop a single reply
```

/proc/sys/lustre/dump_on_timeout

This triggers dumps of the Lustre debug log when timeouts occur.

2.1.1.3 LNET Information

/proc/sys/lnet/peers

Shows all NIDs known to this node and also gives information on the queue state.

```
# cat /proc/sys/lnet/peers
nid                      refs state   max   rtr   min    tx   min queue
0@lo                        1  ~rtr     0     0     0     0     0 0
192.168.10.35@tcp           1  ~rtr     8     8     8     8     6 0
192.168.10.36@tcp           1  ~rtr     8     8     8     8     6 0
192.168.10.37@tcp           1  ~rtr     8     8     8     8     6 0
```

Fields are explained below:

Field	Description
refs	A reference count, used for debugging primarily.
state	Only valid when referring to routers. Possible values: • ~rtr - indicates this node is not a router • up/down - node is a router • auto_fail must be enabled
max	Maximum number of concurrent sends from this peer.
rtr	Routing buffer credits.
min	Minimum routing buffer credits seen.
tx	Send credits.
min	Minimum send credits seen.
queue	Total bytes in active / queued sends.

Credits work like a semaphore. At start they are initialized to allow a certain number of operations (8 in this example). LNET keeps a track of the minimum value so that you can see how congested a resource was.

If **rtr/tx** is less than **max**, there are operations in progress. The number of operations is equal to **rtr** or **tx** subtracted from **max**.

If **rtr/tx** is greater that **max**, there are operations blocking.

LNET also limits concurrent sends and router buffers allocated to a single peer so that no peer can occupy all these resources.

/proc/sys/lnet/nis

```
# cat /proc/sys/lnet/nis
nid                      refs peer   max    tx   min
0@lo                        3    0     0     0     0
192.168.10.34@tcp           4    8   256   256   252
```

Shows current queue health on this node.

Fields are explained below:

Field	Description
nid	The network interface.
refs	Internal reference counter.
peer	Number of peer-to-peer send credits on this NID. Credits are used to size buffer pools.
max	Total number of send credits on this NID.
tx	Current number of send credits available on this NID.
min	Lowest number of send credits available on this NID.
min	Minimum send credits seen.
queue	Total bytes in active / queued sends.

Subtracting **max – tx** yields the number of sends currently active. A large or increasing number of active sends may indicate a problem.

```
# cat /proc/sys/lnet/nis
nid             refs  peer  max   tx    min
0@lo            2     0     0     0     0
10.67.73.173@tcp4    8     256   256   253
```

2.1.1.4 Free Space Distribution

The free-space stripe weighting is set to give a priority of "0" to the free space (versus trying to place the stripes "widely" -- nicely distributed across OSSs and OSTs to maximize network balancing).

You can adjust this priority via the proc file:

```
$ cat /proc/fs/lustre/lov/<fsname>-mdtlov/qos_prio_free
```

Currently, the default is 90%. You can permanently set this value by running this command on the MGS:

```
$ ctl conf_param <fsname>-MDT0000.lov.qos_prio_free=90
```

Setting the priority to 100% just means that OSS distribution does not count in the weighting, but the stripe assignment is still done via weighting. If OST2 has twice as much free space as OST1, it will be twice as likely to be used, but it is NOT guaranteed to be used.

Also note that free-space stripe weighting does not activate until two OSTs are imbalanced by more than 20%. Until then, a faster round-robin stripe allocator is used. (The new round-robin order also maximizes network balancing.)

2.2 Lustre I/O Tunables

The section describes I/O tunables.

/proc/fs/lustre/llite/<*fsname*>-<*uid*>/max_cache_mb

```
# cat /proc/fs/lustre/llite/lustre-ce63ca00/max_cached_mb
128
```

This tunable is the maximum amount of inactive data cached by the client (default is 3/4 of RAM).

2.2.1 Client I/O RPC Stream Tunables

The Lustre engine always attempts to pack an optimal amount of data into each I/O RPC and attempts to keep a consistent number of issued RPCs in progress at a time. Lustre exposes several tuning variables to adjust behavior according to network conditions and cluster size. Each OSC has its own tree of these tunables. For example:

```
$ ls -d /proc/fs/lustre/osc/OSC_client_ost1_MNT_client_2 /localhost
/proc/fs/lustre/osc/OSC_uml0_ost1_MNT_localhost
/proc/fs/lustre/osc/OSC_uml0_ost2_MNT_localhost
/proc/fs/lustre/osc/OSC_uml0_ost3_MNT_localhost
$ ls /proc/fs/lustre/osc/OSC_uml0_ost1_MNT_localhost
blocksizefilesfreemax_dirty_mb  \
ost_server_uuidstats
```

... and so on.

RPC stream tunables are described below.

/proc/fs/lustre/osc/<*object name*>/max_dirty_mb

This tunable controls how many MBs of dirty data can be written and queued up in the OSC. POSIX file writes that are cached contribute to this count. When the limit is reached, additional writes stall until previously-cached writes are written to the server. This may be changed by writing a single ASCII integer to the file. Only values between 0 and 512 are allowable. If 0 is given, no writes are cached. Performance suffers noticably unless you use large writes (1 MB or more).

/proc/fs/lustre/osc/<*object name*>/cur_dirty_bytes

This tunable is a read-only value that returns the current amount of bytes written and cached on this OSC.

/proc/fs/lustre/osc/<*object name*>/max_pages_per_rpc

This tunable is the maximum number of pages that will undergo input/output in a single RPC to the OST. The minimum is a single page and the maximum for this setting is platform depedent (256 for i386/x86_64, possibly less for ia64 / PPC with larger PAGE_SIZE), though generally amounts to a total of 1 MB in the RPC.

/proc/fs/lustre/osc/<*object name*>/max_rpcs_in_flight

This tunable is the maximum number of concurrent RPCs that the OSC will issue at a time to its OST. If the OSC tries to initiate an RPC but finds that it already has the same number of RPCs outstanding, it will wait to issue further RPCs until some complete. The minimum setting is 1 and maximum setting is 32.

The value for max_dirty_mb is recommended to be 4 * max_pages_per_rpc * max_rpcs_in_flight in order to maximize performance.

NOTE:
The <*object name*> varies depending on the specific Lustre configuration. For examples of <*object name*>, see the sample command output.

2.2.2 Watching the Client RPC Stream

In the same directory is a file that gives a histogram of the make-up of previous RPCs.

```
# cat /proc/fs/lustre/osc/spfs-OST0000-osc-c45f9c00/rpc_stats
snapshot_time:         1174867307.156604 (secs.usecs)
read RPCs in flight:  0
write RPCs in flight: 0
pending write pages:  0
pending read pages:   0
                        read                    write
pages per rpc         rpcs   % cum % |       rpcs   % cum %
1:                       0   0   0   |          0   0   0

                        read                    write
rpcs in flight        rpcs   % cum % |       rpcs   % cum %
0:                       0   0   0   |          0   0   0

                        read                    write
offset                rpcs   % cum % |       rpcs   % cum %
0:                       0   0   0   |          0   0   0
```

RPCs in flight

This represents the number of RPCs that are issued by the OSC but are not complete at the time of the snapshot. It should always be less than or equal to **max_rpcs_in_flight**.

pending {read,write} pages

These fields show the number of pages that have been queued for Iinput/output in the OSC.

other RPCs in flight when a new RPC is sent

When an RPC is sent, it records the number of other RPCs that were pending in this table. When the first RPC is sent, the 0: row will be incremented. If the first RPC is sent while another is pending the 1: row will be incremented and so on. The number of RPCs that are pending as each RPC *completes* is not tabulated. This table is a good way of visualizing the concurrency of the RPC stream. Ideally you will see a large clump around the **max_rpcs_in_flight** value which shows that the network is being kept busy.

pages in each RPC

As an RPC is sent, the number of pages it is made of is recorded in order in this table. A single page RPC increments the 0: row, 128 pages the 7: row and so on.

These histograms can be cleared by writing any value into the *rpc_stats* file.

2.2.3 Client Read-Write Offset Survey

The "rw_offset_stats" maintains statistics for the occurences where a series of read or write calls from a process did not access the next sequential location. The offset field is reset to 0 (zero) whenever a different file is read/written.

Example:

```
# cat /proc/fs/lustre/llite/lustre-f57dee00/rw_offset_stats
snapshot_time: 1155748884.591028 (secs.usecs)
R/W PID  RANGE START RANGE END SMALLEST EXTENT LARGEST EXTENT OFFSET
R   8385      0          128          128             128          0
R   8385      0          224          224             224       -128
W   8385      0          250           50             100          0
W   8385    100         1110           10             500       -150
W   8384      0         5233         5233            5233          0
R   8385    500          600          100             100       -610
```

Where:

Field	Description
R/W	Whether the non-sequential call was a read or a write.
PID	The process ID which made the read/write call.
RANGE START - RANGE END	The range in which the read/write calls were sequential.
SMALLEST - EXTENT	The smallest extent(single read/write) in the corresponding range.
LARGEST - EXTENT	The largest extent(single read/write) in the corresponding range.
OFFSET	The difference from the previous range end to the current range start. For example, **SMALLEST-EXTENT** indicates that the writes in the range 100 to 1110 were sequential, with a minimum write of 10 and a maximum write of 500. This range was started with an offset of -150. That means this is the difference between the last entry's range-end and this entry's range-start for the same file. The "rw_offset_stats" file can be cleared by writing to it: `echo > /proc/fs/lustre/llite/lustre-f57dee00/rw_offset_stats`

2.2.4 Client Read-Write Extents Survey

Client-Based I/O Extent Size Survey

The "rw_extent_stats" histogram in the llite directory shows you the statistics for the sizes of the read-write I/O extents. This file does not maintain the per-process statistics.

Example:

```
$ cat /proc/fs/lustre/llite/spfs-c45f9c00/extents_stats
snapshot_time:         1174868361.372513 (secs.usecs)
                               read       |                write
      extents            calls    % cum%  |          calls    % cum%
   0K -    4K :              0    0    0   |              0    0    0
```

The file can be cleared by issuing the following command:

```
$ echo > cat /proc/fs/lustre/llite/spfs-c45f9c00/extents_stats
```

Per-Process Client I/O Statistics

The "extents_stats_per_process" file maintains the I/O extent size statistics on a per-process basis. So you can track the per-process statistics for the last MAX_PER_PROCESS_HIST processes.

Example:

```
$ cat /proc/fs/lustre/llite/spfs-c45f9c00/extents_stats_per_process
snapshot_time:         1174868461.566452 (secs.usecs)
                               read       |                write
      extents            calls    % cum%  |          calls    % cum%
```

2.2.5 Watching the OST Block I/O Stream

Similarly, there is a "brw_stats" histogram in the obdfilter directory which shows you the statistics for number of input/output requests sent to the disk, their size and whether they are contiguous on the disk or not.

```
cat /proc/fs/lustre/obdfilter/lustre-OST0000/brw_stats
snapshot_time:         1174875636.764630 (secs:usecs)
                               read                    write
pages per brw          brws  %      cum    % |    rpcs  %      cum %
1:                     0     0      0        |    0     0      0

                       read                    write
discont pages          rpcs  %      cum    % |    rpcs  %      cum %
1:                     0     0      0        |    0     0      0

                       read                    write
discont blocks         rpcs  %      cum    % |    rpcs  %      cum %
1:                     0     0      0        |    0     0      0

                       read                    write
dio frags              rpcs  %      cum    % |    rpcs  %      cum %
1:                     0     0      0        |    0     0      0

                       read                    write
disk ios in flight     ios   %      cum    % |    rpcs  %      cum %
1:                     0     0      0        |    0     0      0

                       read                    write
io time (1/1000s)      rpcs  %      cum    % |    rpcs  %      cum %
1:                     0     0      0        |    0     0      0

                       read                    write
disk I/O size          count %      cum    % |    count %      cum %
```

The fields are explained below:

Field	Description
pages per brw	Number of pages per RPC request, which should match aggregate client rpc_stats.
discont pages	Number of discontinuities in the logical file offset of each page in a single RPC.
discont blocks	Number of discontinuities in the physical block allocation in the file system for a single RPC.

2.2.6 Mechanics of Lustre Readahead

Readahead is a method of reading part of a file's contents into memory with the expectation that a process working with the file will soon want the data. When readahead works well, a data-consuming process finds that the information it needs is available when it asks, and waiting for disk I/O is not necessary.

Lustre readahead is triggered when two or more sequential reads by an application fail to be satisfied by the Linux buffer cache. The size of the initial readahead is 1 MB. Additional readaheads grow linearly and increment until the readahead cache on the client is full at 40 MB.

/proc/fs/lustre/llite/<*fsname*>-<*uid*>/max_read_ahead_mb

This tunable controls the maximum amount of data readahead on a file. Files are read ahead in RPC-sized chunks (1 MB or the size of read() call, if larger) after the second sequential read on a file descriptor. Random reads are done at the size of the read() call only (no readahead). Reads to non-contiguous regions of the file reset the readahead algorithm, and readahead is not triggered again until there are sequential reads again. Setting this tunable to 0 disables readahead. The default value is 40 MB.

/proc/fs/lustre/llite/<*fsname*>-<*uid*>/max_read_ahead_whole_mb

This tunable controls the maximum size of a file that is read in its entirety, regardless of the size of the read().

2.2.7 mballoc History

/proc/fs/ldiskfs/sda/mb_history

mballoc is short-form for "Multi-Block-Allocate" and is Lustre's ability to ask ext3 to allocate multiple blocks with a single request to the block allocator. Normally, an ext3 file system can allocate only one block at a time. Each mballoc-enabled partition has this file.

Sample output:

```
pidinode       goal             result           found grps  cr    \
merge tailbroken
2838139267     17/12288/1       17/12288/1       1     0     0     \ M 1
8192
2838139267     17/12289/1       17/12289/1       1     0     0     \ M 00
2838139267     17/12290/1       17/12290/1       1     0     0     \ M12
283824577      3/12288/1        3/12288/1        1     0     0     \ M 1
8192
283824578      3/12288/1        3/771/1          1     1     1     \
0  0
283832769      4/12288/1        4/12288/1        1     0     0     \ M 1
8192
283832770      4/12288/1        4/12289/1        13    1     1     \ 00
283832771      4/12288/1        5/771/1          26    2     1     \ 00
283832772      4/12288/1        5/896/1          31    2     1     \ 1128
283832773      4/12288/1        5/897/1          31    2     1     \
0  0
282832774      4/12288/1        5/898/1          31    2     1     \ 12
283832775      4/12288/1        5/899/1          31    2     1     \
0  0
```

```
283832776       4/12288/1          5/900/1           31     2      1      \
1  4
283832777       4/12288/1          5/901/1           31     2      1      \
0  0
283832778       4/12288/1          5/902/1           31     2      1      \ 12
283832779       4/12288/1          5/903/1           31     2      1      \ 00


pidinodegoalresultfoundgrps cr\ merge tailbroken
283832780       4/12288/1          5/904/1           31     2      1      \ 18
283832781       4/12288/1          5/905/1           31     2      1      \ 00
283832782       4/12288/1          5/906/1           31     2      1      \ 12
283832783       4/12288/1          5/907/1           31     2      1      \ 00
283832784       4/12288/1          5/908/1           31     2      1      \
1  4
283832785       4/12288/1          5/909/1           31     2      1      \ 00
283832786       4/12288/1          5/910/1           31     2      1      \ 12
283832787       4/12288/1          5/911/1           31     2      1      \ 00
283832788       4/12288/1          5/912/1           31     2      1      \ 116
283832789       4/12288/1          5/913/1           31     2      1      \
0  0
282832790       4/12288/1          5/914/1           31     2      0      \ 12
283832791       4/12288/1          5/915/1           31     2      1      \
0  0
283832792       4/12288/1          5/916/1           31     2      1      \
1  4
283832793       4/12288/1          5/917/1           31     2      1      \
0  0
283832794       4/12288/1          5/918/1           31     2      1      \ 12
283832795       4/12288/1          5/919/1           31     2      1      \ 00
282832796       4/12288/1          5/920/1           31     2      1      \ 18
283832797       4/12288/1          5/921/1           31     2      1      \
0  0
283832798       4/12288/1          5/922/1           31     2      1      \
1  2
283832799       4/12288/1          5/923/1           31     2      1      \
0  0
283832800       4/12288/1          5/924/1           31     2      1      \
1  4
```

```
pidinode       goal              result            found grps  cr    \
merge tailbroken
283832801      4/12288/1         5/925/1           31    2     1     \ 00
283832802      4/12288/1         5/926/1           31    2     1     \ 12
283832803      4/12288/1         5/927/1           31    2     1     \ 00
283832804      4/12288/1         5/928/1           31    2     1     \ 132
283832805      4/12288/1         5/929/1           31    2     1     \
0  0
283832806      4/12288/1         5/930/1           31    2     1     \ 12
283832807      4/12288/1         5/931/1           31    2     1     \ 00
283824579      3/12288/1         3/12289/1         11    1     1     \ 00
```

The parameters are described below:

Field	Description
pid	Process that made the allocation.
inode	inode number allocated blocks.
goal	Initial request that came to mballoc (group/block-in-group/number-of-blocks)
result	What mballoc actually found for this request.
found	Number of free chunks mballoc found and measured before the final decision.
grps	Number of groups mballoc scanned to satisfy the request.
cr	Stage at which mballoc found the result: **0** - best in terms of resource allocation. The request was 1MB or larger and was satisfied directly via the kernel buddy allocator. **1** - regular stage (good at resource consumption) **2** - fs is quite fragmented (not that bad at resource consumption) **3** - fs is very fragmented (worst at resource consumption)
queue	Total bytes in active / queued sends.
merge	Whether the request hit the goal. This is good as extents code can now merge new blocks to existing extent, eliminating the need for extents tree growth.
tail	Number of blocks left free after the allocation breaks large free chunks.
broken	How large the broken chunk was.

Most customers are probably interested in **found/cr**. If **cr** is 0 1 and **found** is less than 100, then mballoc is doing quite well.

Also, number-of-blocks-in-request (third number in the goal triple) can tell the number of blocks requested by the obdfilter. If the obdfilter is doing a lot of small requests (just few blocks), then either the client is processing input/output to a lot of small files, or something may be wrong with the client (because it is better if client sends large input/output requests). This can be investigated with the OSC rpc_stats or OST brw_stats mentioned above.

Number of groups scanned (grps column) should be small. If it reaches few dozens often either your disk file system is pretty fragmented or mballoc is doing something wrong in the group selection part.

2.2.8 mballoc3 Tunables

mballoc3 is included in Lustre version 1.6.1 and later. mballoc3[1] was built on top of malloc2, and adds these features:

- Pre-allocation for single files (helps to resist fragmentation)
- Pre-allocation for a group of files (helps to pack small files into large, contiguous chunks)
- Stream allocation (helps to decrease the seek rate)

The following mballoc3 tunables are currently available:

Parameter	Description
stats	Enables/disables the collection of statistics. Collected statistics can be found in /proc/fs/ldiskfs2/<dev>/mb_history.
max_to_scan	Maximum number of free chunks that mballoc finds before a final decision to avoid livelock.
min_to_scan	Minimum number of free chunks that mballoc finds before a final decision. This is useful for a very small request, to resist fragmentation of big free chunks.
order2_req	For requests equal to 2^N (where N >= order2_req), a very fast search via buddy structures is used.
stream_req	Requests smaller or equal to this value are packed together to form large write I/Os.

The following tunables, providing more control over allocation policy, will be available in the next version:

Parameter	Description
stats	Enables/disables the collection of statistics. Collected statistics can be found in /proc/fs/ldiskfs2/<dev>/mb_history.
max_to_scan	Maximum number of free chunks that mballoc finds before a final decision to avoid livelock.
min_to_scan	Minimum number of free chunks that mballoc finds before a final decision. This is useful for a very small request, to resist fragmentation of big free chunks.
order2_req	For requests equal to 2^N (where N >= order2_req), a very fast search via buddy structures is used.
small_req	All requests are divided into 3 categories:
large_req	**< small_req** (packed together to form large, aggregated requests) **< large_req** (allocated mostly in linearly) **> large_req** (very large requests so the arm seek does not matter) The idea is that we try to pack small requests to form large requests, and then place all large requests (including compound from the small ones) close to one another, causing as few arm seeks as possible.
prealloc_table	The amount of space to preallocate depends on the current file size. The idea is that for small files we do not need 1MB preallocations and for large files, 1MB preallocations are not large enough; it is better to preallocate 4MB.
group_prealloc	The amount of space preallocated for small requests to be grouped.

1. mballoc3 is enabled, by default.

2.3 Locking

**/proc/fs/lustre/ldlm/ldlm/namespaces/<OSC name|MDCname>
/lru_size**

This variable determines how many locks can be queued up on the client in an LRU queue. The default value of LRU size is 100. Increasing this on a large number of client nodes is not recommended, though servers have been tested with up to 150,000 total locks (num_clients * lru_size). Increasing it for a small number of clients (for example, login nodes with a large working set of files due to interactive use) can speed up Lustre dramatically. Recommended values are in the neighbourhood of 2500 MDC locks and 1000 locks per OSC.

The following command can be used to clear the LRU on a single client, and as a result flush client cache, without changing the LRU size value:

```
$ echo clear > /proc/fs/lustre/ldlm/ldlm/namespaces/<OSC \
name|MDC name>/lru_size
```

If you shrink the LRU size below the number of existing unused locks, the locks are canceled immediately. Use echo "clear" to cancel all locks without changing the value.

2.4 Debug Support

/proc/sys/lnet/debug

Lustre generates a detailed log of all its operations to aid in debugging by default. This can affect the performance or speed you achieve with Lustre. Therefore, it is useful to reduce this overhead by turning down the debug level. Raise the debug level when you need to collect the logs for debugging problems.

You can verify the debug level used by examining the sysctl that controls the debugging as shown below:

```
# sysctl portals.debug
  portals.debug = -1
```

In the above example, -1 indicates full debugging; it is a bitmask. You can disable debugging completely by running the following command on all the concerned nodes:

```
# sysctl -w portals.debug=0
  portals.debug = 0
```

The appropriate debug level for a production environment is 0x3f0400. It collects enough high-level information to aid debugging, but it does not cause any serious performance impact.

You can also verify and change the debug level using the "/proc" interface in Lustre as shown below:

```
# cat /proc/sys/lnet/debug
```

And change it to:

```
# echo 0x3f0400 > /proc/sys/lnet/debug
```

/proc/sys/lnet/subsystem_debug

This controls the debug logs for subsystems (see S_* definitions).

/proc/sys/lnet/debug_path

This indicates the location where debugging symbols should be stored for gdb. The default is set to */r/tmp/lustre-log-localhost.localdomain*.

These values can also be set via **sysctl -w lnet.debug={value}**.

NOTE:
Above entries exist only when Lustre has already been loaded.

Lustre uses the set debug level after it is loaded on a particular node. You can set the debug level by adding the following to the node entry config shell script:

```
--ptldebug <level>
```

2.4.1 RPC Information for Other OBD Devices

Some OBD devices maintain a count of the number of RPC events that they process. Sometimes these events are more specific to operations of the device, like *llite*, than actual raw RPC counts.

```
$ find /proc/fs/lustre/ -name stats
/proc/fs/lustre/osc/lustre-OST0001-osc-ce63ca00/stats
/proc/fs/lustre/osc/lustre-OST0000-osc-ce63ca00/stats
/proc/fs/lustre/osc/lustre-OST0001-osc/stats
/proc/fs/lustre/osc/lustre-OST0000-osc/stats
/proc/fs/lustre/mdt/MDS/mds_readpage/stats
/proc/fs/lustre/mdt/MDS/mds_setattr/stats
/proc/fs/lustre/mdt/MDS/mds/stats
/proc/fs/lustre/mds/lustre-MDT0000/exports/ab206805-0630-6647-8543-
d24265c91a3d/stats
/proc/fs/lustre/mds/lustre-MDT0000/exports/08ac6584-6c4a-3536-2c6d-
b36cf9cbdaa0/stats
/proc/fs/lustre/mds/lustre-MDT0000/stats
/proc/fs/lustre/ldlm/services/ldlm_canceld/stats
/proc/fs/lustre/ldlm/services/ldlm_cbd/stats
/proc/fs/lustre/llite/lustre-ce63ca00/stats
```

The OST .../stats files can be used to track the performance of RPCs that the OST gets from all clients. It is possible to get a periodic dump of values from these files, for instance every 10s, that show the RPC rates (similar to iostat) by using the "llstat.pl" tool like:

```
# llstat /proc/fs/lustre/osc/lustre-OST0000-osc/stats
/usr/bin/llstat: STATS on 09/14/07 /proc/fs/lustre/osc/lustre-OST0000-osc/
stats on 192.168.10.34@tcp
snapshot_time             1189732762.835363
ost_create                1
ost_get_info              1
ost_connect               1
ost_set_info              1
obd_ping                  212
```

You can clear the stats by giving the -c option to llstat.pl. You can also mention how frequently (after how many seconds) it should clear the stats by mentioning an iteger in -i option. For example, following is the output with -c and -i10(stats for every 10 Sec):

```
$ llstat -c -i10 /proc/fs/lustre/ost/OSS/ost_io/stats

/usr/bin/llstat: STATS on 06/06/07 /proc/fs/lustre/ost/OSS/ost_io/stats on\
192.168.16.35@tcp

snapshot_time             1181074093.276072

/proc/fs/lustre/ost/OSS/ost_io/stats @ 1181074103.284895

Name                      Cur.Count  Cur.Rate   #Events

req_waittime                8         0          8         [usec]         2078\
34       259.75        868    317.49

req_qdepth                  8         0          8         [reqs]            1\
0         0.12          1      0.35

req_active                  8         0          8         [reqs]           11\
1         1.38          2      0.52

reqbuf_avail                8         0          8         [bufs]          511\
63        63.88         64      0.35

ost_write                   8         0          8         [bytes]     1697677\
72914    212209.62     387579  91874.29

/proc/fs/lustre/ost/OSS/ost_io/stats @ 1181074113.290180

Name                      Cur.Count  Cur.Rate   #Events

req_waittime               31         3          39        [usec]        30011\
34       822.79      12245   2047.71

req_qdepth                 31         3          39        [reqs]            0\
0         0.03          1      0.16

req_active                 31         3          39        [reqs]           58\
1         1.77          3      0.74

reqbuf_avail               31         3          39        [bufs]         1977\
63        63.79         64      0.41

ost_write                  30         3          38        [bytes]    10284679\
15019    315325.16     910694 197776.51

/proc/fs/lustre/ost/OSS/ost_io/stats @ 1181074123.325560

Name                      Cur.Count  Cur.Rate   #Events

req_waittime               21         2          60        [usec]        14970\
34       784.32      12245   1878.66

req_qdepth                 21         2          60        [reqs]            0\
0         0.02          1      0.13

req_active                 21         2          60        [reqs]           33\
1         1.70          3      0.70

reqbuf_avail               21         2          60        [bufs]         1341\
63        63.82         64      0.39

ost_write                  21         2          59        [bytes]     7648424\
15019    332725.08     910694 180397.87
```

Chapter III - 3. Lustre Tuning

This chapter contains information to tune Lustre for better performance and includes the following sections:

3.1 Module Options

Many options in Lustre are set by means of kernel module parameters. These parameters are contained in the “modprobe.conf” file (On SuSE, this may be “modprobe.conf.local”).

3.1.1 OST Threads

The *ost_num_threads* option allows the number of OST service threads to be specified at module load time on the OSS nodes:

options ost ost_num_threads={N}

An OSS can have a maximum of 36 service threads. Prior to Lustre 1.4.5, the default number of service threads on an OSS depended on the server size. In Lustre 1.4.6, the number of OST threads was a function of the server capacity (RAM + CPUs). For a 2 GB 2-CPU system, this works out to 64 service threads. For larger servers, this might be as high as 512 threads. Giving a specific thread count via the *ost_num_threads* module parameter overrides the default calculation.

Increasing the size of the thread pool may help when:

- Several OSTs are exported from a single OSS
- Back-end storage is running synchronously
- Input / output completions take excessive time

In such cases, a larger number of I/O threads allows the kernel and storage to aggregate many writes together for more efficient disk I/O. The OST thread pool is shared—each thread allocates approximately 1.5 MB (maximum RPC size + 0.5 MB) for internal I/O buffers.

NOTE:
Consider memory consumption when increasing the thread pool size.

3.1.2 MDS Threads

There is a similar parameter for the number of MDS service threads:

options mds mds_num_threads={N}

At this time, CFS has not tested to determine the optimal number of MDS threads. The default value varies, based on server size, up to a maximum of 32. The maximum number of threads (MDS_MAX_THREADS) is 512.

NOTE:
The OSS and MDS automatically start new service threads dynamically in response to server loading within a factor of 4. The default is calculated the same way as before (as explained in 3.1.1 OST Threads on page 165).

Setting the _mu_threads module parameter disables the automatic thread creation behavior.

3.1.3 LNET Tunables

This section describes LNET tunables.

3.1.3.1 Transmit and receive buffer size:

With Lustre release 1.4.7 and later, **ksocklnd** now has separate parameters for the transmit and receive buffers.

```
options ksocklnd tx_buffer_size=0 rx_buffer_size=0
```

If these parameters are left at the default value (0), the system automatically tunes the transmit and receive buffer size. In almost every case, this default produces the best performance. Do not attempt to tune these parameters unless you are a network expert.

3.1.3.2 irq_affinity

By default, this parameter is ON. In the normal case on an SMP system, we would like network traffic to remain local to a single CPU. This helps to keep the processor cache warm, and minimizes the impact of context switches. This is especially helpful when an SMP system has more than one network interface, and ideal when the number of interfaces equals the number of CPUs.

If you have an SMP platform with a single fast interface such as 10 GB Ethernet and more than 2 CPUs, you may see improved performance by turning this parameter to OFF. You should, as always, test to compare the performance impact.

3.2 Options for Formatting MDS and OST

The backing file systems on an MDS and OSTs are independent of one another, so the formatting parameters for them should not be same. The size of the MDS backing file system depends solely on how many inodes you want in the total Lustre file system. It is not related to the size of the aggregate OST space.

3.2.1 Planning for Inodes

Each time you create a file on a Lustre file system, it consumes one inode on the MDS and one inode for each OST object that the file is striped over (normally it is based on the default stripe count option -c; but this may change on a per-file basis). In ext3/ldiskfs file systems, inodes are pre-allocated, so creating a new file does not consume any of the free blocks. However, this also means that the format-time options should be conservative as it is not possible to increase the number of inodes after the file system is formatted. It is possible to add OSTs with additional space and inodes to the file system.

To be on the safe side, plan for 4 KB per inode on the MDS. This is the default. For the OST, the amount of space taken by each object depends entirely upon the usage pattern of the users/applications running on the system. Lustre, by necessity, defaults to a very conservative estimate for the object size (16 KB per object). You can almost always increase this value for file system installations. Many Lustre file systems have average file sizes over 1MB per object.

3.2.2 Calculating MDS Size

When calculating the MDS size, the only important factor is the average size of files to be stored in the file system. If the average file size is, for example, 5 MB and you have 100 TB of usable OST space then you need at least (100 TB * 1024 GB/TB * 1024 MB/GB / 5 MB/inode) = 20 million inodes. CFS recommends to have twice the minimum, that is 40 million inodes in this example. At the default 4 KB per inode, this works out to only 160 GB of space for the MDS.

Conversely, if you have a very small average file size, for example 4 KB, Lustre is not very efficient. This is because you consume as much space on the MDS as you are consume on the OSTs. This is not a very common configuration for Lustre.

3.2.3 Overriding Default Formatting Options

To override the default formatting options for any of the Lustre backing file systems, use the "--mkfsoptions='backing fs options'" argument to mkfs.lustre to pass formatting options to the backing mkfs. For all options to format backing ext3 and ldiskfs file systems, see the mke2fs(8) man page; this section only discusses some Lustre-specific options.

3.2.3.1 Number of Inodes for MDS

To override the inode ratio, use the option '-i <bytes per inode>' (for instance, "--mkfsoptions='-i 4096' " to create 1 inode per 4096 bytes of file system space). Alternately, if you are specifying some absolute number of inodes, use the '-N<number of inodes>' option. To avoid unintentional mistakes, do not specify the ’-i’ option with an inode ratio below one inode per 1024 bytes. Instead, use the '-N' option.

By default, a 2 TB MDS has 512M inodes. Currently, the largest supported file system size is 8 TB, which holds 2B inodes. With an MDS inode ratio of 1024 bytes per inode, a 2 TB MDS holds 2B inodes, and a 4 TB MDS holds 4B inodes, which is the maximum number of inodes currently supported by ext3.

3.2.3.2 Inode Size for MDS

Lustre uses "large" inodes on \ backing file systems to efficiently store Lustre metadata with each file. On the MDS, each inode is at least 512 bytes in size (by default), while on the OST each inode is 256 bytes in size. Lustre (or more specifically the backing ext3 file system), also needs sufficient space left for other metadata like the journal (up to 400 MB), bitmaps and directories. There are also a few regular files that Lustre uses to maintain cluster consistency.

To specify a larger inode size, use the '-I <inodesize>' option. CFS does NOT recommend specifying a smaller-than-default inode size, as this can lead to serious performance problems; and you cannot change this parameter after formatting the file system. The inode ratio must always be larger than the inode size.

3.2.3.3 Number of Inodes for OST

For OST file systems, it is normally advantageous to take local file system usage into account. Try and minimize the number of inodes created on each OST. This helps reduce the format and e2fsck time, and makes more space available for data. With its on-disk block size of 4 KB, Lustre can perform 1 MB reads and writes to the disk in order to increaase the performance.

Presently, Lustre has 1 inode per 16 KB of space in the OST file system (by default). In many environments, this is far too many inodes for the average file size. As a good rule of thumb, the OSTs should have at least a number of inodes indicated by this formula:

num_ost_inodes = 4 * <num_mds_inodes> * <default_stripe_count> / <number_osts>

You can specify the number of inodes on the OST file systems via the '-N<num_inodes>' option to --mkfsoptions. Alternately, if you know the average file size, then you can also specify the OST inode count for the OST file systems via '-i <average_file_size / (number_of_stripes * 4)>' (For example, if the average file size is 16MB and there are by default 4 stripes per file then --mkfsoptions='-i 1048576' would be appropriate.)

For more details on how to format MDS and OST file systems, see 8.1.5 Formatting on page 87.

3.3 DDN Tuning

This section provides guidelines to configure DDN storage arrays for use with Lustre. For more complete information on DDN tuning, refer to the performance management section of the DDN manual of your product, available at http://www.ddnsupport.com/manuals.html.

This section covers the following DDN arrays:

- S2A 8500
- S2A 9500
- S2A 9550

3.3.1 Setting Readahead and MF

For the S2A DDN 8500 storage array, CFS recommends that you disable the readahead. In a 1000-client system, if each client has up to 8 read RPCs in flight, then this is 8 * 1000 * 1 MB = 8 GB of reads in flight. With a DDN cache in the range of 2 to 5 GB (depending on the model), it is unlikely that the LUN-based readahead would have ANY cache hits even if the file data were contiguous on disk (generally, file data is not contiguous).

The Multiplication Factor (MF) also influences the readahead; you should disable it.

CLI commands for the DDN are:

```
cache prefetch=0
cache MF=off
```

For the S2A 9500 and S2A 9550 DDN storage arrays, CFS recommends using the commands above to disable readahead.

3.3.2 Setting Segment Size

The cache segment size noticeably affects I/O performance. Set the cache segment size differently on the MDT (which does small, random I/O) and on the OST (which does large, contiguous I/O). In customer testing, we have found the optimal values to be 64 KB for the MDT and 1 MB for the OST.

NOTE:
The *cache size* parameter is common to all LUNs on a single DDN and cannot be changed on a per-LUN basis.

These are CLI commands for the DDN:

For the MDT LUN:

```
$ cache size=64
size is in KB, 64, 128, 256, 512, 1024, and 2048. Default 128
```

For the OST LUN:

```
$ cache size=1024
```

3.3.3 Setting Write-Back Cache

Performance is noticeably improved by running Lustre with write-back cache turned on. However, there is a risk that when the DDN controller crashes you need to run e2fsck. Still, it takes less time than the performance hit from running with the write-back cache turned off.

For increased data security and in failover configurations, you may prefer to run with write-back cache off. However, you might experience performance problems with the small writes during journal flush. In this mode, it is highly beneficial to increase the number of OST service threads "options ost ost_num_threads=512" in /etc/modprobe.conf. But the OST should have enough RAM (about 1.5 MB / thread is preallocated for I/O buffers). Having more I/O threads allows you to have more I/O requests in flight, waiting for the disk to complete the synchronous write.

You have to decide whether performance is more important than the slight risk of data loss and downtime in case of a hardware / software problem on the DDN.

NOTE:
There is no risk from an OSS / MDS node crashing, only if the DDN itself fails.

3.3.4 Setting maxcmds

For S2A DDN 8500 array, changing maxcmds to 4 (from the default 2) improved write performance by as much as 30% in a particular case. This only works with SATA-based disks and when only one controller of the pair is actually accessing the shared LUNs.

However, this setting comes with a warning. DDN support does **not** recommend changing this setting from the default. By increasing the value to 5, the same setup experienced some serious problems.

The CLI command for the DDN client is provided below (default value is 2).

```
$ diskmaxcmds=3
```

For S2A DDN 9500/9550 hardware, you can safely change the default from 6 to 16. Although the maximum value is 32, values higher than 16 are not currently recommended by DDN support.

3.3.5 Further Tuning Tips

Here are some tips we have drawn from testing at a large installation:

- Use the full device instead of a partition (sda vs sda1). When using the full device, Lustre writes nicely-aligned 1 MB chunks to disk. Partitioning the disk can destroy this alignment and will noticeably impact performance.
- Separate the EXT3 OST into two LUNs, a small LUN for the EXT3 journal and a big one for the "data".
- Since Lustre 1.0.4, CFS supplies EXT3 mkfs options when we create the OST like -j -J and so on in the following manner (where /dev/sdj has been formatted before as a journal). The journal size should not be larger than 1 GB (262144 4 KB blocks) as it can consume up to this amount of RAM on the OSS node per OST.

  ```
  # mke2fs -O journal_dev -b 4096 /dev/sdj [optional size]
  ```

TIP:
A very important tip—on the S2A DDN 8500 storage array, CFS has proved that we need to create one OST per TIER, especially in write through (see output below). This is of concern if you have 16 tiers. Create 16 OSTs consisting of one tier each, instead of eight made of two tiers each.

- Performance is significantly better on the S2A DDN 9500 and 9550 storage arrays with two tiers per LUN.

- Do NOT partition the DDN LUNs, as this causes all I/O to the LUNs to be misaligned by 512 bytes. The DDN RAID stripes and cachelines are aligned on 1 MB boundaries. Having the partition table on the LUN causes all 1 MB writes to do a read-modify-write on an extra chunk, and ALL 1 MB reads to, instead, read 2 MB from disk into the cache, causing a noticable performance loss.

- You are not obliged to lock in cache the small LUNs.

- Configure MDT on a separate volume that is configured as RAID 1+0. This reduces the MDT I/O and doubles the seek speed.

For example, one OST per tier

```
LUNLabel Owner Status      Capacity    Block Tiers Tier  list
                           (Mbytes)    Size

-------------------------------------------------------------------------------
0        1     Ready       102400      512   1      1
1        1     Ready       102400      512   1      2
2        1     Ready       102400      512   1      3
3        1     Ready       102400      512   1      4
4        2     Ready [GHS] 102400      4096  1      5
5        2     Ready [GHS] 102400      4096  1      6
6        2     Critical    102400      512   1      7
7        2     Critical    102400      4096  1      8
10       1     Cache Locked    64      512   1      1
11       1     Ready           64      512   1      2
12       1     Cache Locked    64      512   1      3
13       1     Cache Locked    64      512   1      4
14       2     Ready [GHS]     64      512   1      5
15       2     Ready [GHS]     64      512   1      6
16       2     Ready [GHS]     64      4096  1      7
17       2     Ready [GHS]     64      4096  1      8
System verify extent: 16 Mbytes
System verify delay: 30
```

3.4 Large-Scale Tuning for Cray XT and Equivalents

This section only applies to the Cray XT3 Catamount nodes, and explains the parameters used with the kptllnd module. If it is not relevant to your setup, then ignore it.

3.4.1 Network Tunables

Given the large number of clients and servers possible on these systems, tuning various request pools becomes very important. CFS is in the process of making changes to the ptllnd module.

Parameter	Description
max_nodes	**max_nodes** is the maximum number of queue pairs, and, therefore, the maximum number of peers with which the LND instance may communicate. Set **max_nodes** to a value that is higher than the product of the total number of nodes and maximum processes per node. **Max nodes > (Total # Nodes) * (max_procs_per_node)** If you set **max_nodes** to a lower value than described above, then Lustre throws an error. If you **max_nodes** to a higher value, then excess memory is consumed.
max_procs_per_node	**max_procs_per_node** is the maximum number of cores (CPUs), on a single Catamount node. Portals must know this value to properly clean up various queues. LNET is not notified directly when a Catamount process aborts. The first information LNET receives is when a new Catamount process with the same Cray portals NID starts and sends a connection request. If the number of processes with that Cray portals NID exceeds the **max_procs_per_node** value, then LNET removes the oldest one to make space for the new one.

These two tunables combine to set the size of the ptllnd request buffer pool. The buffer pool must never drop an incoming message, so proper sizing is very important.

Ntx	**Ntx** helps to size the transmit (**tx**) descriptor pool. A **tx** descriptor is used for each send and each passive RDMA. The max number of concurrent sends == '**credits**'. Passive RDMA is a response to a PUT or GET of a payload that is too big to fit in a small message buffer. For servers, this only happens on large RPCs (for instance, where a long file name is included), so the MDS could be under pressure in a large cluster. For routers, this is bounded by the number of servers. If the **tx** pool is exhausted, a console error message appears.
Credits	**Credits** determine how many sends are in-flight at once on ptllnd. Optimally, there are 8 requests in-flight per server. The default value is 128, which should be adequate for most applications.

Chapter III - 4. Lustre Troubleshooting and Tips

This chapter describes tips and information to troubleshoot Lustre, and includes the following sections:

- Lustre Error Messages and Logs
- Performance Tips

4.1 Lustre Error Messages and Logs

To effectively debug Lustre, you need to review the Lustre error messages and logs.

4.1.1 Lustre Error Messages

As Lustre code runs on the kernel, single-digit error codes display to the application; these error codes are an indication of the problem. Refer to the kernel console log (dmesg) for all recent kernel messages from that node. On the node, /var/log/messages holds a log of all messages for at least the past day.

4.1.2 Lustre Logs

The error message initiates with "LustreError" in the console log and provides a short description of:

- What the problem is
- Which process ID had trouble
- Which server node it was communicating with, and so on.

Collect the first group of messages related to a problem, and any messages that precede "LBUG" or "assertion failure" errors. Messages that mention server nodes (OST or MDS) are specific to that server; you must collect similar messages from the relevant server console logs.

Another Lustre debug log holds information for Lustre action for a short period of time which, in turn, depends on the processes on the node to use Lustre. Use the following command to extract these logs on each of the nodes involved, run

```
$ lctldk <filename>
```

4.1 Performance Tips

This section describes various tips to improve Lustre performance.

4.1.1 Setting SCSI I/O Sizes

Some SCSI drivers default to a maximum I/O size that is too small for good Lustre performance. CFS has fixed quite a few drivers, but you may still find that some drivers give unsatisfactory performance with Lustre. As the default value is hard-coded, you need to recompile the drivers to change their default. On the other hand, some drivers may have a wrong default set.

If you suspect bad I/O performance, and an analysis of Lustre statistics indicates that I/O is not 1 MB, then check **/sys/block/<device>/queue/max_sectors_kb**. If it is less than 1024, set it to 1024 to improve the performance. If changing this setting does not change the I/O size as reported by Lustre, you may want to examine the SCSI driver code.

4.1.2 Write Performance Better Than Read Performance

Typically, the performance of write operations on a Lustre cluster is better than read operations. When doing writes, all clients are sending write RPCs asynchronously. The RPCs are allocated, and written to disk in the order they arrive. In many cases, this allows the back-end storage to aggregate writes efficiently.

In the case of read operations, the reads from clients may come in a different order and need a lot of seeking to get read from the disk. This noticeably hampers the read throughput.

Currently, there is no readahead on the OSTs themselves, though the clients do readahead. If there are lots of clients doing reads it would not be possible to do any readahead in any case because of memory consumption (consider that even a single RPC (1 MB) readahead for 1000 clients would consume 1 GB of RAM).

For file systems that use socklnd (TCP, Ethernet) as interconnect, there is also additional CPU overhead because the client cannot receive data without copying it from the network buffers. In the write case, the client CAN send data without the additional data copy. This means that the client is more likely to become CPU-bound during reads than writes.

4.1.3 OST Object Missing or Damaged

When the OSS fails to find an object or finds a damaged object, then you will see this message: “OST object missing or damaged (OST "ost1", object 98148, error -2)”.

- If the reported error is -2 (-ENOENT, or "No such file or directory"), then the object is missing. This can occur either because the MDS and OST are out of sync, or because an OST object was corrupted and deleted.
- If you have recovered the file system from a disk failure by using e2fsck, then unrecoverable objects may have been deleted or moved to /lost+found on the raw OST partition. Because files on the MDS still reference these objects, attempts to access them produce this error.
- If you have recovered a backup of the raw MDS or OST partition, then the restored partition is very likely to be out of sync with the rest of your cluster. No matter which server partition you restored from backup, files on the MDS may reference objects which no longer exist (or did not exist when the backup was taken); accessing those files produces this error.
- If neither of those descriptions is applicable to your situation, then it is possible that you have discovered a programming error that allowed the servers to get out of sync. Please report this condition to CFS, and we will investigate.
- If the reported error is anything else (such as -5, "I/O error"), it likely indicates a storage failure. The low-level file system returns this error if it is unable to read from the storage device.

Suggested Action

If the reported error is -2, you can consider checking in /lost+found on your raw OST device, to see if the missing object is there. However, it is likely that this object is lost forever, and that the file that references the object is now partially or completely lost. Restore this file from backup, or salvage what you can and delete it.

If the reported error is anything else, then you should immediately inspect this server for storage problems.

4.1.4 OSTs Become Read-Only

If the SCSI devices are inaccessible to Lustre at the block device level, then ext3 remounts the device read-only to prevent file system corruption. This is a normal behavior. The status in /proc/fs/lustre/healthcheck also shows "not healthy" on the affected nodes.

To recover from this problem, you must restart Lustre services using these file systems. There is no other way to know that the I/O made to disk, and the state of the cache may be inconsistent with what is on disk.

4.1.5 Identifying Missing OST

If an OST is missing for any reason, you may need to know what files are affected. Although an OST is missing, the files system should be operational. From any mounted client node, generate a list of files that reside on the affected OST. It is advisable to mark the missing OST as 'unavailable' so clients and the MDS do not time out trying to contact it.

1 On MDS and client nodes, run:

```
# lctl dl
```

2 Deactivate the OST, run:

```
# lctl --device N deactivate
```

Note that N will be different for the MDS and clients.

NOTE:
If the OST later becomes available it needs to be reactivated, run:

```
# lctl --device N activate
```

3 Determine all the files that are striped over the missing OST, run:

```
# lfs find -R -o {OST_UUID} /mountpoint
```

This returns a simple list of filenames from the affected file system.

4 If necessary, you can read the valid parts of a striped file, run:

```
# dd if=filename of=new_filename bs=4k conv=sync,noerror
```

5 You can also delete these files with "unlink" or "munlink", run:

6 If you need to know, specifically, which parts of the file are missing data, then you first need to determine the striping pattern (which includes the index of the missing OST). Run:

```
# lfs getstripe -v {filename}
```

7 Use this computation is to determine which offsets in the file are affected:

[(C*N + X)*S, (C*N + X)*S + S - 1], N = { 0, 1, 2, ...}

where:

C = stripe count

S = stripe size

X = index of bad OST for this file

For example, for a file with 2 stripes, stripe size = 1M, bad OST is at index 0, then you would have holes in your file at:

[(2*N + 0)*1M, (2*N + 0)*1M + 1M - 1], N = { 0, 1, 2, ...}

If the file system cannot be mounted, currently there is no way that parses metadata directly from an MDS. If the bad OST is not starting, options for mounting the file system are to provide a loop device OST in its place, or to replace it with a newly-formatted OST. In that case, the missing objects are created and are read as zero-filled.

In Lustre 1.6 you can mount a file system with a missing OST.

4.1.6 Changing Parameters

You can set the following parameters at the mkfs time, on a non-running target disk, via tunefs.lustre or via a live MGS using lctl.

With mkfs.lustre

While you are using the mkfs command and creating the file system, you can simply add the parameters as a "--param" option:

```
$ mkfs.lustre --mdt --param="sys.timeout=50" /dev/sda
```

With tunefs.lustre

If a server is stopped, you can add the parameters via tunefs.lustre with the same “--param” option:

```
$ tunefs.lustre --param="failover.node=192.168.0.13@tcp0" /dev/sda
```

With tunefs.lustre, parameters are "additive" -- to erase all old parameters and just use the newly-specified parameters, use tunefs.lustre --erase-params --param=....

With lctl

While a server is running, you can change many parameters via "lctl conf_param":

```
$ mgs> lctl conf_param testfs-MDT0000.sys.timeout=40
$ anynode> cat /proc/sys/lustre/timeout
```

4.1.7 Adding a Failover Server Node

To add a failover server node to a live Lustre file system, run:

```
$ lctl conf_param testfs-OST0000.failover.node=3@elan,\
192.168.0.3@tcp0
```

On other system you can verify the new node, run:

```
$ cat /proc/fs/lustre/osc/testfs-OST0000-osc/ost_conn_uuid
```

As soon as failover node is added, servers and clients are able to use it immediately. Note that TCP addresses must be in dotted-quad form, not hostname form. Multiple failover hosts can be specified by repeating the failnode= parameter, run:

```
$ failover.mode=<"failout","failover">
```

Failout returns errors immediately; failover waits for recovery. Failover is the default.

4.1.8 Default Striping

These are the default striping settings:

lov.stripesize=<bytes>

lov.stripecount=<count>

lov.stripeoffset=<offset>

To change the default striping information.

- On the MGS:

  ```
  $ lctl conf_param testfs-MDT0000.lov.stripesize=4M
  ```

- On the MDT and clients:

  ```
  $ mdt/cli> cat /proc/fs/lustre/lov/testfs-{mdt|cli}lov/stripe*
  ```

4.1.9 Erasing a File System

If you want to erase a file system, run this command on your targets:

```
$ "mkfs.lustre –reformat"
```

If you are using a separate MGS and want to keep other file systems defined on that MGS, then set the "writeconf" flag[1] on the MDT for that file system. The "writeconf" flag causes the config logs to be erased - they are regenerated the next time the servers start.

To set the “writeconf” flag on the MDT:

1. Unmount all clients/servers using this file system, run:

```
$ umount /mnt/lustre
```

2. Erase the file system and, presumably, replace it with another file system, run:

```
$ mkfs.lustre –reformat --fsname spfs --mdt --mgs /dev/sda
```

3. If you have a separate MGS (that you do not want to reformat), then add the "writeconf" flag to mkfs.lustre on the MDT, run:

```
$ mkfs.lustre --reformat --writeconf –fsname spfs --mdt \
--mgs /dev/sda
```

NOTE:
If you have a combined MGS/MDT, reformatting the MDT reformats the MGS as well, causing all configuration information to be lost; you can start building your new file system. Nothing needs to be done with old disks that will not be part of the new file system, just do not mount them.

4.1.10 Reclaiming Reserved Disk Space

All current Lustre installations run the ext3 file system internally on service nodes. By default, the ext3 reserves 5% of the disk space for the root user. In order to reclaim this space, run the following command on your OSSs:

```
tune2fs [-m reserved_blocks_percent] [device]
```

You do not need to shut down Lustre before running this command or restart it afterwards.

1. The name is historical.

4.1.11 Considerations in Connecting a SAN with Lustre

Depending on your cluster size and workload, you may want to connect a SAN with Lustre. Before making this connection, consider the following:

- In many SAN file systems without Lustre, clients allocate and lock blocks or inodes individually as they are updated. The Lustre design avoids the high contention that some of these blocks and inodes may have.
- Lustre is highly scalable and can have a very large number of clients. SAN switches do not scale to a large number of nodes, and the cost per port of a SAN is generally higher than other networking.
- File systems that allow direct-to-SAN access from the clients have a security risk because clients can potentially read any data on the SAN disks, and misbehaving clients can corrupt the file system for many reasons like improper file system, network, or other kernel software, bad cabling, bad memory, and so on. The risk increases with increase in the number of clients directly accessing the storage.

4.1.12 Handling/Debugging "Bind: Address already in use" Error

During startup, Lustre may report the error "bind: Address already in use;" and reject to start the operation. This is caused by a portmap service (often NFS locking) which starts before Lustre and binds to the default port, 988.

Unfortunately, you cannot set portmap to avoid such ports. However, in this situation, do one of the following:

- Start Lustre before starting any services that use portmap.
- Use a port other than 988 for Lustre. This is configured in /etc/modprobe.conf as an option to the LNET module. For example:

  ```
  options lnet accept_port=988
  ```

- Add 'modprobe ptlrpc' to your system startup scripts before the service that uses portmap. This causes Lustre to bind to 988 and portmap to select a different port.

4.1.13 Replacing An Existing OST or MDS

The OST file system is simply a normal ext3 file system. To copy the contents of an existing OST to a new OST (or an old MDS to a new MDS), use one of the following methods:

- Connect the old OST disk and new OST disk to a single machine, mount both, and use rsync to copy all data between the OST file systems.

  For example:

  ```
  mount -t ext3 /dev/old /mnt/ost_old
  mount -t ext3 /dev/new /mnt/ost_new
  rsync -aSv /mnt/ost_old/ /mnt/ost_new
  # note trailing slash on ost_old/
  ```

- If you are unable to connect both sets of disk to the same computer, use rsync to copy over the network using rsh (or ssh with "-e ssh"):

  ```
  rsync -aSvz /mnt/ost_old/ new_ost_node:/mnt/ost_new
  ```

- Use the same procedure for the MDS, with one additional step:

  ```
  cd /mnt/mds_old; getfattr -R -e base64 -d . > /tmp/mdsea; <copy all MDS
  files\ as above>; cd /mnt/mds_new; setfattr --restore=/tmp/mdsea
  ```

4.1.14 Handling/Debugging Error "- 28"

Linux error -28 is -ENOSPC and indicates that the file system has run out of space. You need to create larger file systems for the OSTs. Normally, Lustre reports this to your application. If the application is checking the return code from its function calls, then it decodes it into a textual error message like "No space left on device." It also appears in the system log messages.

During a "write" or "sync" operation, the file in question resides on an OST which is already full. New files that are created do not use full OSTs, but existing files continue to use the same OST. You need to expand the specific OST or copy/stripe the file over to an OST with more space available. You encounter this situation occasionally when creating files, which may indicate that your MDS has run out of inodes and needs to be enlarged. Use "df -i" to check this.

You may also receive this error if the MDS runs out of free blocks. Since the output of "df" is an aggregate of the data from the MDS and all of the OSTs, it may not show that the file system is full when one of the OSTs has run out of space. To determine which OST or MDS is running out of space, check the free space and inodes on a client:

```
grep '[0-9]' /proc/fs/lustre/osc/*/kbytes{free,avail,total}
grep '[0-9]' /proc/fs/lustre/osc/*/files{free,total}
grep '[0-9]' /proc/fs/lustre/mdc/*/kbytes{free,avail,total}
grep '[0-9]' /proc/fs/lustre/mdc/*/files{free,total}
```

You can find other numeric error codes in /usr/include/asm/errno.h along with their short name and textual description.

4.1.15 Triggering Watchdog for pid NNN

In some cases, a server node triggers a watchdog timer and this causes a process stack to be dumped to the console along with a Lustre kernel debug log being dumped into /tmp (by default). The presence of a watchdog timer does NOT mean that the thread OOPSed, but rather that it is taking longer time than expected to complete a given operation. In some cases, this situation is expected.

For example, if a RAID rebuild is really slowing down I/O on an OST, it might trigger watchdog timers to trip. But another message follows shortly thereafter, indicating that the thread in question has completed processing (after some number of seconds). Generally, this indicates a transient problem. In other cases, it may legitimately signal that a thread is stuck because of a software error (lock inversion, for example).

```
Lustre: 0:0:(watchdog.c:122:lcw_cb())
```

The above message indicates that the watchdog is active for pid 933:

It was inactive for 100000ms:

```
Lustre: 0:0:(linux-debug.c:132:portals_debug_dumpstack())
```

Showing stack for process:

```
933 ll_ost_25     D F896071A     0   933      1    934   932 (L-TLB)
f6d87c60 00000046 00000000 f896071a f8def7cc 00002710 00001822 2da48cae
0008cf1a f6d7c220 f6d7c3d0 f6d86000 f3529648 f6d87cc4 f3529640 f8961d3d
00000010 f6d87c9c ca65a13c 00001fff 00000001 00000001 00000000 00000001
```

Call trace:

```
filter_do_bio+0x3dd/0xb90 [obdfilter]
default_wake_function+0x0/0x20
filter_direct_io+0x2fb/0x990 [obdfilter]
filter_preprw_read+0x5c5/0xe00 [obdfilter]
lustre_swab_niobuf_remote+0x0/0x30 [ptlrpc]
ost_brw_read+0x18df/0x2400 [ost]
ost_handle+0x14c2/0x42d0 [ost]
ptlrpc_server_handle_request+0x870/0x10b0 [ptlrpc]
ptlrpc_main+0x42e/0x7c0 [ptlrpc]
```

4.1.16 Handling Timeouts on Initial Lustre Setup

If you come across timeouts or hangs on the initial setup of your Lustre system, verify that name resolution for servers and clients is working correctly. Some distributions configure "/etc/hosts sts" so the name of the local machine (as reported by the 'hostname' command) is mapped to local host (127.0.0.1) instead of a proper IP address.

This might produce the following error:

```
LustreError: (ldlm_handle_cancel()) received cancel for unknown lock cookie
0xe74021a4b41b954e from nid 0x7f000001 (0:127.0.0.1)
```

4.1.17 Handling/Debugging "LustreError: xxx went back in time"

Each time Lustre changes the state of the disk file system, it records a unique transaction number. Occasionally, when commiting these transactions to the disk, the last committed transaction number displays to other nodes in the cluster to assist the recovery. Therefore, the promised transactions remain absolutely safe on the disappeared disk.

This situation arises when:

- You are using a disk device that claims to have data written to disk before it actually does, as in case of a device with a large cache. If that disk device crashes or loses power in a way that causes the loss of the cache, there can be a loss of transactions that you believe are commited. This is a very serious event, and you should run e2fsck against that storage before restarting Lustre.
- As per the Lustre requirement, the shared storage used for failover is completely cache-coherent. This ensures that if one server takes over for another, it sees the most up-to-date and accurate copy of the data. In case of the failover of the server, if the shared storage does not provide cache coherency between all of its ports, then Lustre can produce an error.

If you know the exact reason for the error, then it is safe to proceed with no further action. If you do not know the reason, then this is a serious issue and you should explore it with your disk vendor.

If the error occurs during failover, examine your disk cache settings. If it occurs after a restart without failover, try to determine how the disk can report that a write succeeded, then lose the Data Device corruption or Disk Errors.

4.1.18 Lustre Error: "Slow Start_Page_Write"

The "slow start_page_write" message appears when the operation takes an extremely long time to allocate a batch of memory pages. Use these pages to receive network traffic first, and then write to disk.

4.1.19 Drawbacks in Doing Multi-client O_APPEND Writes

It is possible to do multi-client O_APPEND writes to a single file, but there are few drawbacks that may make this a sub-optimal solution. These drawbacks are:

- Each client needs to take an EOF lock on all the OSTs, as it is difficult to know which OST holds the end of the file until you check all the OSTs. As all the clients are using the same O_APPEND, there is significant locking overhead.
- The second client cannot get all locks until the end of the writing of the first client, as the taking serializes all writes from the clients.
- To avoid deadlocks, the taking of these locks occurs in a known, consistent order. As a client cannot know which OST holds the next piece of the file until the client has locks on all OSTS, there is a need of these locks in case of a striped file.

Chapter IV - 1. Free Space and Quotas

This chapter describes free space and using quotas, and includes the following sections:

1.1 Querying File System Space

The **lfs df** command is used to determine available disk space on a file system. It displays the amount of available disk space on the mounted Lustre file system and shows space consumption per-OST. If multiple Lustre file systems are mounted, a path may be specified, but is not required.

Options	Description
- h	--human-readable print sizes in human readable format (for example: 1K, 234M, 5G)
-i, --inodes	Lists inodes instead of block usage

Examples

```
fc3:~$ lfs df
UUID                 1K-blocks   Used        Available   Use%  \ Mounted on
mds-p_UUID           4399856     528200      3871656     12    \
/mnt/lustre[MDT:0]
ost-a_UUID           153834852   55804744    98030108    36    \
/mnt/lustre[OST:0]
ost-b_UUID           153834852   55927804    97907048    36    \
/mnt/lustre[OST:1]

filesystem summary:  307669704   111732548   195937156   36    \
/mnt/lustre
fc3:~$ lfs df -h
UUID                 1K-blocks   Used        Available   Use%  \
Mounted on
mds-p_UUID           4.2M        515.8K      3.7M        12    \
/mnt/lustre[MDT:0]
ost-a_UUID           146.7M      53.2M       93.5M       36    \
/mnt/lustre[OST:0]
ost-b_UUID           146.7M      53.3M       93.4M       36    \
/mnt/lustre[OST:1]

filesystem summary:293.4M106.6M186.9M36\
/mnt/lustre
fc3:~$ lfs df -i
UUID                 Inodes      IUsed       Ifree    IUse%     \
Mounted on
mds-p_UUID           1257360     272869      984491      21     \
/mnt/lustre[MDT:0]
ost-a_UUID           19546112    257430      19288682    1      \
/mnt/lustre[OST:0]
ost-b_UUID           19546112    257430      19288682    1      \
/mnt/lustre[OST:1]

filesystem summary:  1257360     272869      984491      21     \
/mnt/lustre
```

1.2 Using Quota

The **lfs quota** command displays disk usage and quotas. By default, only user quotas are displayed (or with the **-u** flag).

A root user can use the **-u** flag, with the optional *user* parameter, to view the limits of other users. Users without root user authority can use the **-g** flag, with the optional *group* parameter, to view the limits of groups of which they are members.

NOTE:
If a user has no files in a file system on which they have a quota, the **lfs quota** command shows *quota: none* for the user. The user's actual quota is displayed when the user has files in the file system.

Examples

To display quotas as user “bob,” run:

```
$ lfs quota -u  /mnt/lustre
```

The above command displays disk usage and limits for user "bob."

To display quotas as root user for user “bob,” run:

```
$ lfs quota -u bob /mnt/lustre
```

The system can also show the below information about disk usage by “bob.”

To display your group's quota as “tom”:

```
$ lfs -g tom /mnt/lustre
```

To display the group's quota of “tom”:

```
$ lfs quota -g tom /mnt/lustre
```

NOTE:
As for ext3, Lustre makes a sparse file in case you truncate at an offset past the end of the file. Space is utilized in the file system only when you actually write the data to these blocks.

Chapter IV - 2. Striping and Other I/O Options

This chapter describes file striping and I/O options, and includes the following sections:

2.1 File Striping

Lustre stores files of one or more objects on OSTs. When a file is comprised of more than one object, Lustre stripes the file data across them in a round-robin fashion. Users can configure the number of stripes, the size of each stripe, and the servers that are used.

One of the most frequently-asked Lustre questions is "*How should I stripe my files, and what is a good default?*" The short answer is that it depends on your needs. A good rule of thumb is to stripe over as few objects as will meet those needs and no more.

2.1.1 Advantages of Striping

There are two reasons to create files of multiple stripes: bandwidth and size.

2.1.1.1 Bandwidth

There are many applications which require high-bandwidth access to a single file – more bandwidth than can be provided by a single OSS. For example, scientific applications which write to a single file from hundreds of nodes or a binary executable which is loaded by many nodes when an application starts.

In cases like these, stripe your file over as many OSSs as it takes to achieve the required peak aggregate bandwidth for that file. In our experience, the requirement is “as quickly as possible,” which usually means all OSSs.

NOTE:
This assumes that your application is using enough client nodes, and can read/write data fast enough to take advantage of this much OSS bandwidth. The largest useful stripe count is bounded by the I/O rate of your clients/jobs divided by the performance per OSS.

2.1.1.2 Size

The second reason to stripe is when a single OST does not have enough free space to hold the entire file.

There is never an exact, one-to-one mapping between clients and OSTs. Lustre uses a round-robin algorithm for OST stripe selection until free space on OSTs differ by more than 20%. However, depending on actual file sizes, some stripes may be mostly empty, while others are more full. For a more detailed description of stripe assignments, see Free Space Management on page 194.

After every ostcount+1 objects, Lustre skips an OST. This causes Lustre’s "starting point" to precess around, eliminating some degenerated cases where applications that create very regular file creation/striping patterns would have preferentially used a particular OST in the sequence.

2.1.2 Disadvantages of Striping

There are two disadvantages to striping which should deter you from choosing a default policy that stripes over all OSTs unless you really need it: increased overhead and increased risk.

2.1.2.1 Increased Overhead

Increased overhead comes in the form of extra network operations during common operations such as stat and unlink, and more locks. Even when these operations are performed in parallel, there is a big difference between doing 1 network operation and 100 operations.

Increased overhead also comes in the form of server contention. Consider a cluster with 100 clients and 100 OSSs, each with one OST. If each file has exactly one object and the load is distributed evenly, there is no contention and the disks on each server can manage sequential I/O. If each file has 100 objects, then the clients all compete with one another for the attention of the servers, and the disks on each node seek in 100 different directions. In this case, there is needless contention.

2.1.2.2 Increased Risk

Increased risk is evident when you consider the example of striping each file across all servers. In this case, if any one OSS catches on-fire, a small part of every file is lost. By comparison, if each file has exactly one stripe, you lose fewer files, but you lose them in their entirety. Most users would rather lose some of their files entirely than all of their files partially.

2.1.3 Stripe Size

Choosing a stripe size is a small balancing act, but there are reasonable defaults. The stripe size must be a multiple of the page size. For safety, Lustre's tools enforce a multiple of 64 KB (the maximum page size on ia64 and PPC64 nodes), so users on platforms with smaller pages do not accidentally create files which might cause problems for ia64 clients.

Although you can create files with a stripe size of 64 KB, this is a poor choice. Practically, the smallest recommended stripe size is 512 KB because Lustre tries to batch I/O into 512 KB chunks over the network. This is a good amount of data to transfer at one time. Choosing a smaller stripe size may hinder the batching.

Generally, a good stripe size for sequential I/O using high-speed networks is between 1 MB and 4 MB. Stripe sizes larger than 4 MB do not parallelize as effectively because Lustre tries to keep the amount of dirty cached data below 32 MB per server (with the default configuration).

Writes which cross an object boundary are slightly less efficient than writes which go entirely to one server. Depending on your application's write patterns, you can assist it by choosing a stripe size with that in mind. If the file is written in a very consistent and aligned way, make the stripe size a multiple of the write() size.

The choice of stripe size has no effect on a single-stripe file.

2.2 Individual Files and Directories Examined with lfs getstripe

Use **lfs** to print the index and UUID for each OST in the file system, along with the OST index and object ID for each stripe in the file. For directories, the default settings for files created in that directory are printed.

```
lfs getstripe <filename>
```

Use **lfs find** to inspect an entire tree of files.

```
lfs find [--recursive | -r] <file or directory> ...
```

If a process is doing I/O to a file, use the 'lfs getstripe' command to see which OST it is writing to.

Using cat as an example, run:

```
$ cat > foo
```

While that is running, in another terminal, run:

```
$ readlink /proc/$(pidof cat)/fd/1
/barn/users/jacob/tmp/foo
```

You can also do ls -l /proc/<pid>/fd/ to find open files using Lustre, run:

```
$ lfs getstripe $(readlink /proc/$(pidof cat)/fd/1)
OBDS:
0: databarn-ost1_UUID ACTIVE
1: databarn-ost2_UUID ACTIVE
2: databarn-ost3_UUID ACTIVE
3: databarn-ost4_UUID ACTIVE
/barn/users/jacob/tmp/foo
        obdidx           objid          objid            group
             2          835487        0xcbf9f                0
```

This shows that the file lives on obdidx 2, which is databarn-ost3. To see which node is serving that OST, run:

```
$ cat /proc/fs/lustre/osc/*databarn-ost3*/ost_conn_uuid
NID_oss1.databarn.87k.net_UUID
```

The above condition/operation also works with connections to the MDS. For that, replace osc with mdc and ost with mds in the above commands

2.3 lfs setstripe – Setting Striping Patterns

Use **lfs setstripe** to create new files with a specific stripe configuration.

```
lfs setstripe <filename|dirname> [--size|-s stripe-size] \
[--index|-i stripe_index] [--count|-c stripe_count]
```

Stripe-Size

If you pass a stripe-size of **0**, the file system's default stripe size is used. Otherwise, the stripe-size must be a multiple of 16 KB.

Starting-OST

If you pass a starting-ost of **-1**, a random first OST is chosen. Otherwise, the file starts on the specified OST index, starting at zero (0).

Stripe-Count

If you pass a stripe-count of **0**, the file system's default number of OSTs is used. A stripe-count of **-1** means that all available OSTs should be used.

NOTE:
If you pass a starting-ost of 0 and a stripe-count of 1, all files are written to OST #0, until space is exhausted. This is probably not what you meant to do. If you want to adjust only the stripe-count and keep the other parameters at their default settings, use this syntax:

```
lfs setstripe 0 -1 <stripe_count>
```

2.3.1 Changing Striping for a Subdirectory

For a directory, **lfs setstripe** sets a default striping configuration for files created within the directory. The usage is the same as **lfs setstripe** for a regular file, except that the directory must exist prior to setting the default striping configuration. If a file is created in a directory with a default stripe configuration (without otherwise specifying striping), Lustre uses those striping parameters instead of the file system default for the new file.

To change the striping pattern for a sub-directory, create a directory with desired striping pattern as described above. Su-directories inherit the striping pattern of the parent directory.

NOTE:
Striping on directories only affects NEW files and NEW sub-directories created within them.

2.3.2 Using a Specific Striping Pattern for a Single File

For a single file:

lfs setstripe creates a file with a given stripe pattern

lfs setstripe fails if the file already exists

2.4 Free Space Management

In Lustre 1.6, the MDT assigns file stripes to OSTs based on location (which OSS) and size considerations (free space) to optimize file system performance. Emptier OSTs are preferentially selected for stripes, and stripes are preferentially spread out between OSSs to increase network bandwidth utilization. The weighting factor between these two optimizations is user-adjustable.

There are two stripe allocation methods, round-robin and weighted. The allocation method is determined by the amount of free-space imbalance on the OSTs. The **weighted allocator** is used when any two OSTs are imbalanced by more than 20%. Until then, a faster **round-robin allocater** is used. (The round-robin order maximizes network balancing.)

2.4.1 Round-Robin Allocator

When OSTs have approximately the same amount of free space (within 20%), an efficient round-robin allocator is used. The round-robin allocator alternates stripes between OSTs on different OSSs. Here are several sample round-robin stripe orders (the same letter represents the different OSTs on a single OSS):

3: AAA	one 3-OST OSS
3x3: ABABAB	two 3-OST OSSs
3x4: BBABABA	one 3-OST OSS (A) and four OST OSSs (B)
3x5: BBABBABA	
3x5x1: BBABABABC	
3x5x2: BABABCBABC	
4x6x2: BABABCBABABC	

NOTE:
If you "mknod() and truncate()" a new file (that is, you do not open the file at all) to the maximum file size, the MDS picks enough OSTs to stripe the file over. This adds enough stripes on OSTs with enough free space to hold the expected file size (though it does not actually reserve this space. Hence, parallel creates / writes may still fail).

In Lustre 1.4, this was only useful for files larger than 2 TB (that is, when num_stripes = size / 2 TB).

2.4.2 Weighted Allocator

When the free space difference between the OSTs is significant, then a weighting algorithm is used to influence OST ordering based on size and location. Note that these are weightings for a *random* algorithm, so the "emptiest" OST is not, necessary, be strictly chosen every time. On average, the weighted allocator fills emptier OSTs faster.

2.4.3 Adjusting the Weighting Between Free Space and Location

This priority can be adjusted via the */proc/fs/lustre/lov/lustre-mdtlov/qos_prio_free* proc file. In the future, the default will be 90%. On existing Lustre betas, use the following command to permanently set this on the MGS:

```
lctl conf_param <fsname>-MDT0000.lov.qos_prio_free=90
```

Increasing the value puts more weighting on free space. When the free space priority is set to 100%, then location is no longer used in stripe-ordering calculations, and weighting is based entirely on free space.

Note that setting the priority to 100% means that OSS distribution does not count in the weighting, but the stripe assignment is still done via a weighting—if OST2 has twice as much free space as OST1, then OST2 is twice as likely to be used, but it is not *guaranteed* to be used.

2.5 Performing Direct I/O

Starting with 1.4.7, Lustre supports the O_DIRECT flag to open.

Applications using the read() and write() calls must supply buffers aligned on a page boundary (usually 4 K). If the alignment is not correct, the call returns -EINVAL. Direct I/O may help performance in cases where the client is doing a large amount of I/Oa and is CPU-bound (CPU utilization 100%).

2.5.1 Making File System Objects Immutable

An immutable file or directory is one that cannot be modified, renamed or removed. To do this:

```
chattr +i <file>
```

To remove this flag, use chattr –i

2.6 Other I/O Options

This section describes other I/O options, including end-to-end client checksums and striping using ioctl.

2.6.1 End-to-End Client Checksums

To guard against data corruption, a Lustre client can perform end-to-end data checksums. This must be enabled on the individual client nodes. If the checksum is bad, the client will not have an I/O error. The bad checksum is reported immediately as a syslog message. Both the client and the OST log messages at intervals showing that checksums are being validated. A /proc file controls the checksum behavior. The file is:

```
/proc/fs/lustre/llite/fs0/checksum_pages
```

To enable checksums on a client:

```
echo 1 > /proc/fs/lustre/llite/fs0/checksum_pages
```

2.7 Striping Using ioctl

You can set striping from inside programs like ioctl. To compile the sample program, you need to download libtest.c and liblustreapi.c files from the Lustre source tree.

A simple C program to demonstrate striping API – libtest.c

```
/* -*- mode: c; c-basic-offset: 8; indent-tabs-mode: nil; -*-
 * vim:expandtab:shiftwidth=8:tabstop=8:
 *
 * lustredemo - simple code examples of liblustreapi functions
 */

#include <stdio.h>
#include <fcntl.h>
#include <sys/stat.h>
#include <sys/types.h>
#include <dirent.h>
#include <errno.h>
#include <string.h>
#include <unistd.h>
#include <stdlib.h>

#include <lustre/liblustreapi.h>
#include <lustre/lustre_user.h>
#define MAX_OSTS 1024
#define LOV_EA_SIZE(lum, num) (sizeof(*lum) + num * sizeof(*lum-
>lmm_objects))
#define LOV_EA_MAX(lum) LOV_EA_SIZE(lum, MAX_OSTS)

/*
This program provides crude examples of using the liblustre API functions
*/

/* Change these definitions to suit */

#define TESTDIR "/tmp"             /* Results directory */
#define TESTFILE "lustre_dummy"    /* Name for the file we create/destroy */
#define FILESIZE 262144            /* Size of the file in words */
#define DUMWORD "DEADBEEF"         /* Dummy word used to fill files */
```

```
#define MY_STRIPE_WIDTH 2        /* Set this to the number of OST required */
#define MY_LUSTRE_DIR "/mnt/lustre/ftest"

int close_file(int fd)
{
        if (close(fd) < 0) {
                fprintf(stderr, "File close failed: %d (%s)\n", errno,
strerror(errno));
                return -1;
        }
        return 0;
}

int write_file(int fd)
{
        char *stng =  DUMWORD;
        int cnt = 0;

        for( cnt = 0; cnt < FILESIZE; cnt++) {
                write(fd, stng, sizeof(stng));
        }
        return 0;
}
/* Open a file, set a specific stripe count, size and starting OST
   Adjust the parameters to suit */

int open_stripe_file()
{
        char *tfile = TESTFILE;
        int stripe_size = 65536;                /* System default is 4M */
        int stripe_offset = -1;                 /* Start at default */
        int stripe_count = MY_STRIPE_WIDTH;     /* Single stripe for this
demo */
       int stripe_pattern = 0;                /* only RAID 0 at this time */
        int rc, fd;
        /*
         */
        rc = llapi_file_create(tfile,
stripe_size,stripe_offset,stripe_count,stripe_pattern);
```

```
        /* result code is inverted, we may return -EINVAL or an ioctl error.
           We borrow an error message from sanity.c
        */
        if (rc) {
                fprintf(stderr,"llapi_file_create failed: %d (%s) \n", rc,
strerror(-rc));
                return -1;
        }
        /* llapi_file_create closes the file descriptor, we must re-open */
        fd = open(tfile, O_CREAT | O_RDWR | O_LOV_DELAY_CREATE, 0644);
        if (fd < 0) {
             fprintf(stderr, "Can't open %s file: %d (%s)\n", tfile, errno,
strerror(errno));
                return -1;
        }
        return fd;
}

/* output a list of uuids for this file */
int get_my_uuids(int fd)
{
        struct obd_uuid uuids[1024], *uuidp;            /* Output var */
        int obdcount = 1024;
        int rc,i;

        rc = llapi_lov_get_uuids(fd, uuids, &obdcount);
        if (rc != 0) {
                fprintf(stderr, "get uuids failed: %d (%s)\n",errno,
strerror(errno));
        }
        printf("This file system has %d obds\n", obdcount);
        for (i = 0, uuidp = uuids; i < obdcount; i++, uuidp++) {
                printf("UUID %d is %s\n",i, uuidp->uuid);
        }
        return 0;
}

/* Print out some LOV attributes. List our objects */
int get_file_info(char *path)
```

```
{


        struct lov_user_md *lump;
        int rc;
        int i;

        lump = malloc(LOV_EA_MAX(lump));
        if (lump == NULL) {
                return -1;
        }

        rc = llapi_file_get_stripe(path, lump);

        if (rc != 0) {
                fprintf(stderr, "get_stripe failed: %d (%s)\n",errno,
strerror(errno));
                return -1;
        }

        printf("Lov magic %u\n", lump->lmm_magic);
        printf("Lov pattern %u\n", lump->lmm_pattern);
        printf("Lov object id %llu\n", lump->lmm_object_id);
        printf("Lov object group %llu\n", lump->lmm_object_gr);
        printf("Lov stripe size %u\n", lump->lmm_stripe_size);
        printf("Lov stripe count %hu\n", lump->lmm_stripe_count);
        printf("Lov stripe offset %u\n", lump->lmm_stripe_offset);
        for (i = 0; i < lump->lmm_stripe_count; i++) {
                printf("Object index %d Objid %llu\n", lump-
>lmm_objects[i].l_ost_idx, lump->lmm_objects[i].l_object_id);
        }

        free(lump);
        return rc;

}
/* Ping all OSTs that belong to this filesysem */
```

```
int ping_osts()
{
        DIR *dir;
        struct dirent *d;
        char osc_dir[100];
        int rc;

        sprintf(osc_dir, "/proc/fs/lustre/osc");
        dir = opendir(osc_dir);
        if (dir == NULL) {
                printf("Can't open dir\n");
                return -1;
        }
        while((d = readdir(dir)) != NULL) {
                if ( d->d_type == DT_DIR ) {
                        if (! strncmp(d->d_name, "OSC", 3)) {
                                printf("Pinging OSC %s ", d->d_name);
                                rc = llapi_ping("osc", d->d_name);
                                if (rc) {
                                        printf("  bad\n");
                                } else {
                                        printf("  good\n");
                                }
                        }
                }
        }
        return 0;


}

int main()
{
        int file;
        int rc;
        char filename[100];
        char sys_cmd[100];
```

```
        sprintf(filename, "%s/%s",MY_LUSTRE_DIR, TESTFILE);

        printf("Open a file with striping\n");
        file = open_stripe_file();
        if ( file < 0 ) {
                printf("Exiting\n");
                exit(1);
        }
        printf("Getting uuid list\n");
        rc = get_my_uuids(file);
        printf("Write to the file\n");
        rc = write_file(file);
        rc = close_file(file);
        printf("Listing LOV data\n");
        rc = get_file_info(filename);
        printf("Ping our OSTs\n");
        rc = ping_osts();

        /* the results should match lfs getstripe */
        printf("Confirming our results with lfs getsrtipe\n");
        sprintf(sys_cmd, "/usr/bin/lfs getstripe %s/%s", MY_LUSTRE_DIR,
TESTFILE);
        system(sys_cmd);

        printf("All done\n");
        exit(rc);
}
```

Makefile for sample application:

```
gcc -g -O2 -Wall -o lustredemo libtest.c -llustreapi
clean:
rm -f core lustredemo *.o
run:
make
rm -f /mnt/lustre/ftest/lustredemo
rm -f /mnt/lustre/ftest/lustre_dummy
cp lustredemo /mnt/lustre/ftest/
```

Chapter IV - 3. Lustre Security

This chapter describes Lustre security and includes the following section:

3.1 Using ACLs

An access control list (ACL), is a set of data that informs an operating system about permissions or access rights that each user or group has to specific system objects, such as directories or files. Each object has a unique security attribute that identifies users who have access to it. The ACL lists each object and user access privileges such as read, write or execute.

3.1.1 How ACLs Work

Implementing ACLs varies between operating systems. Systems that support the Portable Operating System Interface (POSIX) family of standards share a simple yet powerful file system permission model, which should be well-known to the Linux/Unix administrator. ACLs add finer-grained permissions to this model, allowing for more complicated permission schemes. For a detailed explanation of ACLs on Linux, CFS recommends the SuSE Labs article, “Posix Access Control Lists on Linux” found here:

http://www.suse.de/~agruen/acl/linux-acls/online/

CFS has implemented ACLs according to this model. Lustre supports the standard Linux ACL tools, **setfacl**, **getfacl**, and the historical **chacl**, normally installed with the **acl** package.

3.1.2 Lustre ACLs

Lustre versions 1.4.6 and above support POSIX ACLs. When using a Lustre client at version 1.4.5 or below with an MDS at version 1.4.6, or vice versa, the userspace program generates an “Operation not supported” error during ACL operations.

The MDS needs to be configured to enable ACLs. This can be enabled when creating your configuration with *--mountfsoptions*:

```
$ mkfs.lustre --fsname spfs --mountfsoptions=acl --mdt –mgs \  /dev/sda
```

Alternately, you can enable ACLs at run time by using the --acl option with mkfs.lustre:

```
$ mount -t lustre -o acl /dev/sda /mnt/mdt
```

ACLs on the client are enabled at mount time when ACLs are enabled on the MDS. You do not need to change the client configuration, and the “acl” string will not appear in the client /etc/mtab. The client acl mount option is no longer needed. If a client is mounted with that option, then this message appears in the MDS syslog:

```
...MDS requires ACL support but client does not
```

The message is harmless but indicates a configuration issue, which should be corrected.

If ACLs are not enabled on the MDS, then any attempts to reference an ACL on a client return an “Operation not supported” error.

3.1.3 Examples

These examples are taken directly from the POSIX paper referenced above. ACLs on a Lustre file system work exactly like ACLs on any Linux file system. They are manipulated with the standard tools in the standard manner. Below, we create a directory and allow a specific user access.

```
[root@client spfs]# umask 027
[root@client spfs]# mkdir rain
[root@client spfs]# ls -ld rain
drwxr-x---  2 root root 4096 Feb 20 06:50 rain
[root@client spfs]# getfacl rain
# file: rain
# owner: root
# group: root
user::rwx
group::r-x
other::---

[root@client spfs]# setfacl -m user:chirag:rwx rain
[root@client spfs]# ls -ld rain
drwxrwx---+ 2 root root 4096 Feb 20 06:50 rain
[root@client spfs]# getfacl --omit-heade rain
user::rwx
user:chirag:rwx
group::r-x
mask::rwx
other::---
```

Chapter IV - 4. Other Lustre Operating Tips

This chapter describes tips to improve Lustre operations and includes the following sections:

- Expanding the File System by Adding OSTs
- A Simple Data Migration Script

4.1 Expanding the File System by Adding OSTs

To add OSTs to existing Lustre file systems:

1 Add a new OST by passing on the following commands, run:

```
$ mkfs.lustre --fsname=spfs --ost --mgsnode=mds16@tcp0 /dev/sda
$ mkdir -p /mnt/test/ost0
$ mount -t lustre /dev/sda /mnt/test/ost0
```

2 Migrate the data (possibly).

The file system is quite unbalanced when new empty OSTs are added. New file creations are automatically balanced. If this is a scratch file system or files are pruned at a regular interval, then no further work may be needed. Files existing prior to the expansion can be rebalanced with an in-place copy, which can be done with a simple script.

The basic method is to copy existing files to a temporary file, then mv the temp file over the old one. This should not be attempted with files which are currently being written to by users or applications. This operation redistributes the stripes over the entire set of OSTs. For a sample data migration script, see A Simple Data Migration Script on page 208.

A very clever migration script would do the following:

- Examine the current distribution of data.
- Calculate how much data should move from each full OST to the empty ones.
- Search for files on a given full OST (using **lfs getstripe**).
- Force the new destination OST (using **lfs setstripe**).
- Copy only enough files to address the imbalance.

If an enterprising Lustre administrator wants to explore this approach further, per-OST disk-usage statistics can be found under /proc/fs/lustre/osc/*/rpc_stats.

Example Script:

```
#!/bin/bash
# set -x
# A script to copy and check files
# To guard against corruption, the file is chksum'd
# before and after the operation.
# You must supply a temporary directory for the operation.

#

CKSUM=${CKSUM:-md5sum}
MVDIR=$1

if [ $# -ne 1 ]; then
echo "Usage: $0 <dir to copy>"
exit 1
fi

cd $MVDIR

for i in `find . -print`
do
# if directory, skip
if [ -d $i ]; then
echo "dir $i"
else
# Check for write permission
if [ ! -w $i ]; then
echo "No write permission for $i, skipping"
continue
fi
```

```
OLDCHK=$($CKSUM $i | awk '{print $1}')
NEWNAME=$(mktemp $i.tmp.XXXXXX)
cp $i $NEWNAME
RES=$?
if [ $RES -ne 0 ];then
echo "$i copy error - exiting"
rm -f $NEWNAME
exit 1
fi
NEWCHK=$($CKSUM $NEWNAME | awk '{print $1}')

if [ $OLDCHK != $NEWCHK ]; then
echo "$NEWNAME bad checksum - $i not
moved, exiting"
rm -f $NEWNAME
exit 1
else
mv $NEWNAME $i
if [ $RES -ne 0 ];then
echo "$i move error - exiting"
rm -f $NEWNAME
exit 1
fi
fi
fi
done
```

4.2 A Simple Data Migration Script

```
#!/bin/bash
# set -x

# A script to copy and check files
# To guard against corruption, the file is chksum'd
# before and after the operation.
# You must supply a temporary directory for the operation.
#

CKSUM=${CKSUM:-md5sum}
MVDIR=$1

if [ $# -ne 1 ]; then
echo "Usage: $0 <dir to copy>"
exit 1
fi


cd $MVDIR

for i in `find . -print`
do
# if directory, skip
if [ -d $i ]; then
echo "dir $i"
else
# Check for write permission
if [ ! -w $i ]; then
echo "No write permission for $i, skipping"
continue
```

```
fi

OLDCHK=$($CKSUM $i | awk '{print $1}')
NEWNAME=$(mktemp $i.tmp.XXXXXX)
cp $i $NEWNAME
RES=$?
if [ $RES -ne 0 ];then
echo "$i copy error - exiting"
rm -f $NEWNAME
exit 1
fi
NEWCHK=$($CKSUM $NEWNAME | awk '{print $1}')
if [ $OLDCHK != $NEWCHK ]; then
echo "$NEWNAME bad checksum - $i not moved, \  exiting"
rm -f $NEWNAME
exit 1
else
mv $NEWNAME $i
if [ $RES -ne 0 ];then
echo "$i move error - exiting"
rm -f $NEWNAME
exit 1
fi
fi
fi
done
```

4.3 Adding Multiple SCSI LUNs on Single HBA

The configuration of the kernels packaged by CFS is similar to that of the upstream RedHat and SuSE packages. Currently, RHEL does not enable *CONFIG_SCSI_MULTI_LUN* because it can cause problems with SCSI hardware.

To enable this, set the *scsi_mod max_scsi_luns=xx'* option (typically, *xx* is 128) in either modprobe.conf (2.6 kernel) or modules.conf (2.4 kernel).

To pass this option as a kernel boot argument (in grub.conf or lilo.conf), compile the kernel with *CONFIG_SCSI_MULT_LUN=y*

4.4 Failures While Running a Client and an OST on the Same Machine

While running a client and an OST on the same machine, the following failures can occur:

- If the client contains a dirty file system in memory and memory pressure, a kernel thread flushes dirty pages to the file system, and it writes to a local OST. To complete the write, the OST needs to do an allocation. Then the blocking of allocation occurs while waiting for the above kernel thread to complete the write process and free up some memory. This is a deadlock condition.
- If the node with both a client and OST crashes, then the OST waits for the mounted client on that node to recover. However, since the client is now in crashed state, the OST considers it to be a new client and blocks it from mounting until the recovery completes.

As a result, running OST and client on same machine can cause a double failure and prevent a complete recovery.

4.5 Improving Lustre Metadata Performance While Using Large Directories

To improve metadata performance while using large directories can be improved by:

- Have more RAM on the MDS – On the MDS, more memory translates into bigger caches, thereby increasing the metadata performance.
- Patching the core kernel on the MDS with the 3G/1G patch (if not running a 64-bit kernel), which increases the available kernel address space. This translates into support for bigger caches on the MDS.

Chapter V - 1. User Utilities (man1)

This chapter describes user utilities and includes the following sections:

1.1 lfs

Use **lfs**, a Lustre client file system utility, to display striping information for existing files and to create a file with a specific striping pattern.

1.1.1 Synopsis

```
lfs
lfs find [--atime|-A N] [--mtime|-M N] [--ctime|-C N] [--maxdepth|-D N] \ [-
-print0|-P] [--print|-p] [--obd|-O <uuid>] <dir/file>
lfs find [--quiet|-q] [--verbose|-v] [--recursive|-r] <dir|file>
lfs getstripe [--obd|-O <uuid>] [--quiet|-q] [--verbose|-v] \
[--recursive|-r] <dir/file>
lfs setstripe <filename|dirname> [--size|-s stripe_size] \
[--index|-i stripe_index] [--count|-c stripe_count]
lfs quotachown [-i] <filesystem>
lfs quotacheck [-ug] <filesystem>
lfs quotaon [-ugf] <filesystem>
lfs quotaoff [-ug] <filesystem>
lfs setquota [-u|-g] <name> <block-softlimit> <block-hardlimit> \
<inode-softlimit> <inode-hardlimit> <filesystem>
lfs quota [-o obd_uuid] [-u|-g] <name> <filesystem>
lfs setstripe <filename> <stripe-size> <start-ost> <stripe-cnt>
```

```
lfs check <mds| osts| servers>
lfs df [-i] [-h] [path]
```

NOTE:
In the above example, *<filesystem>* refers to the mount point of the Lustre file system (default is /mnt/lustre).

1.1.2 Description

The **lfs** utility is used to create a new file with a specific striping pattern, determine the default striping pattern, and gather the extended attributes (object numbers and location) for a specific file and for setting Lustre quota. It can be invoked interactively without any arguments or in a non-interactive mode with one of the supported arguments.

To invoke **lfs** in an interactive mode, run:

```
$ lfs
lfs> help
```

For a complete list of available commands, type “help” at the **lfs** prompt. To get basic help on the description and syntax of a command, type “help command.” The tab key activates command completion. Command history is available via the “UP” and “DOWN” arrow keys.

Available sub-commands are:

setstripe:

- Creates a new file with a specific striping pattern.

getstripe:

- Lists the striping pattern for a given file name or files in a given directory.
- Lists the striping pattern recursively for all files in a directory tree.
- Lists the files that have objects on a specific OST.

Find:

Searches the directory tree rooted at the given directory or filename for the files that match the given parameters.

Parameter	Description
--atime	The file was last accessed N*24 hours ago. It checks if the file was last accessed, changed, modified N days ago, within the interval of (N+1,N] days. This number can be specified as +N and -N, for more than and less than N days ago, respectively
--ctime	The status of the file was last changed N*24 hours ago.
--mtime	The data in the file was last modified N*24 hours ago.
--obd	The file has an object on a specific OST.
--maxdepth	Allows the **find** command to descend at most N levels of the directory tree [--print0|-P] [--print|-p] prints the full file name on the standard output, followed by a null character or a new line, respectively.

lfind:

The **lfind** option lists the striping pattern for a given file name or files in a directory or recursively for all files in a directory tree by using one of the following options.

[--quiet|-q] [--verbose|-v] [--recursive|-r]

If one of the above options is specified, **lfind** works in the so-called “old” mode - filename and striping. This mode is obsolete; use **lfs getstripe** instead.

NOTE:
In ’new’ mode, **lfind** can run on a non-Lustre file system, and can cross all Lustre / non-Lustre mount points (and vice versa) correctly.

Parameter	Description
df	Reports file system disk space usage or inode usage for each MDS / OST.
quotachown	Changes the owner or group of a file on OSTs of the specified file system.
quotacheck	Scans the specified file system for disk usage and creates or updates quota files.
quotaon	Turns on file system quotas.
quotaoff	Turns off file system quotas.
setquota	Sets file system quotas.
quota	Displays the disk usage and limits.
check	Displays the status of MDS or OSTs (specified in the command) or all servers (MDS and OSTs).
osts	Lists all OSTs for the file system.
help	Provides brief help on various arguments.
exit / quit	Quits the interactive **lfs** session.

1.1.3 Examples

To create a file striped on one OST, run:

```
$ lfs setstripe /mnt/lustre/file1 131072 0 1
```

To create a file striped on two OSTs with 128 KB on each stripe, run:

```
$ lfs setstripe /mnt/lustre/file1 131072 -1 2
```

To create a default striping pattern on an existing directory for all the new files created therein, run:

```
$ lfs setstripe /mnt/lustre/dir 131072 0 1
```

To delete the default striping pattern on a directory, run:

```
$ lfs setstripe -d /mnt/lustre/dir
```

(New files use the default striping pattern created therein.)

stripe-size	If you pass a stripe-size of 0, the file system default stripe size is used. Otherwise, the stripe-size must be a multiple of 16 KB.
stripe-start	If you pass a starting-ost of -1, a random first OST is chosen. Otherwise, the file starts on the specified OST index (starting at 0).
stripe-count	If you pass a stripe-count of 0, the file system default number of OSTs is used. A stripe-count of -1 means that all available OSTs should be used.
Note on defaults	The default stripe-size is 0. The default stripe-start is -1. Do NOT confuse them! If you set stripe-start to 0, all new file creations occur on OST 0 (seldom a good idea).

This is an example of setting and getting stripes, run:

```
$ lfs > setstripe lustre.iso 0 -1 0
$ lfs > getstripe lustre.iso
   OBDS:
   0: ost1_UUID ACTIVE
   1: ost2_UUID_2 ACTIVE
   ./lustre
      obdidx   objid    objid    group
      1        4        0x4      0
```

To list the object allocations of all the files in a given directory, run:

```
$ lfs find/mnt/lustre/
```

To list the object allocation of a given file, run:

```
$ lfs find/mnt/lustre/file1
```

To list the extended attributes of a given file, run:

```
$ lfs find /mnt/lustre/foo1
      OBDS:
         0: OST_localhost_UUID
/mnt/lustre/foo1
obdidx   objid    objid    group
0        1        0x1      0
```

To list the extended attributes of all files in a given directory, run:

```
$ lfs find /mnt/lustre/
fs find -r /mnt/lustre/
```

To recursively list objects of all the files in a given directory tree, run:

```
$ lfs find -r /mnt/lustre/
```

To recursively list all the files in a given directory that have objects on OST2-UUID, run:

```
$ lfs find -r --obd OST2-UUID /mnt/lustre/
```

To change the file owner and group, run:

```
$ lfs quotachown -i /mnt/lustre
```

To check the quota for a user and a group, run:

```
$ lfs quotacheck -ug /mnt/lustre
```

To turn on the quotas for a user and a group, run:

```
$ lfs quotaon -ug /mnt/lustre
```

To turn off the quotas for a user and a group, run:

```
$ lfs quotaoff -ug /mnt/lustre
```

To set the quotas for a user as 1 GB block quota and 10,000 file quota, run:

```
$ lfs setquota -u {username} 0 1000000 0 10000 /mnt/lustre
```

To ignore the error if the file does not exist, run the following command. For example:

```
$ lfs quotachown -i {file|directory} /mnt/lustre
```

To check the disk space in available inodes consumed by individual MDS and OST, run:

```
$ lfs df -i /mnt/lustre
uuid        inodes      used  free        use%  mounted on
mds-1_uuid  53265600    28266 53237334    0     /mnt/lustre[MDT:0]
ost-1_uuid  24405606    41349 244054715   0     /mnt//lustre[OST:0]
ost-2_uuid  244056064   884   244055180   0     /mnt/lustre[OST:1]
```

To check the disk space in size available on individual MDS and OST, run:

```
$ lfs df -h /mnt/lustre
uuid        1k-blocks   used     free     use%  mounted on
mds-1_uuid  203.5M      12.1M    191.5M   5     /mnt/lustre[MDT:0]
ost-1_uuid  1.8G        384.7M   1.4G     20    /mnt//lustre[OST:0]
ost-2_uuid  1.8G        343.0M   1.5G     18    /mnt/lustre[OST:1]
ost-3_uuid  1.8G        332.2M   1.5G     18    /mnt/lustre[OST:2]
```

To list the quotas of a user, run:

```
$ lfs quota -u {username} /mnt/lustre
```

To check the status of all the servers – MDS and OSTs, run:

```
$ lfs check servers
OSC_localhost.localdomain_OST_localhost_mds1 active.
OSC_localhost.localdomain_OST_localhost_MNT_localhost active.
MDC_localhost.localdomain_mds1_MNT_localhost active.
```

To check the status of all the servers – MDSs, run:

```
$ lfs check mds
```

To check the status of all the servers – OSTs, run:

```
$ lfs check ost
```

To list all of the OSTs, run:

```
$ lfs osts
   OBDS:
         0: OST_localhost_UUID
```

To list the logs of particular types, run:

```
$ lfs catinfo {keyword} [node name]
```

Keywords are: **config**, **deletions**

The node name must be provided when using the keyword **config**.

For example, run:

```
$ lfs catinfo {config|dele*tions}{mdsnode|ostnode}
```

To join the files, run:

```
$ join <filename_A> <filename_B>
```

1.2 lfsck

The e2fsprogs package contains an **lfsck** tool which does distributed coherency checking for the Lustre file system, after e2fsck has been run. In most cases, e2fsck is sufficent to repair any file system issues and **lfsck** is not required (at the small chance of having some leaked space in the file system). To avoid lengthy downtime, you can also run **lfsck** once Lustre is already started (with care).

1.2.1 Synopsis

```
lfsck [-h|--help] [-n|--nofix] [-l|--lostfound][-d|--delete] [-f|--force] [-
v|--verbose] --mdsdb mdsdb --ostdb ost1db,[ost2db,...] filesystem
```

NOTE:
For the above example <*filesystem*> refers to the mount point of the Lustre file system (default is /mnt/lustre).

The parameters and their meanings:

Parameter	Description
-n	Performs a read-only check; does not repair the file system.
-l	Puts orphaned objects into a lost+found directory in the root of the file system.
-d	Deletes orphaned objects from the file system. Since objects on the OST are usually only one of several stripes of a file, it is often difficult to put multiple objects back together into a single usable file.
-h	Prints a brief help message.
--mdsdb mds_database_file	MDS database file created by running e2fsck --mdsdb mds_database_file device on the MDS backing device.
--ostdb ost1_database_file[,ost2_database_file,...]	OST database files created by running e2fsck --ostdb ost_database_file device on each OST backing device.

1.2.2 Description

If an MDS or an OST becomes corrupt, you can run a distributed check on the file system to determine what sort of problems exist.

1. Run 'e2fsck -f' on the individual MDS / OST that had problems to fix any local file system damage.

   It is a very good idea to run this e2fsck under "script" so you have a log of whatever changes it made to the file system (in case this is needed later). After this is complete, you can bring the file system up if necessary to reduce the outage window.

2. Run a full e2fsck of the MDS to create a database for **lfsck**.

   The '-n' option is critical for a mounted file system, otherwise you might corrupt your file system. The mdsdb file can grow fairly large, depending on the number of files in the file system (10 GB or more for millions of files, though the actual file size is larger because the file is sparse). It is fastest if this is written to a local file system because of the seeking and small writes. Depending on the number of files, this step can take several hours to complete. In the following example, /tmp/mdsdb is the database file.

   ```
   e2fsck -n -v --mdsdb /tmp/mdsdb /dev/{mdsdev}
   ```

Example:

```
e2fsck -n -v --mdsdb /tmp/mdsdb /dev/sdb
e2fsck 1.39.cfs1 (29-May-2006)
Warning: skipping journal recovery because doing a read-only filesystem
check.
lustre-MDT0000 contains a file system with errors, check forced.
Pass 1: Checking inodes, blocks, and sizes
MDS: ost_idx 0 max_id 288
MDS: got 8 bytes = 1 entries in lov_objids
MDS: max_files = 13
MDS: num_osts = 1
mds info db file written
Pass 2: Checking directory structure
Pass 3: Checking directory connectivity
Pass 4: Checking reference counts
Pass 5: Checking group summary information
Free blocks count wrong (656160, counted=656058).
Fix? no

Free inodes count wrong (786419, counted=786036).
Fix? no

Pass 6: Acquiring information for lfsck
MDS: max_files = 13
MDS: num_osts = 1
```

```
MDS: 'lustre-MDT0000_UUID' mdt idx 0: compat 0x4 rocomp 0x1 incomp 0x4

lustre-MDT0000: ********** WARNING: Filesystem still has errors **********


      13 inodes used (0%)
       2 non-contiguous inodes (15.4%)
         # of inodes with ind/dind/tind blocks: 0/0/0
  130272 blocks used (16%)
       0 bad blocks
       1 large file

     296 regular files
      91 directories
       0 character device files
       0 block device files
       0 fifos
       0 links
       0 symbolic links (0 fast symbolic links)
       0 sockets
--------
     387 files
```

3 Make this file accessible on all OSTs (either via a shared file system or by copying it to the OSTs – pdcp is very useful here. It copies files to groups of hosts and in parallel, it gets installed with pdsh. You can download it at:

http://sourceforge.net/projects/pdsh).

Run a similar e2fsck step on the OSTs. You can run this step simultaneously on OSTs. The mdsdb is read-only in this step—a single copy can be shared by all OSTs.

```
e2fsck -n -v --mdsdb /tmp/mdsdb --ostdb /tmp/{ostNdb} /dev/{ostNdev}
```

Example:

```
[root@oss161 ~]# e2fsck -n -v --mdsdb /tmp/mdsdb --ostdb /tmp/ostdb /dev/sda
e2fsck 1.39.cfs1 (29-May-2006)
Warning: skipping journal recovery because doing a read-only filesystem
check.
lustre-OST0000 contains a file system with errors, check forced.
Pass 1: Checking inodes, blocks, and sizes
Pass 2: Checking directory structure
Pass 3: Checking directory connectivity
```

```
Pass 4: Checking reference counts
Pass 5: Checking group summary information
Free blocks count wrong (989015, counted=817968).
Fix? no

Free inodes count wrong (262088, counted=261767).
Fix? no

Pass 6: Acquiring information for lfsck
OST: 'lustre-OST0000_UUID' ost idx 0: compat 0x2 rocomp 0 incomp 0x2
OST: num files = 321
OST: last_id = 321

lustre-OST0000: ********** WARNING: Filesystem still has errors **********


      56 inodes used (0%)
      27 non-contiguous inodes (48.2%)
         # of inodes with ind/dind/tind blocks: 13/0/0
   59561 blocks used (5%)
       0 bad blocks
       1 large file

     329 regular files
      39 directories
       0 character device files
       0 block device files
       0 fifos
       0 links
       0 symbolic links (0 fast symbolic links)
       0 sockets
--------
     368 files
```

4 Make the mdsdb and all of the ostdb files available on a mounted client so **lfsck** can be run to examine the file system and, optionally, correct defects that it finds.

NOTE:
The ostdb list is a comma-separated list of the ostdb files, so using wildcards in the filename does not work.

```
lfsck -n -v --mdsdb /tmp/mdsdb --ostdb /tmp/{ost1db},{ost2db},... /lustre/
mount/point
```

Example:

```
lfsck -n -v --mdsdb /home/mdsdb --ostdb /home/ostdb /mnt/lustre/client/
MDSDB: /home/mdsdb
OSTDB[0]: /home/ostdb
MOUNTPOINT: /mnt/lustre/client/
MDS: max_id 288 OST: max_id 321
lfsck: ost_idx 0: pass1: check for duplicate objects
lfsck: ost_idx 0: pass1 OK (287 files total)
lfsck: ost_idx 0: pass2: check for missing inode objects
lfsck: ost_idx 0: pass2 OK (287 objects)
lfsck: ost_idx 0: pass3: check for orphan objects
[0] uuid lustre-OST0000_UUID
[0] last_id 288
[0] zero-length orphan objid 1
lfsck: ost_idx 0: pass3 OK (321 files total)
lfsck: pass4: check for duplicate object references
lfsck: pass4 OK (no duplicates)
lfsck: fixed 0 errors
```

By default, **lfsck** does not repair any inconsistencies it finds, it only reports errors. It checks for three kinds of inconsistencies:

- Inode exists but has missing objects = dangling inode. Normally, this happens if there was a problem with an OST.
- Inode is missing but the OST has unreferenced objects = orphan object. Normally, this happens if there was a problem with the MDS.
- Multiple inodes reference the same objects. This happens if there was corruption on the MDS or if the MDS storage is cached and loses some, but not all, writes.

If the file system is busy, **lfsck** may report inconsistencies where none exist because of files and objects being created / removed after the database files were collected. Examined the results closely; you probably want to contact CFS Support for guidance.

The easiest problem to resolve is orphaned objects. Use the '-l' option to **lfsck** so it links these objects to new files and puts them into lost+found in the Lustre file system, where they can be examined and saved or deleted as necessary. If you are certain that the objects are not necessary, **lfsck** can run with the '-d' option to delete orphaned objects and free up any space they are using.

To fix dangling inodes, **lfsck** creates new zero-length objects on the OSTs if the '-c' option is given. These files read back with binary zeros for the stripes that had objects recreated. Such files can also be read even without **lfsck** repair by using this command, run:

```
$ dd if=/lustre/bad/file of=/new/file bs=4k conv=sync,noerror.
```

Because it is rarely useful to have files with large holes in them, most users delete these files after reading them (if useful) and/or restoring them from backup.

NOTE:
It is not possible to write to the holes of such files without having **lfsck** recreate the objects, so it is generally easier to delete these files and restore them from backup.

To fix inodes with duplicate objects, **lfsck** copies the duplicate object to a new object, and assign that to one of the files if the '-c' option is given. One of the files will be okay, and one will likely contain garbage; but lfsck cannot, by itself, tell which one is correct.

1.3 Mount

Lustre uses the standard Linux 'mount' command, and also supports a few extra options. For Lustre 1.4, the server-side options should be added to the XML configuration with the –mountfsoptions= argument.

Here are the Lustre-specific options:

Server options:	**Description**
extents	Use extended attributes (required)
mballoc	Use Lustre file system allocator (required)
Lustre 1.6 server options:	
abort_recov	Abort recovery when starting a target (currently an **lconf** option)
nosvc	Start only MGS/MGC servers
exclude	Start with a dead OST
Client options:	
flock	Enable / disable flock support
user_xattr/nouser_xattr	Enable / disable user-extended attributes
retry=	Number of times a client will retry mount

1.4 Handling Timeouts

Timeouts are the most common cause of hung applications. After a timeout involving an MDS or failover OST, applications attempting to access the disconnected resource wait until the connection gets established.

When a client performs any remote operation, it gives the server a reasonable amount of time to respond. If a server does not reply either due to a down network, hung server, or any other reason, a timeout occurs which requires a recovery.

If a timeout occurs, a message (similar to this one), appears on the console of the client, and in /var/log/messages:

```
LustreError: 26597:(client.c:810:ptlrpc_expire_one_request()) @@@ timeout
req@a2d45200 x5886/t0 o38->mds_svc_UUID@NID_mds_UUID:12 lens 168/64 ref 1 fl
RPC:/0/0 rc 0
```

Chapter V - 2. Lustre Programming Interfaces (man3)

This chapter describes public programming interfaces to control various aspects of Lustre from userspace. These interfaces are generally not guaranteed to remain unchanged over time, although CFS will make an effort to notify the user community well in advance of major changes. This chapter includes the following section:

2.1 User/Group Cache Upcall

This section describes user and group upcall.

2.1.1 Name

Use **/proc/fs/lustre/mds/mds-service/group_upcall** to look up a given user's group membership.

2.1.2 Description

The **group upcall** file contains the path to an executable that, when properly installed, is invoked to resolve a numeric UID to a group membership list. This utility should complete the mds_grp_downcall_data data structure (below) and write it to the **/proc/fs/lustre/mds/mds-service/group_info** pseudo-file.

For a sample upcall program, see **lustre/utils/l_getgroups.c** in the Lustre source distribution.

2.1.3 Parameters

The name of the MDS service.

The numeric UID.

2.1.4 Data structures

```
#include <lustre/lustre_user.h>
#define MDS_GRP_DOWNCALL_MAGIC 0x6d6dd620
struct mds_grp_downcall_data {
   __u32       mgd_magic;
   __u32       mgd_err;
   __u32       mgd_uid;
   __u32       mgd_gid;
   __u32       mgd_ngroups;
   __u32       mgd_groups[0];
};
```

Chapter V - 3. Config Files and Module Parameters (man5)

This section describes configuration files and module parameters and includes the following sections:

3.1 Introduction

LNET network hardware and routing are now configured via module parameters. Parameters should be specified in the /etc/modprobe.conf file, for example:

```
alias lustre llite
options lnet networks=tcp0,elan0
```

The above option specifies that this node should use all the available TCP and Elan interfaces.

Module parameters are read when the module is first loaded. Type-specific LND modules (for instance, ksocklnd) are loaded automatically by the **lnet** module when LNET starts (typically upon *modprobe ptlrpc*).

Under Linux 2.6, LNET configuration parameters can be viewed under /sys/module/; generic and acceptor parameters under **lnet,** and LND-specific parameters under the name of the corresponding LND.

Under Linux 2.4, sysfs is not available, but the LND-specific parameters are accessible via equivalent paths under */proc*.

Important: All old (pre v1.4.6) Lustre configuration lines should be removed from the module configuration files and replaced with the following. Make sure that CONFIG_KMOD is set in your linux.config so LNET can load the following modules it needs. The basic module files are:

modprobe.conf (for Linux 2.6)

```
alias lustre llite
options lnet networks=tcp0,elan0
```

modules.conf (for Linux 2.4)

```
alias lustre llite
options lnet networks=tcp0,elan0
```

For the following parameters, default option settings are shown in parenthesis. Changes to parameters marked with a **W** affect running systems. (Unmarked parameters can only be set when LNET loads for the first time.) Changes to parameters marked with **Wc** only have effect when connections are established (existing connections are not affected by these changes.)

3.2 Module Options

- With routed or other multi-network configurations, use *ip2nets* rather than networks, so all nodes can use the same configuration.
- For a routed network, use the same “routes” configuration everywhere. Nodes specified as routers automatically enable forwarding and any routes that are not relevant to a particular node are ignored. Keep a common configuration to guarantee that all nodes have consistent routing tables.
- A separate modprobe.conf.lnet included from modprobe.conf makes distributing the configuration much easier.
- If you set “config_on_load=1”, LNET starts at modprobe time rather than waiting for Lustre to start. This ensures routers start working at module load time.

  ```
  # lctl
  ```

  ```
  # lctl> net down
  ```

- Remember **lctl ping** – it is a very handy way to check your LNET configuration.

3.2.1 LNET Options

This section describes LNET options.

3.2.1.1 Network Topology

Network topology module parameters determine which networks a node should join, whether it should route between these networks, and how it communicates with non-local networks.

Here is a list of various networks and the supported software stacks:

Network	Software Stack
openib	OpenIB gen1 / Mellanox Gold
iib	Silverstorm (Infinicon)
vib	Voltaire
o2ib	OpenIB gen2
cib	Cisco
mx	Myrinet MX
gm	Myrinet GM-2
elan	Quadrics QSNet

NOTE:
Lustre ignores the loopback interface (lo0), but Lustre use any IP addresses aliased to the loopback (by default). When in doubt, explicitly specify networks.

ip2nets ("") is a string that lists globally-available networks, each with a set of IP address ranges. LNET determines the locally-available networks from this list by matching the IP address ranges with the local IPs of a node. The purpose of this option is to be able to use the same modules.conf file across a variety of nodes on different networks. The string has the following syntax.

<ip2nets> :== <net-match> [<comment>] { <net-sep> <net-match> }

<net-match> :== [<w>] <net-spec> <w> <ip-range> { <w> <ip-range> }

[<w>]

<net-spec> :== <network> ["(" <interface-list> ")"]

<network> :== <nettype> [<number>]

<nettype> :== "tcp" | "elan" | "openib" | ...

<iface-list> :== <interface> ["," <iface-list>]

<ip-range> :== <r-expr> "." <r-expr> "." <r-expr> "." <r-expr>

<r-expr> :== <number> | "*" | "[" <r-list> "]"

<r-list> :== <range> ["," <r-list>]

<range> :== <number> ["-" <number> ["/" <number>]]

<comment :== "#" { <non-net-sep-chars> }

<net-sep> :== ";" | "\n"

<w> :== <whitespace-chars> { <whitespace-chars> }

<net-spec> contains enough information to uniquely identify the network and load an appropriate LND. The LND determines the missing "address-within-network" part of the NID based on the interfaces it can use.

<iface-list> specifies which hardware interface the network can use. If omitted, all interfaces are used. LNDs that do not support the <iface-list> syntax cannot be configured to use particular interfaces and just use what is there. Only a single instance of these LNDs can exist on a node at any time, and <iface-list> must be omitted.

<net-match> entries are scanned in the order declared to see if one of the node's IP addresses matches one of the <ip-range> expressions. If there is a match, <net-spec> specifies the network to instantiate. Note that it is the first match for a particular network that counts. This can be used to simplify the match expression for the general case by placing it after the special cases. For example:

```
ip2nets="tcp(eth1,eth2) 134.32.1.[4-10/2]; tcp(eth1) *.*.*.*"
```

4 nodes on the 134.32.1.* network have 2 interfaces (134.32.1.{4,6,8,10}) but all the rest have 1.

```
ip2nets="vib 192.168.0.*; tcp(eth2) 192.168.0.[1,7,4,12]"
```

This describes an IB cluster on 192.168.0.*. Four of these nodes also have IP interfaces; these four could be used as routers.

Note that match-all expressions (For instance, *.*.*.*) effectively mask all other <net-match> entries specified after them. They should be used with caution.

Here is a more complicated situation, the route parameter is explained below. We have:

- Two TCP subnets
- One Elan subnet
- One machine set up as a router, with both TCP and Elan interfaces
- IP over Elan configured, but only IP will be used to label the nodes.

```
options lnet ip2nets="tcp   198.129.135.* 192.128.88.98; \
                elan  198.128.88.98 198.129.135.3;" \
          routes="tcp  1022@elan        # Elan NID of router;\
             elan  198.128.88.98@tcp # TCP NID of router  "
```

3.2.1.2 networks ("tcp")

This is an alternative to "ip2nets" which can be used to specify the networks to be instantiated explicitly. The syntax is a simple comma separated list of <net-spec>s (see above). The default is only used if neither “ip2nets” nor “networks” is specified.

3.2.1.3 routes (“”)

This is a string that lists networks and the NIDs of routers that forward to them.

It has the following syntax (<w> is one or more whitespace characters):

<routes> :== <route>{ ; <route> }

<route> :== [<net>[<w><hopcount>]<w><nid>{<w><nid>}

So a node on the network tcp1 that needs to go through a router to get to the Elan network

options lnet networks=tcp1 routes="elan 1 192.168.2.2@tcp1”

The hopcount is used to help choose the best path between multiply-routed configurations.

A simple but powerful expansion syntax is provided, both for target networks and router NIDs as follows...

<expansion> :== "[" <entry> { "," <entry> } "]"

<entry> :== <numeric range> | <non-numeric item>

<numeric range> :== <number> ["-" <number> ["/" <number>]]

The expansion is a list enclosed in square brackets. Numeric items in the list may be a single number, a contiguous range of numbers, or a strided range of numbers. For example, r*outes="elan 192.168.1.[22-24]@tcp*" says that network elan0 is adjacent (hopcount defaults to 1); and is accessible via 3 routers on the tcp0 network (192.168.1.22@tcp, 192.168.1.23@tcp and 192.168.1.24@tcp).

routes="[tcp,vib] 2 [8-14/2]@elan" says that 2 networks (tcp0 and vib0) are accessible through 4 routers (8@elan, 10@elan, 12@elan and 14@elan). The hopcount of 2 means that traffic to both these networks will be traversed 2 routers - first one of the routers specified in this entry, then one more.

Duplicate entries, entries that route to a local network, and entries that specify routers on a non-local network are ignored.

Equivalent entries are resolved in favor of the route with the shorter hopcount. The hopcount, if omitted, defaults to 1 (the remote network is adjacent).

It is an error to specify routes to the same destination with routers on different local networks.

If the target network string contains no expansions, then the hopcount defaults to 1 and may be omitted (that is, the remote network is adjacent). In practice, this is true for most multi-network configurations. It is an error to specify an inconsistent hop count for a given target network. This is why an explicit hopcount is required if the target network string specifies more than one network.

3.2.1.4 forwarding ("")

This is a string that can be set either to "enabled" or "disabled" for explicit control of whether this node should act as a router, forwarding communications between all local networks.

A standalone router can be started by simply starting LNET (“*modprobe ptlrpc*”) with appropriate network topology options.

Variable	Description
acceptor	The acceptor is a TCP/IP service that some LNDs use to establish communications. If a local network requires it and it has not been disabled, the acceptor listens on a single port for connection requests that it redirects to the appropriate local network. The acceptor is part of the LNET module and configured by the following options: **secure** - Accept connections only from reserved TCP ports (< 1023). **all** - Accept connections from any TCP port. NOTE: this is required for liblustre clients to allow connections on non-privileged ports. **none** - Do not run the acceptor.
accept_port (988)	Port number on which the acceptor should listen for connection requests. All nodes in a site configuration that require an acceptor must use the same port.
accept_backlog (127)	Maximum length that the queue of pending connections may grow to (see listen(2)).
accept_timeout (5, W)	Maximum time in seconds the acceptor is allowed to block while communicating with a peer.
accept_proto_version	Version of the acceptor protocol that should be used by outgoing connection requests. It defaults to the most recent acceptor protocol version, but it may be set to the previous version to allow the node to initiate connections with nodes that only understand that version of the acceptor protocol. The acceptor can, with some restrictions, handle either version (that is, it can accept connections from both 'old' and 'new' peers). For the current version of the acceptor protocol (version 1), the acceptor is compatible with old peers if it is only required by a single local network.

3.2.2 SOCKLND Kernel TCP/IP LND

The **SOCKLND kernel TCP/IP LND** (socklnd) is connection-based and uses the acceptor to establish communications via sockets with its peers.

It supports multiple instances and load balances dynamically over multiple interfaces. If no interfaces are specified by the *ip2nets or networks* module parameter, all non-loopback IP interfaces are used. The address-within-network is determined by the address of the first IP interface an instance of the socklnd encounters.

Consider a node on the “edge” of an InfiniBand network, with a low-bandwidth management Ethernet (eth0), IP over IB configured (ipoib0), and a pair of GigE NICs (eth1,eth2) providing off-cluster connectivity. This node should be configured with "networks=vib,tcp(eth1,eth2)” to ensure that the socklnd ignores the management Ethernet and IPoIB.

Variable	Description
timeout (50,W)	Time (in seconds) that communictions may be stalled before the LND completes them with failure.
nconnds (4)	Sets the number of connection daemons.
min_reconnectms (1000,W)	Minimum connection retry interval (in milliseconds). After a failed connection attempt, this is the time that must elapse before the first retry. As connections attempts fail, this time is doubled on each successive retry up to a maximum of 'max_reconnectms'.
max_reconnectms (60000,W)	Maximum connection retry interval (in milliseconds).
eager_ack (0 on linux, 1 on darwin,W)	Boolean that determines whether the socklnd should attempt to flush sends on message boundaries.
typed_conns (1,Wc)	Boolean that determines whether the socklnd should use different sockets for different types of messages. When clear, all communication with a particular peer takes place on the same socket. Otherwise, separate sockets are used for bulk sends, bulk receives and everything else.
min_bulk (1024,W)	Determines when a message is considered "bulk".
tx_buffer_size, **rx_buffer_size** (8388608,Wc)	Socket buffer sizes. Setting this option to zero (0), allows the system to auto-tune buffer sizes. WARNING: Be very careful changing this value as improper sizing can harm performance.
nagle (0,Wc)	Boolean that determines if nagle should be enabled. It should never be set in production systems.
keepalive_idle (30,Wc)	Time (in seconds) that a socket can remain idle before a keepalive probe is sent. Setting this value to zero (0) disables keepalives.
keepalive_intvl (2,Wc)	Time (in seconds) to repeat unanswered keepalive probes. Setting this value to zero (0) disables keepalives.
keepalive_count (10,Wc)	Number of unanswered keepalive probes before pronouncing socket (hence peer) death.

Variable	Description
enable_irq_affinity (1,Wc)	Boolean that determines whether to enable IRQ affinity. When set, socklnd attempts to maximize performance by handling device interrupts and data movement for particular (hardware) interfaces on particular CPUs. This option is not available on all platforms. This option requires an SMP system to exist and produces best performance with multiple NICs. Systems with multiple CPUs and a single NIC may see increase in the performance with this parameter disabled.
zc_min_frag (2048,W)	Determines the minimum message fragment that should be considered for zero-copy sends. Increasing it above the platform's PAGE_SIZE disables all zero copy sends. This option is not available on all platforms.

3.2.3 QSW LND

The **QSW LND** (qswlnd) is connection-less and, therefore, does not need the acceptor. It is limited to a single instance, which uses all Elan "rails" that are present and dynamically load balances over them.

The address-with-network is the node's Elan ID. A specific interface cannot be selected in the "networks" module parameter.

Variable	Description
tx_maxcontig (1024)	Integer that specifies the maximum message payload (in bytes) to copy into a pre-mapped transmit buffer.
ntxmsgs (8)	Number of "normal" message descriptors for locally-initiated communications that may block for memory (callers block when this pool is exhausted).
nnblk_txmsg (512 with a 4K page size, 256 otherwise)	Number of "reserved" message descriptors for communications that may not block for memory. This pool must be sized large enough so it is never exhausted.
nrxmsg_small (256)	Number of "small" receive buffers to post (typically everything apart from bulk data).
ep_envelopes_small (2048)	Number of message envelopes to reserve for the "small" receive buffer queue. This determines a breakpoint in the number of concurrent senders. Below this number, communication attempts are queued, but above this number, the pre-allocated envelope queue will fill, causing senders to back off and retry. This can have the unfortunate side effect of starving arbitrary senders, who continually find the envelope queue is full when they retry. This parameter should therefore be increased if envelope queue overflow is suspected.
nrxmsg_large (64)	Number of "large" receive buffers to post (typically for routed bulk data).
ep_envelopes_large (256)	Number of message envelopes to reserve for the "large" receive buffer queue. For more information on message envelopes, see the **ep_envelopes_small** option (above).
optimized_puts (32768,W)	Smallest non-routed PUT that will be RDMA’d.
optimized_gets (1,W)	Smallest non-routed GET that will be RDMA’d.

3.2.4 RapidArray LND

The **RapidArray LND** (ralnd) is connection-based and uses the acceptor to establish connections with its peers. It is limited to a single instance, which uses all (both) RapidArray devices present. It load balances over them using the XOR of the source and destination NIDs to determine which device to use for communication.

The address-within-network is determined by the address of the single IP interface that may be specified by the "networks" module parameter. If this is omitted, then the first non-loopback IP interface that is up is used instead.

Variable	Description
n_connd (4)	Sets the number of connection daemons.
min_reconnect_interval (1,W)	Minimum connection retry interval (in seconds). After a failed connection attempt, this sets the time that must elapse before the first retry. As connections attempts fail, this time is doubled on each successive retry, up to a maximum of the **max_reconnect_interval** option.
max_reconnect_interval (60,W)	Maximum connection retry interval (in seconds).
timeout (30,W)	Time (in seconds) that communications may be stalled before the LND completes them with failure.
ntx (64)	Number of "normal" message descriptors for locally-initiated communications that may block for memory (callers block when this pool is exhausted).
ntx_nblk (256)	Number of "reserved" message descriptors for communications that may not block for memory. This pool must be sized large enough so it is never exhausted.
fma_cq_size (8192)	Number of entries in the RapidArray FMA completion queue to allocate. It should be increased if the ralnd starts to issue warnings that the FMA CQ has overflowed. This is only a performance issue.
max_immediate (2048,W)	Size (in bytes) of the smallest message that will be RDMA’d, rather than being included as immediate data in an FMA. All messages greater than 6912 bytes must be RDMA’d (FMA limit).

3.2.5 VIB LND

The **VIB LND** is connection-based, establishing reliable queue-pairs over InfiniBand with its peers. It does not use the acceptor for this. It is limited to a single instance, which uses a single HCA that can be specified via the "networks" module parameter. It this is omitted, it uses the first HCA in numerical order it can open. The address-within-network is determined by the IPoIB interface corresponding to the HCA used.

Variable	Description
service_number (0x11b9a2)	Fixed IB service number on which the LND listens for incoming connection requests. NOTE: All instances of the viblnd on the same network must have the same setting for this parameter.
arp_retries (3,W)	Number of times the LND will retry ARP while it establishes communications with a peer.
min_reconnect_interval (1,W)	Minimum connection retry interval (in seconds). After a failed connection attempt, this sets the time that must elapse before the first retry. As connections attempts fail, this time is doubled on each successive retry, up to a maximum of the **max_reconnect_interval** option.
max_reconnect_interval (60,W)	Maximum connection retry interval (in seconds).
timeout (50,W)	Time (in seconds) that communications may be stalled before the LND completes them with failure.
ntx (32)	Number of "normal" message descriptors for locally-initiated communications that may block for memory (callers block when this pool is exhausted).
ntx_nblk (256)	Number of "reserved" message descriptors for communications that may not block for memory. This pool must be sized large enough so it is never exhausted.
concurrent_peers (1152)	Maximum number of queue pairs and, therefore, the maximum number of peers that the instance of the LND may communicate with.
hca_basename ("InfiniHost")	Used to construct HCA device names by appending the device number.
ipif_basename ("ipoib")	Used to construct IPoIB interface names by appending the same device number as is used to generate the HCA device name.
local_ack_timeout (0x12,Wc)	Low-level QP parameter. Only change it from the default value if so advised.
retry_cnt (7,Wc)	Low-level QP parameter. Only change it from the default value if so advised.
rnr_cnt (6,Wc)	Low-level QP parameter. Only change it from the default value if so advised.
rnr_nak_timer (0x10,Wc)	Low-level QP parameter. Only change it from the default value if so advised.
fmr_remaps (1000)	Controls how often FMR mappings may be reused before they must be unmapped. Only change it from the default value if so advised.
cksum (0,W)	Boolean that determines if messages (NB not RDMAs) should be check-summed. This is a diagnostic feature that should not normally be enabled.

3.2.6 OpenIB LND

The **OpenIB LND** is connection-based and uses the acceptor to establish reliable queue-pairs over InfiniBand with its peers. It is limited to a single instance that uses only IB device '0'.

The address-within-network is determined by the address of the single IP interface that may be specified by the "networks" module parameter. If this is omitted, the first non-loopback IP interface that is up, is used instead. It uses the acceptor to establish connections with its peers.

Variable	Description
n_connd (4)	Sets the number of connection daemons. The default value is 4.
min_reconnect_interval (1,W)	Minimum connection retry interval (in seconds). After a failed connection attempt, this sets the time that must elapse before the first retry. As connections attempts fail, this time is doubled on each successive retry, up to a maximum of 'max_reconnect_interval'.
max_reconnect_interval (60,W)	Maximum connection retry interval (in seconds).
timeout (50,W)	Time (in seconds) that communications may be stalled before the LND completes them with failure.
ntx (64)	Number of "normal" message descriptors for locally-initiated communications that may block for memory (callers block when this pool is exhausted).
ntx_nblk (256)	Number of "reserved" message descriptors for communications that may not block for memory. This pool must be sized large enough so it is never exhausted.
concurrent_peers (1024)	Maximum number of queue pairs and, therefore, the maximum number of peers that the instance of the LND may communicate with.
cksum (0,W)	Boolean that determines whether messages (NB not RDMAs) should be check-summed. This is a diagnostic feature that should not normally be enabled.

3.2.7 Portals LND (Linux)

The **Portals LND Linux** (ptllnd) can be used as a interface layer to communicate with Sandia Portals networking devices. This version is intended to work on Cray XT3 Linux nodes that use Cray Portals as a network transport.

Message Buffers

When ptllnd starts up, it allocates and posts sufficient message buffers to allow all expected peers (set by 'concurrent_peers') to send one unsolicited message. The first message that a peer actually sends is a (so-called) "HELLO" message, used to negotiate how much additional buffering to setup (typically 8 messages). If 10000 peers actually exist, then enough buffers are posted for 80000 messages.

The maximum message size is set by the *max_msg_size* module parameter (default value is 512). This parameter sets the bulk transfer breakpoint. Below this breakpoint, payload data is sent in the message itself. Above this breakpoint, a buffer descriptor is sent and the receiver gets the actual payload.

The buffer size is set by the *rxb_npages* module parameter (default value is 1). The default conservatively avoids allocation problems due to kernel memory fragmentation. However, increasing this value to 2 is probably not risky.

The ptllnd also keeps an additional *rxb_nspare* buffers (default value is 8) posted to account for full buffers being handled.

Assuming a 4K page size with 10000 peers, 1258 buffers can be expected to be posted at startup, increasing to a maximum of 10008 as peers that are actually connected. By doubling *rxb_npages* halving *max_msg_size*, this number can be reduced by a factor of 4.

ME / MD Queue Length

The ptllnd uses a single portal set by the *portal* module parameter (default value of 9) for both message and bulk buffers. Message buffers are always attached with PTL_INS_AFTER and match anything sent with "message" matchbits. Bulk buffers are always attached with PTL_INS_BEFORE and match only specific matchbits for that particular bulk transfer.

This scheme assumes that the majority of ME / MDs posted are for "message" buffers, and that the overhead of searching through the preceding "bulk" buffers is acceptable. Since the number of "bulk" buffers posted at any time is also dependent on the bulk transfer breakpoint set by *max_msg_size*, this seems like an issue worth measuring at scale.

TX Descriptors

The ptllnd has a pool of so-called "tx descriptors", which it uses not only for outgoing messages, but also to hold state for bulk transfers requested by incoming messages. This pool should scale with the total number of peers.

To enable the building of the Portals LND (ptllnd.ko) configure with the following option:

./configure --with-portals=<path-to-portals-headers>

Variable	Description
ntx (256)	Total number of message descriptors.
concurrent_peers (1152)	Maximum number of concurrent peers. Peers that attempt to connect beyond the maximum are not allowed.
peer_hash_table_size (101)	Number of hash table slots for the peers. This number should scale with concurrent_peers. The size of the peer hash table is set by the module parameter *peer_hash_table_size* which defaults to a value of 101. This number should be prime to ensure the peer hash table is populated evenly. It is advisable to increase this value to 1001 for ~10000 peers.
cksum (0)	Set to non-zero to enable message (not RDMA) checksums for outgoing packets. Incoming packets are always check-summed if necessary, independent of this value.
timeout (50)	Amount of time (in seconds) that a request can linger in a peers-active queue before the peer is considered dead.
portal (9)	Portal ID to use for the ptllnd traffic.
rxb_npages (64 * #cpus)	Number of pages in an RX buffer.
credits (128)	Maximum total number of concurrent sends that are outstanding at a given time.
peercredits (8)	Maximum number of concurrent sends that are outstanding to a single peer at a given time.
max_msg_size (512)	Maximum immediate message size. This MUST be the same on all nodes in a cluster. A peer that connects with a different **max_msg_size** value will be rejected.

3.2.8 Portals LND (Catamount)

The **Portals LND Catamount** (ptllnd) can be used as a interface layer to communicate with Sandia Portals networking devices. This version is intended to work on the Cray XT3 Catamount nodes using Cray Portals as a network transport.

To enable the building of the Portals LND configure with the following option:

./configure --with-portals=<*path-to-portals-headers*>

The following PTLLND tunables are currently available:

Variable	Description
PTLLND_DEBUG (boolean, dflt 0)	Enables or disables debug features.
PTLLND_TX_HISTORY (int, dflt debug?1024:0)	Sets the size of the history buffer.
PTLLND_ABORT_ON_PROTOCOL_MISMATCH (boolean, dflt 1)	Calls abort action on connecting to a peer running a different version of the ptllnd protocol.
PTLLND_ABORT_ON_NAK (boolean, dflt 0)	Calls abort action when a peer sends a NAK. (Example: When it has timed out this node).
PTLLND_DUMP_ON_NAK (boolean, dflt debug?1:0)	Dumps peer debug and the history on receiving a NAK.
PTLLND_WATCHDOG_INTERVAL (int, dflt 1)	Sets intervals to check some peers for timed out communications while the application blocks for communications to complete.
PTLLND_TIMEOUT (int, dflt 50)	The communication timeout (in seconds).
PTLLND_LONG_WAIT (int, dflt debug?5:PTLLND_TIMEOUT)	The time (in seconds) after which the ptllnd prints a warning if it blocks for a longer time during connection establishment, cleanup after an error, or cleanup during shutdown.

The following environment variables can be set to configure the PTLLND's behavior.

Variable	Description
PTLLND_PORTAL (9)	The portal ID to use for the ptllnd traffic.
PTLLND_PID (9)	The virtual pid on which to contact servers.
PTLLND_PEERCREDITS (8)	The maximum number of concurrent sends that are outstanding to a single peer at any given instant.
PTLLND_MAX_MESSAGE_SIZE (512)	The maximum messages size. This MUST be the same on all nodes in a cluster.
PTLLND_MAX_MSGS_PER_BUFFER (64)	The number of messages in a receive buffer. Receive buffer will be allocated of size PTLLND_MAX_MSGS_PER_BUFFER times PTLLND_MAX_MESSAGE_SIZE.
PTLLND_MSG_SPARE (256)	Additional receive buffers posted to portals.
PTLLND_PEER_HASH_SIZE (101)	Number of hash table slots for the peers.
PTLLND_EQ_SIZE (1024)	Size of the Portals event queue (that is, maximum number of events in the queue).

3.2.9 MX LND

MXLND supports a number of load-time parameters using Linux's module parameter system. The following variables are available:

Variable	Description
n_waitd	Number of completion daemons.
max_peers	Maximum number of peers that may connect.
cksum	To enable small message (< 4KB) checksums, set non-zero.
ntx	Number of total tx message descriptors.
credits	Number of concurrent sends to a single peer.
board	Index value of the Myrinet board (NIC).
ep_id	MX endpoint ID.
polling	Use zerio (0) to block (wait). A value > 0 will poll that many times before blocking.
hosts	IP-to-hostname resolution file.

Of the described variables, only **hosts** is required. It must be the absolute path to the MXLND hosts file.

For example:

options kmxlnd hosts=/etc/hosts.mxlnd

The file format for the hosts file is:

IP HOST BOARD EP_ID

The values must be space and/or tab separated where:

IP is a valid IPv4 address

HOST is the name returned by `hostname` on that machine

BOARD is the index of the Myricom NIC (0 for the first card, etc.)

EP_ID is the MX endpoint ID

To obtain the optimal performance for your platform, you may want to vary the remaining options.

n_waitd (1) sets the number of threads that process completed MX requests (sends and receives).

max_peers (1024) tells MXLND the upper limit of machines that it will need to communicate with. This affects how many receives it will pre-post and each receive will use one page of memory. Ideally, on clients, this value will be equal to the total number of Lustre servers (MDS and OSS). On servers, it needs to equal the total number of machines in the storage system. cksum (0) turns on small message checksums. It can be used to aid in troubleshooting. MX also provides an optional checksumming feature which can check all messages (large and small). For details, see the MX README.

ntx (256) is the number of total sends in flight from this machine. In actuality, MXLND reserves half of them for connect messages so make this value twice as large as you want for the total number of sends in flight.

credits (8) is the number of in-flight messages for a specific peer. This is part of the flow-control system in Lustre. Increasing this value may improve performance but it requires more memory because each message requires at least one page.

board (0) is the index of the Myricom NIC. Hosts can have multiple Myricom NICs and this identifies which one MXLND should use. This value must match the board value in your MXLND hosts file for this host.

ep_id (3) is the MX endpoint ID. Each process that uses MX is required to have at least one MX endpoint to access the MX library and NIC. The ID is a simple index starting at zero (0). This value must match the endpoint ID value in your MXLND hosts file for this host.

polling (0) determines whether this host will poll or block for MX request completions. A value of 0 blocks and any positive value will poll that many times before blocking. Since polling increases CPU usage, CFS suggests that you set this to zero (0) on the client and experiment with different values for servers.

Chapter V - 4. System Configuration Utilities (man8)

This chapter includes system configuration utilities and includes the following sections:

4.1 mkfs.lustre

mkfs.lustre is a utility to format a disk for a Lustre service.

4.1.1 Synopsis

```
mkfs.lustre <target_type> [options] device
```

where <*target_type*> is one of the following:

- OST object storage target
- MDT meta data storage target
- MGS configuration management service - one per site. This service can be combined with one --mdt service by specifying both types.

4.1.2 Description

mkfs.lustre is used to format a disk device in order to use it as part of a Lustre file system. After formatting, a disk can be mounted to start the Lustre service defined by this command.

Option	Description
--backfstype=fstype	Force a particular format for the backing file system (like ext3, ldiskfs)
--comment=comment	Set user comment about this disk, ignored by Lustre
--device-size=KB	Set device size for loop devices
--failnode=nid,...	Set the NIDs of a failover partner. This option can be repeated as desired.
--fsname=filesystem_name	The Lustre file system of which this service/node will be a part. Default file system name is lustre.
--index=index	Force a particular OST or MDT index.
--mkfsoptions=opts	Format options for the backing file system. For example, ext3 options could be set here.
--mountoptions=opts	Set permanent mount options, equivalent to the setting in /etc/fstab
--mgsnode=nid,...	Set the NIDs of the MGS node, required for all targets other than the MGS.
--noformat	Only print woud be done; this does not affect the disk
--param key=value	Set permanent parameter key to value. This option can be repeated as desired. Typical options might include:
--param sys.timeout=40	System obd timeout
--param lov.stripe.size=2097152	Default stripe size
--param lov.stripe.count=2	Default stripe count
--param failover mode=failout	Return errors instead of waiting for recovery
--quiet	Print less information
--reformat	Reformat an existing Lustre disk
--stripe-count-hint=stripes	Used for optimizing MDT inode sizes
--verbose	Print more informaiton

4.1.3 Examples

To create a file system with MGS and MDT combined on the same node (cfs21), run:

```
$ mkfs.lustre --fsname=testfs --mdt --mgs /dev/sda1
```

To create OST for file system testfs on any number of nodes using the above MGS, run:

```
$ mkfs.lustre --fsname=testfs --ost --mgsnode=cfs21@tcp0 /dev/sdb
```

To create standalone MGS on, say, node cfs22, run:

```
$ mkfs.lustre --mgs /dev/sda1
```

To create MDT for file system myfs1 on any node, using the above MGS, run:

```
$ mkfs.lustre --fsname=myfs1 --mdt --mgsnode=cfs22@tcp0 /dev/sda2
```

4.2 tunefs.lustre

tunefs.lustre is the utility to modify the information of Lustre configuration on a disk.

4.2.1 Synopsis

```
tunefs.lustre [options] device
```

4.2.2 Description

tunefs.lustre is used to modify the configuration information on a Lustre target disk. This includes upgrading old (pre-Lustre 1.6) disks. This does not reformat the disk or erase the target information, but modifying the configuration information can result in an unusable file system.

WARNING
Changes made here will affect a file system only when the target is next mounted.

Options	Description
--comment=comment	Set user comment about this disk, ignored by Lustre.
--erase-params	Remove all previous parameter information.
--failnode=nid,	Set the NID(s) of a failover partner. This option can be repeated as desired.
--fsname=filesystem_name	The Lustre file system of which this service will be a part. Default is 'lustre'.
--index=index	Force a particular OST or MDT index.
--mountfsoptions=opts	Set permanent mount options, equivalent to setting in /etc/fstab.
--mgs	Add a configuration management service to this target.
--msgnode=nid,...	Set the NID(s) of the MGS node, required for all targets other than the MGS.
--noformat	Only print what would be done; does not affect the disk.
--nomgs	Remove a configuration management service to this target.
--quiet	Print less information.
--verbose	Print more information.
--writeconf	Erase all config logs for the file system of which this target is a part. This may prove VERY dangerous.

4.2.3 Examples

To create a file system with MGS and MDT combined on the same node (cfs21) -

```
$ tunefs.lustre --fsname=testfs --mdt --mgs /dev/sda1
```

To create OST for file system testfs on any number of nodes using the above MGS -

```
$ tunefs.lustre --fsname=testfs --ost --mgsnode=cfs21@tcp0 /dev/sdb
```

To create standalone MGS on, say, node cfs22 -

```
$ tunefs.lustre --mgs /dev/sda1
```

To create MDT for file system myfs1 on any node, using the above MGS -

```
$ tunefs.lustre --fsname=myfs1 --mdt --mgsnode=cfs22@tcp0 /dev/sda2
```

4.3 lctl

lctl is a Lustre utility used for low level configurations of Lustre file system. It also provides low-level testing and manages Lustre network (LNET) information.

4.3.1 Synopsis

```
lctl
lctl --device <devno> <command [args]>
lctl --threads <numthreads> <verbose> <devno> <command [args]
```

4.3.2 Description

lctl can be invoked in interactive mode by issuing the commands given below.

```
$ lctl
lctl> help
```

The most common commands in **lctl** are in matching pairs - like device and attach, detach and setup, cleanup and connect, disconnect and help and quit. To get a complete listing of available commands, type “help” on the lctl prompt. To get basic help on meaning and syntax of a command, type “help command.” Command completion is activated with the TAB key, and command history is available via the “UP” and “DOWN” arrow keys.

For non-interactive single threaded use, one uses the second invocation, which runs command after connecting to the device. Some commands are used only when testing specific functionality inside Lustre and are not normally invoked by users, theses commands are identified by the string (*CFS Dev*). Several commands are old and will be removed in the next major release of Lustre. These commands are identified with the string (*Old*).

Network-Related Options	Description
--net <tcp/elan/myrinet>	The network type to be used for the operation.
network <tcp/elans/myrinet>	Indicates what kind of network is applicable for the configuration commands that follow.
interface_list	Displays the interface entries and requires the 'network' command.
list_nids	Displays network identifiers (NIDs) defined on this node.
which_nid <remote host>	Identifies path to a specific host by NID. Can be used to verify network setup and connectivity.
add_interface	Adds an interface entry. (*Old*)
del_interface [ip]	Deletes an interface entry. (*Old*)
peer_list	Displays the peer entries.
add_peer <nid> <host> <port>	Adds a peer entry. (*CFS Dev*)
del_peer <nid> <host> <port>	Removes a peer entry. (*CFS Dev*)
conn_list	Displays all the connected remote NIDs.
disconnect <nid>	Disconnects from a remote NID. (*CFS Dev*)
active_tx	Displays active transmits; is used only for the Elan network type.
mynid [nid]	Informs the socknal of the local NID. It defaults to host name for TCP networks, and is automatically setup for Elan/ Myrinet networks. (*CFS Dev*)
add_uuid <uuid> <nid>	Associates a given UUID with an NID. (*CFS Dev)*
close_uuid <uuid>	Disconnects a UUID.
del_uuid <uuid>	Deletes a UUID association. (*CFS Dev*)
add_route <gateway> <target> [target]	Adds an entry to the routing table for the given target. (*Old*)
del_route <target>	Deletes an entry for a target from the routing table. (*Old*)
set_route <gateway> <up/down> [<time>]	Enables/ disables routes via the given gateway in the protals routing table. <time> is used to specify when a gateway should come back online (*Old*)
route_list	Displays the complete routing table
fail nid|_all_ [count]	Fails/ restores communications. Omitting the count implies an indefinite fail. A count of zero indicates that communication should be restored. A non-zero count indicates the number of LNET messages to be dropped after which the communication is restored. The argument "nid" is used to specify the gateway, which is one peer of the communication .(*CFS Dev)*

Network-Related Options	Description
show_route	Displays the complete routing table, same output as route_list.
ping nid [timeout] [pid]	Checks LNET connectivity, outputs a NIDs list on the target machine.

Device Selection	Description
newdev	Creates a new device.
device	Selects the specified OBD device. All other commands depend on the device being set.
cfg_device	Sets the current device being configured to <$name>. (*Old*)
device_list	Shows all devices.
lustre_build_version	Displays the Lustre build version.

Device Configuration	Description
attach type [name [uuid]]	Attaches a type to the current device (which is set using the device command), and gives that device a name and a UUID. This allows us to identify the device for later use, and to know the type of that device.
setup <args...>	Types specific device setup commands. For obdfilter, a setup command tells the driver which block device it should use for storage and what type of file system is on that device.
cleanup	Cleans up a previously-setup device.
detach	Removes a driver (and its name and UUID) from the current device.
lov_getconfig lov-uuid	Reads LOV configuration from an MDS device. Returns default-stripe-count, default-stripe-size, offset, pattern, and a list of OST UUIDs. (*Old*)
record cfg-uuid-name	Records the commands that follow in the log.
endrecord	Stops recording.
parse config-uuid-name	Parses the log of recorded commands for a configuration.
dump_log config-uuid-name	Displays the log of recorded commands for a config to kernel debug log.
clear_log config-name	Deletes the current configuration log of recorded commands.

Device Operations	Description
probe [timeout]	Builds a connection handle to a device. This command is used to suspend configuration until the lctl command ensures the availability of the MDS and OSC services. This avoids mount failures in a rebooting cluster.
close	Closes the conneciton handle.
getattr <objid>	Gets the attributes for an OST object <objid> (*CFS Dev*)
setattr <objid> <mode>	Sets the mode attribute for an OST object <objid> (*CFS Dev*)
create [num [mode [verbose]]]	Creates the specified number <num> of OST objects with the given <mode> (*CFS Dev*)
destroy <num>	Starting at <objid>, destroys <num> number of objects starting from the object with object id <objid> (*CFS Dev*)
test_getattr <num> [verbose [[t]objid]]	Does <num> getattrs on an OST object <objid> (objectid+1 on each thread) (*CFS Dev*)
test_brw [t]<num> [write [verbose [npages [[t]objid]]]]	Does <num> bulk read/ writes on an OST object <objid> (<npages> per I/O) (*CFS Dev*)
dump_ldlm	Dumps all the lock manager states. This is very useful for debugging
activate	Activates an import.
deactivate	De-activates an import.
recover	<connection UUID>
lookup <directory> <file>	Displays the information of the given file.
notransno	Disables the sending of committed transnumber updates.
readonly	Disables writes to the underlying device.
abort_recovery	Aborts recovery on the MDS device.
mount_option	Dumps mount options to a file.
get_stripe	Shows stripe information for an echo client object.
set_stripe <objid>[width!count[@offset] [:id:id....]	Sets stripe information for an echo client
unset_stripe <objid>	Unsets stripe information for an echo client object.
del_mount_option profile	Deletes a specified profile.

Device Operations	Description
set_timeout <secs>	Sets the timeout (obd_timeout) for a server to wait before failing recovery.
set_lustre_upcall </full/path/to/upcall>	Sets the lustre upcall (obd_lustre_upcall) via the lustre.upcall sysctl
llog_catlist	Lists all the catalog logs on current device.
llog_info <$logname|#oid#ogr#ogen>	Displays the log header information.
llog_print <$logname|#oid#ogr#ogen> [from] [to]	Displays the log content information. It displays all the records from index 1 by default.
llog_check <$logname|#oid#ogr#ogen> [from] [to]	Checks the log content information. It checks all the records from index 1 by default.
llog_cancel <catalog id|catalog name> <log id> <index>	Cancels a record in the log.
llog_remove <catalog id|catalog name> <log id>	Removes a log from the catalog and erases it from the disk.

Debug	Description
debug_daemon	Debugs the daemon control and dumps to a file.
debug_kernel [file] [raw]	Gets the debug buffer and dumps to a file.
debug_file <input> [output]	Converts the kernel-dumped debug log from binary to plain text format.
clear	Clears the kernel debug buffer.
mark <text>	Inserts marker text in the kernel debug buffer.
filter <subsystem id/debug mask>	Filters message type from the kernel debug buffer.
show <subsystem id/debug mask>	Shows the specific type of messages.
debug_list <subs/types>	Lists all the subsystem and debug types.
modules <path>	Provides gdb-friendly module information.
panic	Forces the kernel to panic.
lwt start/stop [file]	Lightweight tracing.
memhog <page count> [<gfp flags>]	Memory-pressure testing.

Control	Description
help	Shows a complete list of commands. help <command name> can be used to get help on a specific command
exit	Closes the lctl session.
quit	Closes the lctl session.

Options (that can be used to invoke lctl)	**Description**
--device	The device number to be used for the operation. The value of devno is an integer, normally found by calling lctl name2dev on a device name.
--threads	The numthreads variable is a strictly positive integer indicating the number of threads to be started. The devno option is used as above.
--ignore_errors | ignore_errors	Ignores errors during the script processing.
dump	Saves ioctls to a file.

4.3.3 Examples

attach

```
$ lctl
lctl > newdev
lctl > attach obdfilter OBDDEV OBDUUID
lctl > dl
4 AT obdfilter OBDDEV OBDUUID 1
```

getattr

```
$ lctl
lctl > newdev
lctl > attach obdfilter OBDDEV OBDUUID
lctl > dl
4 AT obdfilter OBDDEV OBDUUID 1lctl > getattr 12
id: 12
grp: 0
atime: 1002663714
mtime: 1002663535
ctime: 1002663535
size: 10
blocks: 8
blksize: 4096
mode: 100644
uid: 0
gid: 0
flags: 0
obdflags: 0
nlink: 1
valid: ffffffff
inline:
obdmd:
lctl > disconnect
Finished (success)
setup
lctl > setup /dev/loop0 extN
lctl > quit
```

4.3.4 Network Commands

The example below shows how to use lctl for identifying interface information and peers that are up. In this case, we have one MDS (ft2) and two OSS nodes (d1_q_0, d2_q_0). First we display the interface information on the MDS, and then list MDS peers:

```
$ lctl > network tcp up
$ lctl > interface_list
ft2: (10.67.73.181/255.255.255.0) npeer 0 nroute 2

$ lctl > peer_list
12345-10.67.73.150@tcp [1]ft2->d2_q_0:988 #6
12345-10.67.73.160@tcp [1]ft2->d1_q_0:988 #6
```

To identify routes and check connectivity to another node:

```
#  lctl list_nids
10.67.73.181@tcp
# lctl which_nid d1_q_0
10.67.73.160@tcp
lctl ping d1_q_0
12345-0@lo
12345-10.67.73.160@tcp
```

'Which_nid' does a lookup of the NID, and attempts to expand it. 'which_nid' does not care about the node state. In the example below, the machine 'dellap' is real, the machine 'bogus' and the IP '10.67.73.212' are fake.

```
# lctl which_nid bogus@tcp
Can't parse NID bogus@tcp
# lctl which_nid dellap@tcp
10.67.73.89@tcp
# lctl which_nid 10.67.73.212@tcp
10.67.73.212@tcp
# lctl which_nid 10.67.758.54@tcp
Can't parse NID 10.67.758.54@tcp
```

4.4 mount.lustre

mount.lustre is a utility that starts a Lustre client or target service.

4.4.1 Synopsis

```
$ mount -t lustre [-o options] device dir
```

4.4.2 Description

mount.lustre is used to start a Lustre client or target service. This program should not be called directly; rather it is a helper program invoked through mount(8) as shown in Synopsis on page 250. Lustre clients and targets are stopped by using the umount(8) command.

There are two forms for the device option, depending on whether a client or a target service is started:

<mgsspec>:/<fsname>

This is a client mount command to mount the Lustre file system named <fsname> by contacting the Management Service at <mgsspec>. The format for <mgsspec> is defined below.

<disk_device>

This starts the target service defined by the mkfs.lustre command on the physical disk <disk_device>

Options	Description
<mgsspec>:=<mgsnode>[:<mgsnode>]	The mgs specification may be a colon-separated list of nodes...
<mgsnode>:=<mgsnid>[,<mgsnid>]	...and each node may be specified by a comma-separated list of NIDs.

In addition to the standard mount options, Lustre understands the following client-specific options:

Options	Description
flock	Enable flock support.
noflock	Disable flock support.
user_xattr	Enable get/set user xattr.
nouser_xattr	Disable user xattr.
acl	Enable ACL support.
noacl	Disable ACL support.

In addition to the standard mount options and backing disk type (e.g. LDISKFS) options, Lustre understands the following server-specific options:

Options	Description
nosvc	Only start the MGC (and MGS, if co-located) for a target service, and not the actual service.
exclude=ostlist	Start a client or MDT with a (colon-separated) list of known inactive OSTs
abort_recov	Abort recovery (targets only)

4.4.3 Examples

Mounting a client – no failover:

MDS nid is '10.10.0.5@tcp0'

MDT is 'mds-p' (specified by –mds in .xml file)

Mount point is '/mnt/lustre'

'client' is defined in the .xml file

```
# mount -t lustre 10.10.0.5@tcp0:/mds-p/client /mnt/lustre
```

Add a failover MDS at 10.10.0.6@tcp0:

```
# mount -t lustre 10.10.0.5@tcp0:10.10.0.6@tcp0:/mds-p/client \
/mnt/lustre
```

4.5 New Utilities in Lustre 1.6

This section describes new utilities that are available in Lustre 1.6.

4.5.1 General Purpose

lustre_rmmod.sh

lustre_rmmod.sh, located in /usr/bin/, is a general-purpose utility.

If the Lustre services are not running safe, then remove all the Lustre and LNET modules.

NOTE:
The lustre_rmmod.sh utility does not succeed if the modules are in use or if you have manually fired the command lctl network up.

4.5.2 Managing Large Clusters

lustre_config.sh

The lustre_config.sh utility, located in /usr/bin/, is used to manage large clusters.

lustre_config.sh helps automate the formatting and setup of disks on multiple nodes. Describe the entire installation in a comma-separated file and pass it to this script. This formats the drives, updates modprobe.conf, and produces HA configuration files. lustre_config.sh - format and set up multiple lustre servers from a csv file This script is used to parse each line of a spreadsheet (CSV file) and execute remote commands to format (mkfs.lustre) every Lustre target that will be part of the Lustre cluster. In addition, it can also verify the network connectivity and hostnames in the cluster, configure Linux MD/LVM devices, and produce high-availability software configurations for Heartbeat or CluManager.

lustre_createcsv.sh

The lustre_createcsv.sh script, located in /usr/sbin/, generates a CSV file describing the currently-running installation.

lustre_up14.sh

The lustre_up14.sh script, located in /usr/sbin/, grabs client configuration files from old MDTs. When upgrading a 1.4.x Lustre system to 1.6, if the MGS is not co-located with the MDT or the client name is non-standard, use this utility to retrieve the old client log. For more information, see Upgrading Lustre on page 113.

4.5.3 Profiling Application

lustre_req_history.sh

When run from a client, the lustre_req_history.sh script, located in /usr/bin/, assembles as much Lustre RPC request history as possible from the local node and servers that were contacted; this provides a better picture of the coordinated network activity.

llstat.sh

The llstat.sh script, located in /usr/bin/, handles a wider range of proc files, and has command line switches to produce an output which can be easily graphed.

plot-llstat.sh

The plot-llstat.sh script, located in /usr/bin/, plots the output from llstat using gnuplot.

4.5.4 More /proc Statistics for Profiling Application

vfs_ops_stats

The script client vfs_ops_stats tracks Linux VFS operation calls into Lustre for a single PID, PPID, GID, or everything.

```
/proc/fs/lustre/llite/*/vfs_ops_stats
/proc/fs/lustre/llite/*/vfs_track_[pid|ppid|gid]
```

extents_stats

The script client extents_stats shows the size distribution of I/O calls from the client, cumulative and by process.

```
/proc/fs/lustre/llite/*/extents_stats, extents_stats_per_process
```

offset_stats

The script client offset_stats shows the read/write seek activity of a client by offsets and ranges.

```
/proc/fs/lustre/llite/*/offset_stats
```

- Per-client stats tracked on the servers

  Each MDT and OST now tracks LDLM and operations statistics for every connected client, for comparisons or simpler collection of distributed job statistics.

```
/proc/fs/lustre/mds|obdfilter/*/exports/
```

- Finer MDT stats

  More detailed MDT operations statistics are collected for better profiling.

  ```
  /proc/fs/lustre/mds/*/stats
  ```

4.5.5 Testing / Debugging

The loadgen script, located in /usr/bin/, is a test program you can use to generate large loads on local or remote OSTs or echo servers.

For more information on Loadgen and its usage, refer to:

https://mail.clusterfs.com/wikis/lustre/LoadGen

The llog_reader script, located in /usr/sbin/, translates a Lustre configuration log into human-readable form.

The lr_reader script, located in /usr/sbin/, translates a last received file into human-readable form.

Chapter V - 5. System Limits

This chapter describes various limits on the size of files and file systems. These limits are imposed either by the Lustre architecture or by the Linux VFS and VM subsystems. In a few cases, a limit is defined within the code and could be changed by re-compiling Lustre. In those cases, the selected limit is supported by CFS testing and may change in future releases. This chapter includes the following sections:

5.1 Maximum Stripe Count

The maximum number of stripe count is 160. This limit is a hard-coded option and reflects current tested performance limits. It may be increased in future releases. Under normal circumstances, the stripe count is not affected by ACLs.

5.2 Maximum Stripe Size

For a 32-bit machine, the product of stripe size and stripe count (stripe_size * stripe_count) must be less than 2^32. The ext3 limit of 2TB for a single file applies for a 64-bit machine. (Lustre can support 160 stripes of 2 TB each on a 64-bit system.)

5.3 Minimum Stripe Size

Due to the 64KB PAGE_SIZE on some 64-bit machines, the minimum stripe size is set to 64 KB.

5.4 Maximum Number of OSTs and MDSs

You can set the maximum number of OSTs by a compile option. The limit of 512 OSTs in Lustre 1.4.6 is raised to 1020 OSTs in Lustre releases 1.4.7 and later. Rigorous testing is in progress to move the limit to 4000 OSTs.

The maximum number of MDSs will be determined after accomplishing MDS clustering.

5.5 Maximum Number of Clients

The number of clients is currently limited to 32768. CFS has tested up to 22000 clients.

5.6 Maximum Size of a File System

For i386 systems in 2.6 kernels, the block devices are limited to 16 TB. Each OST or MDS can have a file system up to 8 TB (The 8 TB limit is imposed by ext3 for 2.6 kernels). You can have multiple OST file systems on a single node. Currently, the largest Lustre file system has 448 OSTs in a single file system (running the 1.4.3 Lustre version). There is a compile-time limit of 1020 OSTs in a single file system, giving a single file system limit of 8 PB.

Several production Lustre file systems have around 100 OSSs in a single file system. The largest file system in production is at least 1.3 PB (184 OSTs). All these facts indicate that Lustre would scale just fine if more hardware is made available.

5.7 Maximum File Size

Individual files have a hard limit of nearly 16 TB on 32-bit systems imposed by the kernel memory subsystem. On 64-bit systems this limit does not exist. Hence, files can be 64-bits in size. Lustre imposes an additional size limit of up to the number of stripes, where each stripe is 2 TB. A single file can have a maximum of 160 stripes, which gives an upper single file limit of 320 TB for 64-bit systems. The actual amount of data that can be stored in a file depends upon the amount of free space in each OST on which the file is striped.

5.8 Maximum Number of Files or Subdirectories in a Single Directory

Lustre uses the ext3 hashed directory code, which has a limit of about 25 million files. On reaching this limit, the directory grows to more than 2 GB depending on the length of the filenames. The maximum number of subdirectories in the versions before Lustre 1.2.6 is 32,000. You can have unlimited subdirectories in all the later versions of Lustre due to a small ext3 format change.

In fact, Lustre is tested with ten million files in a single directory. On a properly-configured dual-CPU MDS with 4 GB RAM, random lookups in such a directory are possible at a rate of 5,000 files / second.

5.9 MDS Space Consumption

A single MDS imposes an upper limit of 4 billion inodes. The default limit is slightly less than the device size of 4 KB. That means about 512 MB inodes for a file system with MDS of 2 TB. This can be increased initially, at the time of MDS file system creation, by specifying the "--mkfsoptions='-i 2048'" option on the "--add mds" config line for the MDS.

For newer releases of e2fsprogs, you can specify '-i 1024' to create 1 inode for every 1KB disk space. You can also specify '-N {num inodes}' to set a specific number of inodes. Note that the inode size (-I) should not be larger than half the inode ratio (-i). Otherwise mke2fs will spin trying to write more number of inodes than the inodes that can fit into the device.

5.10 Maximum Length of a Filename and Pathname

This limit is 255 bytes for a single filename, the same as in an ext3 file system. The Linux VFS imposes a full pathname length of 4096 bytes.

5.11 Maximum Number of Open Files for Lustre Filesystems

Lustre does not impose maximum number of open files, but practically it depends on amount of RAM on the MDS. There are no "tables" for open files on the MDS, as they are only linked in a list to a given client's export. Each client process probably has a limit of several thousands of open files which depends on the ulimit.

Feature List

Networks

Utilities

Special System Cell Behavior

Modules

Task List

Key Concepts

User Tasks

Administrator Tasks

add storage

grow disk

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mount / unmount (-force)

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Architect Tasks

Networking

understand hardware options

naming: nid’s networks

Multihomed servers

routes

Version Log

Manual Version	Date	Details of Edits	Bug
1.8	09/29/07	1. Added new chapter (POSIX) to manual.	12048
		2. Added new chapter (Benchmarking) to manual.	12026
		3. Added new chapter (Lustre Recovery) to manual.	12049 / 12141
		4. Updated content in Configuring Quotas chapter.	13433
		5. Updated content in More Complicated Configurations chapter.	12169
		6. Updated content in Lustre Proc chapter.	12385 / 12383 / 12039
		7. Corrected Section 4.1.1.2 errors.	12981
		8. Merge MXLND information from Myricom.	12158
		9. Updated content in Configuring Lustre Examples chapter.	12136
		10. Updated content in RAID chapter.	12170 / 12140
		11. Updated content in Configuration Files Module Parameters chapter.	12299
1.7	08/30/07	1. Add mballoc3 content to Lustre Proc chapter.	12384 / 10816
1.6	08/23/07	1. Updated content in Expanding the File System by Adding OSTs.	13118
		2. Updated content in Failover chapter.	13022 / 12168 / 12143
		3. Mechanics of Lustre readahead.	13022
		4. Updated content in Lustre Troubleshooting and Tips chapter.	12164 / 12037 / 12047 / 12045
		5. Updated content in Free Space and Quotas chapter.	12037
		6. Updated content in Lustre Operating Tips chapter.	12037
		7. Added new appendix - Knowledge Base chapter.	12037
1.5	07/20/07	1. Updated content in Lustre Installation chapter.	12037
		2. Updated content in Failover chapter.	12037
		3. Updated content in Bonding chapter.	12037
		4. Updated content in Striping and I/O Options chapter (mined from CFS Junkyard).	12037 / 12025
		5. Updated content in Lustre Operating Tips chapter.	12037

Manual Version	Date	Details of Edits	Bug
		6. Developmental edit of remaining chapters in manual.	11417
		7. Add new chapter (Lustre SNMP Module) to manual.	12037
		8. Add new chapter (Backup and Recovery) to manual.	12037
1.4	07/08/07	1. Content added to Configuring Lustre Network chapter (mined from CFS Junkyard).	12037
		2. Content added to LustreProc chapter (mined from CFS Junkyard).	12037
		3. Content added to Lustre Troubleshooting Tips chapter (mined from CFS Junkyard).	12037
		4. Content added to Lustre Tuning chapter (mined from CFS Junkyard).	12037
		5. Content added to Prerequisites chapter (mined from CFS Junkyard).	12037 / 12174
		6. Complete re-development of manual's index.	11417
		7. Developmental edit of selected chapters in manual.	11417
1.3	06/08/07	1. Update to 2.2.1.1 - added Note	12483
		2. Enhancements to 3.3 DDN Tuning chapter.	12173
		3. Updates to user utilities (man1) content.	
		4. Add lfsck and e2fsck content to Lustre Programming Interfaces (man2) chapter.	12036
		5. Removed x.x.x MDS Space Utilization content.	12483
		6. Add training slide edits to manual.	12478
		7. Enhanced 8.1.5 Formatting section.	
1.2	05/25/07	1. Added Striping Using ioctl (Part IV Chapter 2)	12032
		2. Added Client Read/Write Offset Survey and Read/Write Extents Survey content (Part III Chapter 2)	12033
		3. Added Building RPMs content (Part II Chapter 2)	12035
		4. Added Setting the Striping Pattern content and I/O (Part IV Chapter 2 - lfs setstripe)	12036
		5. Added Free Space Management content (Part III Chapter 2 - 2.1.1 /proc entries)	12175 / 12039 / 12028
		6. Added /proc content and I/O (Part III Chapter 2 - 2.1.1 /proc entries)	12172
		7. Update DDN Tuning content	12173 / 12142
		8. Added new 1.6 utilities content	12176
		9. Add mballoc content and I/O	12384
		10. Added Options for Formatting MDS and OST and Formatting content (Part III Chapter 3 - 3.2)	12483

Manual Version	Date	Details of Edits	Bug
		11. Added Creating an External Journal content 12. Revise System Limits content	
1.1	02/03/07	1. Upgraded all chapters from 1.4 to 1.6 version of Lustre. 2. Introduction and information of new features of Lustre 1.6 like MountConf, MGS, MGC, and so on. 3. Introduction and information of utilities like mkfs.justre, mount.lustre and tunefs.lustre. 4. Removed lmc and lconf utilities. 5. Added Chapter II - 10. Upgrading Lustre from 1.4 to 1.6. 6. Removed the Appendix Upgrading from 1.4.5 to 1.4.6. 7. Added information on how to remove an OST permanently.	

Knowledge Base

The Knowledge Base is a collection of tips and general information regarding Lustre.

How to reclaim the 5 percent of disk space reserved for root?

If your file system normally looks like this:

```
$ df -h /mnt/lustre
Filesystem            Size  Used Avail Use% Mounted on
databarn              100G   81G   14G  81% /mnt/lustre
```

You might be wondering: where did the other 5 percent go? This space is reserved for the root user.

Currently, all Lustre installations run the ext3 file system internally on service nodes. By default, ext3 reserves 5 percent of the disk for the root user.

To reclaim this space for use by all users, run this command on your OSSs:

```
tune2fs [-m reserved_blocks_percent] [device]
```

This command takes effect immediately. You do not need to shut down Lustre beforehand or restart Lustre afterwards.

Why are applications hanging?

The most common cause of hung applications is a timeout. For a timeout involving an MDS or failover OST, applications attempting to access the disconnected resource wait until the connection is re-established.

In most cases, applications can be interrupted after a timeout with the KILL, INT, TERM, QUIT, or ALRM signals. In some cases, for a command which communicates with multiple services in a single system call, you may have to wait for multiple timeouts.

How do I abort recovery? Why would I want to?

If an MDS or OST is not gracefully shut down, for example a crash or power outage occurs, the next time the service starts it is in "recovery" mode.

This provides a window for any existing clients to re-connect and re-establish any state which may have been lost in the interruption. By doing so, the Lustre software can completely hide failure from user applications.

The recovery window ends when either:

- All clients which were present before the crash have reconnected; or
- A recovery timeout expires

This timeout must be long enough to for all clients to detect that the node failed and reconnect. If the window is too short, some critical state may be lost, and any in-progress applications receive an error. To avoid this, the recovery window of Lustre 1.x is conservatively long.

If a client which was not present before the failure attempts to connect, it receives an error, and a message about recovery displays on the console of the client and the server. New clients may only connect after the recovery window ends.

If the administrator knows that recovery will not succeed, because the entire cluster was rebooted or because there was an unsupported failure of multiple nodes simultaneously, then the administrator can abort recovery.

With Lustre 1.4.2 and later, you can abort recovery when starting a service by adding **--abort-recovery** to the **lconf** command line. For earlier Lustre versions, or if the service has already started, follow these steps:

1 Find the correct device. The server console displays a message similar to:

"RECOVERY: service mds1, 10 recoverable clients, last_transno 1664606"

2 Obtain a list of all Lustre devices. On the MDS or OST, run:

```
lctl device_list
```

3 Look for the name of the recovering service, in this case "mds1":

3 UP mds mds1 mds1_UUID 2

4 Instruct Lustre to abort recovery, run:

```
lctl --device 3 abort_recovery
```

The device number is on the left.

What does "denying connection for new client" mean?

When service nodes are performing recovery after a failure, only clients which were connected before the failure are allowed to connect. This enables the cluster to first re-establish its pre-failure state, before normal operation continues and new clients are allowed to connect.

How do I set a default debug level for clients?

If using zeroconf (`mount -t lustre`), you can add a line similar to the following to your modules.conf:

```
post-install portals sysctl -w portals.debug=0x3f0400
```

This sets the debug level, whenever the portals module is loaded, to whatever value you specify. The value specified above is a good starting choice, and will become the in-code default in Lustre 1.0.2, as it provides useful information for diagnosing problems without materially impairing the performance of Lustre.)

How can I improve Lustre metadata performance when using large directories (> 0.5 million files)?

On the MDS, more memory translates into bigger caches and, therefore, higher performance. One of the requirements for higher metadata performance is to have lots of RAM on the MDS.

The other requirement (if not running a 64-bit kernel) is to patch the core kernel on the MDS with the 3G/1G patch to increase the available kernel address space. This, again, translates into having support for bigger caches on the MDS.

Usually the address space is split in a 3:1 ratio (3G for userspace and 1G for kernel). The 3G/1G patch changes this ratio to 3G for kernel/1G for user (3:1) or 2G for kernel and 2G for user (2:2).

File system refuses to mount because of UUID mismatch

When Lustre exports a device for the first time on a target (MDS or OST), it writes a randomly-generated unique identifier (UUID) to the disk from the .xml configuration file. On subsequent exports of that device, the Lustre code verifies that the UUID on disk matches the UUID in the .xml configuration file.

This is a safety feature which avoids many potential configuration errors, such as devices being renamed after the addition of new disks or controller cards to the system, cabling errors, etc. This results in messages, such as the following, appearing on the system console, which normally indicates a system configuration error:

```
af0ac_mds_scratch_2b27fc413e does not match last_rcvd UUID
8a9c5_mds_scratch_8d2422aa88
```

In some cases, it is possible to get the incorrect UUID in the configuration file, for example by regenerating the .xml configuration file a second time. In this case, you must specify the device UUIDs when the configuration file is built with the **--ostuuid** or **--mdsuuid** options to match the original UUIDs instead of generating new ones each time.

```
lmc -add ost --node ostnode --lov lov1 --dev /dev/sdc --ostuuid
3dbf8_OST_ostnode_ddd780786b

lmc -add mds --node mdsnode --mds mds_scratch --dev /dev/sdc --mdsuuid
8a9c5_mds_scratch_8d2422aa88
```

How do I set up multiple Lustre file systems on the same node?

Assuming you want to have separate file systems with different mount locations, you need a dedicated MDS partition and Logical Object Volume (LOV) for each filessystem. Each LOV requires a dedicated OST(s).

For example, if you have an MDS server node, **mds_server**, and want to have mount points **/mnt/foo** and **/mnt/bar**, the following lines are an example of the setup (leaving out the --add net lines):

Two MDS servers using distinct disks:

```
lmc -m test.xml --add mds --node mds_server --mds foo-mds --group foo-mds
--fstype ldiskfs --dev /dev/sda
lmc -m test.xml --add mds --node mds_server --mds bar-mds --group bar-mds
--fstype ldiskfs --dev /dev/sdb
```

Now for the LOVs:

```
lmc -m test.xml --add lov --lov foo-lov --mds foo-mds --stripe_sz 1048576
--stripe_cnt 1 --stripe_pattern 0
lmc -m test.xml --add lov --lov bar-lov --mds bar-mds --stripe_sz 1048576
--stripe_cnt 1 --stripe_pattern 0
```

Each LOV needs at least one OST:

```
lmc -m test.xml --add ost --node ost_server --lov foo-lov --ost foo-ost1 --group
foo-ost1 --fstype ldiskfs --dev /dev/sdc
lmc -m test.xml --add ost --node ost_server --lov bar-lov --ost bar-ost1 --
group
bar-ost1 --fstype ldiskfs --dev /dev/sdd
```

Set up the client mount points:

```
lmc -m test.xml --add mtpt --node foo-client --path /mnt/foo --mds foo-mds --lov
foo-lov
lmc -m test.xml --add mtpt --node bar-client --path /mnt/bar --mds bar-mds --lov
bar-lov
```

If the Lustre file system "foo" already exists, and you want to add the file system "bar" without reformatting foo, use the group designator to reformat only the new disks:

```
ost_server> lconf --group bar-ost1 --select bar-ost1 --reformat test.xml
mds_server> lconf --group bar-mds --select bar-mds --reformat test.xml
```

If you change the --dev that foo-mds uses, you also need to commit that new configuration (foo-mds must not be running):

```
mds_server> lconf --group foo-mds --select foo-mds --write_conf test.xml
```

NOTE:
If you want both mount points on a client, you can use the same client node name for both mount points.

Is it possible to change the IP address of a OST? MDS? Change the UUID?

The IP address of any node can be changed, as long as the rest of the machines in the cluster are updated to reflect the new location. Even if you used hostnames in the xml config file, you need to regenerate the configuration logs on your metadata server.

It is also possible to change the UUID, but unfortunately it is not very easy as two binary files would need editing.

How do I set striping on a file?

To stripe a file across <*n*> OSTs with stripesize of <*b*> blocks per stripe, run:

```
lfs setstripe <new_filename> <stripe_size> <stripe_offset> <stripe_count>
```

This creates "new_filename" (which must not already exist).

CFS strongly recommends that the stripe_size value be 1MB or larger (size in bytes). Best performance is seen with one or two stripes per file unless it is a file that has shared IO from a large number of clients, when the maximum number of stripes is best (pass -1 as the stripe count to get maximum striping).

The stripe_offset (OST index which holds the first stripe, subsequent stripes are created on sequential stripes) should be "-1" which means allocate stripes in a round-robin manner. Abusing the stripe_offset value leads to uneven usage of the OSTs and premature file system usage.

Most users want to use:

```
lfs setstripe <new_filename> 2097152 -1 N
```

Or use system-wide default stripe size:

```
lfs setstripe <new_filename> 0 -1 N
```

You may want to make a simple wrapper script that only accepts the <stripe_count> parameter. Usage info via "lfs help setstripe".

How do I set striping for a large number of files at one time?

You can set a default striping on a directory, and then any regular files created within that directory inherit the default striping configuration. To do this, first create a directory if necessary and then set the default striping in the same manner as you do for a regular file:

```
lfs setstripe <directory> <stripe_size> -1 <stripe_count>
```

If the stripe_size value is zero (0), it uses the system-wide stripe size. If the stripe_count value is zero (0), it uses the default stripe count. If the stripe_count value is -1, it stripes across all available OSTs. The best performance for many clients writing to individual files is at 1 or 2 stripes per file, and maximum stripes for large shared-I/O files (i.e. many clients reading or writing the same file at one time).

If I set the striping of N and B for a directory, do files in that directory inherit the striping or revert to the default?

All new files get the new striping parameters, and existing files will keep their current striping (even if overwritten). To "undo" the default striping on a directory (to use system-wide defaults again) set the striping to "0 -1 0".

Can I change the striping of a file or directory after it is created?

You cannot change the striping of a file after it is created. If this is important (e.g., performance of reads on some widely-shared large input file) you need to create a new file with the desired striping and copy the data into the old file. It is possible to change the default striping on a directory at any time, although you must have write permission on this directory to change the striping parameters.

How do I replace an OST or MDS?

The OST filesystem is simply a normal ext3 filesystem, so you can use any number of methods to copy the contents to the new OST.

If possible, connect both the old OST disk and new OST disk to a single machine, mount them, and then use rsync to copy all of the data between the OST filesystems. For example:

```
mount -t ext3 /dev/old /mnt/ost_old
mount -t ext3 /dev/new /mnt/ost_new

rsync -aSv /mnt/ost_old/ /mnt/ost_new       # note trailing slash on ost_old/
```

If you are unable to connect both sets of disk to the same computer, use:

```
rsync to copy over the network using rsh (or ssh with "-e ssh"):
rsync -aSvz /mnt/ost_old/ new_ost_node:/mnt/ost_new
```

The same can be done for the MDS, but it needs an additional step:

```
cd /mnt/mds_old; getfattr -R -e base64 -d . > /tmp/mdsea;
<copy all MDS files as above>; cd /mnt/mds_new; setfattr --restore=/tmp/mdsea
```

How do I configure recoverable / failover object servers?

There are two object server modes: the default failover (recoverable) mode, and the fail-out mode. In fail-out mode, if a client becomes disconnected from an object server because of a server or network failure, applications which try to use that object server will receive immediate errors.

In failover mode, applications attempting to use that resource pause until the connection is restored, which is what most people want. This is the default mode in Lustre 1.4.3 and later.

To disable failover mode:

1. If this is an existing Lustre configuration, shut down all client, MDS, and OSS nodes.
2. Change the configuration script to add `--failover` to all "ost" lines.

   Change lines like:

   ```
   lmc --add ost ...
   ```

   to:

   ```
   lmc --add ost ... --failover
   ```

   and regenerate your Lustre configuration file.
3. Start your object servers.

   They should report that recovery is enabled to syslog:

   ```
   Lustre: 1394:0:(filter.c:1205:filter_common_setup()) databarn-ost3:
   recovery enabled
   ```
4. Update the MDS and client configuration logs. On the MDS, run:

   ```
   lconf --write_conf /path/to/lustre.xml
   ```
5. Start the MDS as usual.
6. Mount Lustre on the clients.

How do I resize an MDS / OST file system?

This is a method to back up the MDS, including the extended attributes containing the striping data. If something goes wrong, you can restore it to a newly-formatted larger file system, without having to back up and restore all OSS data.

WARNING:
if this data is very important to you, we strongly recommend that you try to back it up before you proceed.

It is possible to run out of space or inodes in both the MDS and OST file systems. If these file systems reside on some sort of virtual storage device (e.g., LVM Logical Volume, RAID, etc.) it may be possible to increase the storage device size (this is device-specific) and then grow the file system to use this increased space.

1 Prior to doing any sort of low-level changes like this, back up the file system and/or device. See How do I backup / restore a Lustre file system?

2 After the file system or device has been backed up, increase the size of the storage device as necessary. For LVM this would be:

```
lvextend -L {new size} /dev/{vgname}/{lvname}
```

or

```
lvextend -L +{size increase} /dev/{vgname}/{lvname}
```

3 Run a full e2fsck on the filesystem, using the CFS e2fsprogs (available from the CFS customer download site or http://ftp.lustre.org/other/e2fsprogs). Run:

```
e2fsck -f {dev}
```

4 Resize the file system to use the increased size of the device. Run:

```
resize2fs -p {dev}
```

How do I backup / restore a Lustre file system?

Several types of Lustre backups are available.

CLIENT FILE SYSTEM-LEVEL BACKUPS

It is possible to back up Lustre file systems from a client (or many clients in parallel working in different directories), via any number of user-level backup tools like tar, cpio, Amanda, and many enterprise-level backup tools. However, due to the very large size of most Lustre file systems, full backups are not always possible. Doing backups of subsets of the filesystem (subdirectories, per user, incremental by date, etc.) using normal file backup tools is still recommended, as this is the easiest method from which to restore data.

TARGET RAW DEVICE-LEVEL BACKUPS

In some cases, it is desirable to do full device-level backups of an individual MDS or OST storage device for various reasons (before hardware replacement, maintenance or such). Doing full device-level backups ensures that all of the data is preserved in the original state and is the easiest method of doing a backup.

If hardware replacement is the reason for the backup or if there is a spare storage device then it is possible to just do a raw copy of the MDS/OST from one block device to the other as long as the new device is at least as large as the original device using the command:

```
dd if=/dev/{original} of=/dev/{new} bs=1M
```

If hardware errors are causing read problems on the original device then using the command below allows as much data as possible to be read from the original device while skipping sections of the disk with errors:

```
dd if=/dev/{original} of=/dev/{new} bs=4k conv=sync,noerror
```

Even in the face of hardware errors, the ext3 filesystem is very robust and it may be possible to recover file system data after e2fsck is run on the new device.

TARGET FILE SYSTEM-LEVEL BACKUPS

In other cases, it is desirable to make a backup of just the file data in an MDS or OST file system instead of backing up the entire device (e.g., if the device is very large but has little data in it, if the configuration of the parameters of the ext3 filesystem need to be changed, to use less space for the backup, etc).

In this case it is possible to mount the ext3 filesystem directly from the storage device and do a file-level backup. Lustre MUST BE STOPPED ON THAT NODE.

To back up such a filesystem properly also requires that any extended attributes (EAs) stored in the filesystem be backed up, but unfortunately current backup tools do not properly save this data so an extra step is required.

1 Make a mountpoint for the **mkdir /mnt/mds** file system.

2 Mount the file system there.

- For 2.4 kernels use: `mount -t ext3 {dev} /mnt/mds`
- For 2.6 kernels use: `mount -t ldiskfs {dev} /mnt/mds`

3 Change to the mount point being backed up. Type:

```
cd /mnt/mds
```

4 Back up the EAs. Type:

```
getfattr -R -d -m '.*' -P . > ea.bak
```

The `getfattr` command is part of the "attr" package in most distributions.

If the `getfattr` command returns errors like "Operation not supported" then your kernel does not support EAs correctly. STOP and use a different backup method, or contact CFS for assistance.

5 Verify that the ea.bak file has properly backed up your EA data on the MDS.

Without this EA data your backup is not useful. You can look at this file with "more" or a text editor, and it should have an item for each file like:

```
# file: ROOT/mds_md5sum3.txt
```

```
trusted.lov=0s0AvRCwEAAABXoKUCAAAAAAAAAAAAAAAAAAAQAAEAAADD5QoAAAAAAAAAAAAAA
AAAAAAAAAEAAAA=
```

6 Back up all file system data. Type:

```
tar czvf {backup file}.tgz
```

7 Change out of the mounted file system. Type.

```
cd -
```

8 Unmount the file system. Type:

```
umount /mnt/mds
```

Follow the same process on each of the OST device file systems. The backup of the EAs (described in Step 4), is not currently required for OST devices, but this may change in the future.

To restore the file-level backup you need to format the device, restore the file data, and then restore the EA data.

1 Format the new device. The easiest way to get the optimal ext3 parameters is to use **`lconf --reformat {config}.xml`** ONLY ON THE NODE being restored.

   If there are multiple services on the node, then this reformats all of the devices on that node and should NOT be used. Instead, use the step below:

   - For MDS file systems, use: **`mke2fs -j -J size=400 -I {inode_size} -i 4096 {dev}`**

     where *{inode_size}* is at least 512, and possibly larger if you have a default,

     stripe count > 10 (inode_size = power_of_2_>=_than(384 + stripe_count * 24)).

   - For OST filesystems, use: **`mke2fs -j -J size=400 -I 256 -i 16384 {dev}`**

2 Enable ext3 filesystem directory indexing. Type:

   `tune2fs -O dir_index {dev}`

3 Mount the file system. Type:

   - For 2.4 kernels use: **`mount -t ext3 {dev} /mnt/mds`**
   - For 2.6 kernels use: **`mount -t ldiskfs {dev} /mnt/mds`**

4 Change to the new file system mount point. Type:

   `cd /mnt/mds`

5 Restore the file system backup. Type:

   `tar xzvpf {backup file}`

6 Restore the file system EAs. Type:

   `setfattr --restore=ea.bak`

7 Remove the (now invalid) recovery logs. Type:

   `rm OBJECTS/* CATALOGS`

Again, the restore of the EAs (described in Step 6) is not currently required for OST devices, but this may change in the future.

If the file system was used between the time the backup was made and when it was restored, then the "lfsck" tool (part of the CFS e2fsprogs) can be run to ensure the filesystem is coherent. If all of the device filesystems were backed up at the same time after the whole Lustre filesystem was stopped this is not necessary. The file system should be immediately usable even if lfsck is not run, though there will be IO errors reading from files that are present on the MDS but not the OSTs, and files that were created after the MDS backup will not be accessible/visible.

How do I control multiple services on one node independently?

You can do this by assigning an OST (or MDS) to a specific group, often with a name that relates to the service itself (e.g. ost1a, ost1b, ...). In the `lmc` configuration script, put each OST into a separate group, use:

```
lmc --add ost --group <name> ...
```

When starting up each OST use:

```
lconf --group <name>  {--reformat,--cleanup,etc} foo.xml
```

to start up each one individually.

Unless a group is specified all of the services on the that node will be affected by the command.

Beginning with Lustre 1.4.4, managing individual services has been substantially simplified.
The group / select mechanics are gone, and you can operate purely on the basis of service names:

```
lconf --service <service> [--reformat --cleanup ...] foo.xml
```

For example, if you add the service ost1-home, type:

```
lmc --add ost --ost ost1-home ...
```

You can start it with:

```
lconf --service ost1-home foo.xml
```

As before, if you do not specify a service, all services configured for that node will be affected by your command.

What extra resources are required for automated failover?

To automate failover with Lustre, you need power management software, remote control power equipment, and cluster management software.

Power Management Software

PowerMan, by the Lawrence Livermore National Laboratory, is a tool that manipulates remote power control (RPC) devices from a central location. PowerMan natively supports several RPC varieties. Expect-like configurability simplifies the addition of new devices. For more information about PowerMan, see:

http://www.llnl.gov/linux/powerman/

Other power management software is available, but PowerMan is the best we have used so far, and the one with which we are most familiar.

Power Equipment

A multi-port, Ethernet-addressable RPC is relatively inexpensive. For recommended products, see the list of supported hardware on the PowerMan website.

If you can afford them, Linux Networx ICEboxes are very good tools. They combine both remote power control and remote serial console in a single unit.

Cluster management software

There are two options for cluster management software that have been implemented successfully by Lustre customers. Both software options are open source and available free for download.

- **Heartbeat**

  The Heartbeat program is one of the core components of the High-Availability Linux (Linux-HA) project. Heartbeat is highly-portable, and runs on every known Linux platform, as well as FreeBSD and Solaris.

  For information, see: http://linux-ha.org/heartbeat/

  To download, see: http://linux-ha.org/download/

- **Red Hat Cluster Manager (CluManager)**

  Red Hat Cluster Manager allows administrators to connect separate systems (called members or nodes) together to create failover clusters that ensure application availability and data integrity under several failure conditions.

  Administrators can use Red Hat Cluster Manager with database applications, file sharing services, web servers, and more.

NOTE:
CluManager requires two 10M LUNs visible to each member of a failover group.

For more information, see: http://www.redhat.com/docs/manuals/enterprise/RHEL-3-Manual/cluster-suite/

For more download, see: http://ftp.redhat.com/pub/redhat/linux/enterprise/3/en/RHCS/i386/SRPMS/

In the future, CFS hopes to publish more information and sample scripts to configure Heartbeat and CluManager with Lustre.

Is there a way to tell which OST a process on a client is using?

If a process is doing I/O to a file, use the `lfs getstripe` command to see the OST to which it is writing.

Using cat as an example, run:

```
$ cat > foo
```

While that is running, on another terminal, run:

```
$ readlink /proc/$(pidof cat)/fd/1
/barn/users/jacob/tmp/foo
```

You can also `ls -l /proc/<pid>/fd/` to find open files using Lustre.

```
$ lfs getstripe $(readlink /proc/$(pidof cat)/fd/1)
OBDS:
0: databarn-ost1_UUID ACTIVE
1: databarn-ost2_UUID ACTIVE
2: databarn-ost3_UUID ACTIVE
3: databarn-ost4_UUID ACTIVE
/barn/users/jacob/tmp/foo
        obdidx           objid           objid            group
             2          835487        0xcbf9f                0
```

The output shows that this file lives on obdidx 2, which is databarn-ost3.

To see which node is serving that OST, run:

```
$ cat /proc/fs/lustre/osc/*databarn-ost3*/ost_conn_uuid
NID_oss1.databarn.87k.net_UUID
```

The above also works with connections to the MDS - just replace `osc` with `mdc` and `ost` with `mds` in the above command.

I need multiple SCSI LUNs per HBA - what is the best way to do this?

The kernels packaged by CFS are configured approximately the same as the upstream Ret Hat and SuSE packages.

Currently, RHEL does not enable CONFIG_SCSI_MULTI_LUN because it is said to causes problems with some SCSI hardware.

If you need to enable this, you must set 'option scsi_mod max_scsi_luns=*xx*' (*xx* is typically 128) in either modprobe.conf (2.6 kernel) or modules.conf (2.4 kernel).

Passing this option as a kernel boot argument (in grub.conf or lilo.conf) will not work unless the kernel is compiled with CONFIG_SCSI_MULT_LUN=y

Can I run Lustre in a heterogeneous environment (32-and 64-bit machines)?

As of Lustre v1.4.2, this is supported with different word sizes. It is also supported for clients with different endianness (for example, i368 and PPC).

One limitation is that the PAGE_SIZE on the client must be at least as large as the PAGE_SIZE of the server.

In particular, ia64 clients with large pages (up to 64KB pages) can run with i386 servers (4KB pages). If i386 clients are running with ia64 servers, the ia64 kernel must be compiled with 4kB PAGE_SIZE.

How do I clean up a device with lctl?

How do I destroy this object using lctl based on the following information:

lctl > device_list

0 UP obdfilter ost003_s1 ost003_s1_UUID 3

1 UP ost OSS OSS_UUID 2

2 UP echo_client ost003_s1_client 2b98ad95-28a6-ebb2-10e4-46a3ceef9007

1 Try:

```
lconf --cleanup --force
```

2 If that does not work, start lctl (if it is not running already). Then, starting with the highest-numbered device and working backward, clean up each device:

```
root# lctl
lctl> cfg_device ost003_s1_client
lctl> cleanup force
lctl> detach
lctl> cfg_device OSS
lctl> cleanup force
lctl> detach
lctl> cfg_device ost003_s1
lctl> cleanup force
lctl> detach
```

At this point it should also be possible to unload the Lustre modules.

How to build and configure Infiniband support for Lustre

The kernels distributed by CFS do not yet include 3rd-party Infiniband modules. As a result, our Lustre packages can not include IB network drivers for Lustre either, however we do distribute the source code. You will need to build your Infiniband software stack against the CFS kernel, and then build new Lustre packages. If this is outside your realm of expertise, and you are a CFS enterprise support customer, we can help.

- **Volatire**

  To build Lustre with Voltaire Infiniband sources, add: **`--with-vib=<path-to-voltaire-sources>`** as an argument to the configure script.

  To configure Lustre, use: **`--nettype vib --nid <IPoIB address>`**

- **OpenIB generation 1 / Mellanox Gold**

  To build Lustre with OpenIB Infiniband sources, add **`--with-openib=<path_to_openib sources>`** as an argument to the configure script.

  To configure Lustre, use: **`--nettype openib --nid <IPoIB address>`**

- **Silverstorm**

  A Silverstorm driver for Lustre is available.

- **OpenIB 1.0**

  An OpenIB 1.0 driver for Lustre is available.

Currently (v1.4.5) the Voltaire IB module (kvibnal) will _not work on the Altix system. This is due to hardware differences in the Altix system.

To build Silverstorm with Lustre, configure Lustre with:

`--with-iib=<path to silverstorm sources>`

Can the same Lustre file system be mounted at multiple mount points on the same client system?

Yes, this is perfectly safe.

How do I identify files affected by a missing OST?

If an OST is missing for any reason, you may need to know what files are affected.

The file system should still be operational, even though one OST is missing, so from any mounted client node it is possible to generate a list of files that reside on that OST.

In such situations it is advisable to mark the missing OST unavailable so clients and the MDS do not time out trying to contact it. On MDS+client nodes:

```
# lctl dl    # to generate a list of devices, find the OST device number
# lctl --device N deactivate  # N will be different between the MDS and
clients
```

If the OST later becomes available it needs to be reactivated:

```
# lctl --device N activate
```

Determine all the files striped over the missing OST:

```
# lfs find -R -o {OST_UUID} /mountpoint
```

This returns a simple list of filenames from the affected file system.

It is possible to read the valid parts of a striped file (if necessary):

```
# dd if=filename of=new_filename bs=4k conv=sync,noerror
```

Otherwise, it is possible to delete these files with "unlink" or "munlink".

If you need to need to know specifically which parts of the file are missing data you first need to determine the striping pattern, which includes the index of the missing OST:

```
# lfs getstripe -v {filename}
```

The following computation is used to determine which offets in the file are affected:

```
[(C*N + X)*S, (C*N + X)*S + S - 1], N = { 0, 1, 2, ...}
```

where:

C = stripe count

S = stripe size

X = index of bad ost for this file

Example: for a file with 2 stripes, stripe size = 1M, bad OST is index 0 you would have holes in your file at:

```
[(2*N + 0)*1M, (2*N + 0)*1M + 1M - 1], N = { 0, 1, 2, ...}
```

If the file system can't be mounted, there isn't anything currently that would parse metadata directly from an MDS. If the bad OST is definitely not starting, options for mounting the filesystem anyway are to provide a loop device OST in its place, or to replace it with a newly formatted OST. In that case the missing objects are created and will read as zero-filled.

How-To: New Lustre network configuration

Updating Lustre's network configuration during an upgrade to version 1.4.6.

Outline necessary changes to Lustre configuration for the new networking features in v. 1.4.6. Further details may be found in the Lustre manual excerpts found at:

https://wiki.clusterfs.com/cfs/intra/FrontPage?action=AttachFile&do=get&target=LustreManual.pdf

Backwards Compatibility

The 1.4.6 version of Lustre itself uses the same wire protocols as the previous release, but has a different network addressing scheme and a much simpler configuration for routing.

In single-network configurations, LNET can be configured to work with the 1.4.5 networking (portals) so that rolling upgrades can be performed on a cluster. See the 'portals_compatibility' parameter below.

When 'portals_compatibility' is enabled, old XML configuration files remain compatible. lconf automatically converts old-style network addresses to the new LNET style.

If a rolling upgrade is not required (that is, all clients and servers can be stopped at one time), then follow the standard procedure:

1. Shut down all clients and servers
2. Install new packages everywhere
3. Edit the Lustre configuration
4. Update the configuration on the MDS with 'lconf --write_conf'
5. Restart

New Network Addressing

A NID is a Lustre network address. Every node has one NID for each network to which it is attached.

The NID has the form <*address*>[@<*network*>], where the <*address*> is the network address and <*network*> is an identifier for the network. (network type + instance)

Examples:

First TCP network: 192.73.220.107@tcp0

Second TCP network: 10.10.1.50@tcp1

Elan: 2@elan

The "--nid '*' " syntax for the generic client is still valid.

Modules/modprobe.conf

Network hardware and routing are now configured via module parameters, specified in the usual locations. Depending on your kernel version and Linux distribution, this may be /etc/modules.conf, /etc/modprobe.conf, or /etc/modprobe.conf.local.

All old Lustre configuration lines should be removed from the module configuration file. The RPM install should do this, but check to be certain.

The base module configuration requires two lines:

```
alias lustre llite
options lnet networks=tcp0
```

A full list of options can be found at Module Parameters on page 37. Detailed examples can be found in the section, 'Configuring the Lustre Network'. Some brief examples:

Example 1: Use eth1 instead of eth0:

options lnet networks="tcp0(eth1)"

Example 2: Servers have two tcp networks and one Elan network. Clients are either TCP or Elan.

Servers: options lnet 'networks="tcp0(eth0,eth1),elan0"

Elan clients: options lnet networks=elan0

TCP clients: options lnet networks=tcp0

Portals Compatibility

If you are upgrading Lustre on all clients and servers at the same time, then you may skip this section.

If you need to keep the filesystem running while some clients are upgraded, the following module parameter controls interoperability with pre-1.4.6 Lustre.

NOTE:
Compatibility between versions is not possible if you are using portals routers/gateways. If you use gateways, you must update the clients, gateways, and servers at the same time.

portals_compatibility="strong"|"weak"|"none"

"strong" is compatible with Lustre 1.4.5, and 1.4.6 running in either 'strong' or 'weak' compatibility mode.

Since this is the only mode compatible with 1.4.5, all 1.4.6 nodes in the cluster must use "strong" until the last 1.4.5 node has been upgraded.

"weak" is not compatible with 1.4.5, or with 1.4.6 running in "none" mode.

"none" is not compatible with 1.4.5, or with 1.4.6 running in 'strong' mode.

For more information, see Upgrading Lustre on page 113.

NOTE:
Lustre v.1.4.2 through v.1.4.5 clients are only compatible zero-conf mounting from a 1.4.6 MDS if the MDS was originally formatted with Lustre 1.4.5 or earlier. If the files ystem was formatted with v.1.4.6 on the MDS, or "lconf --write-conf" was run on the MDS then the backward compatibility is lost. It is still possible to mount 1.4.2 through 1.4.5 clients with "lconf --node {client_node} {config}.xml".

How to fix bad LAST_ID on an OST

The file system must be stopped on all servers prior to performing this procedure.

For hex <–> decimal translations:

Use GDB:

```
(gdb) p /x 15028
$2 = 0x3ab4
```

Or bc:

```
echo "obase=16; 15028" | bc
```

1 Determine a reasonable value for LAST_ID. Check on the MDS:

```
# mount -t ldiskfs /dev/<mdsdev> /mnt/mds
# od -Ax -td8 /mnt/mds/lov_objid
```

There is one entry for each OST, in OST index order. This is what the MDS thinks the last in-use object is.

2 Determine the OST index for this OST.

```
# od -Ax -td4 /mnt/ost/last_rcvd
```

It will have it at offset 0x8c.

3 Check on the OST. With debugfs, check LAST_ID:

```
debugfs -c -R 'dump /O/0/LAST_ID /tmp/LAST_ID' /dev/XXX ; od -Ax -td8 /tmp/
LAST_ID"
```

4 Check objects on the OST:

```
mount -rt ldiskfs /dev/{ostdev} /mnt/ost
# note the ls below is a number one and not a letter L
ls -1s /mnt/ost/O/0/d* | grep -v [a-z] |
  sort -k2 -n > /tmp/objects.{diskname}
```

```
tail -30 /tmp/objects.{diskname}
```

This shows you the OST state. There may be some pre-created orphans, check for zero-length objects. Any zero-length objects with IDs higher than LAST_ID should be deleted. New objects will be pre-created.

If the OST LAST_ID value matches that for the objects existing on the OST, then it is possible the lov_objid file on the MDS is incorrect. Delete the lov_objid file on the MDS and it will be re-created from the LAST_ID on the OSTs.

If you determine the LAST_ID file on the OST is incorrect (that is, it does not match what objects exist, does not match the MDS lov_objid value), then you have decided on a proper value for LAST_ID.

Once you have decided on a proper value for LAST_ID, use this repair procedure.

1 Access:

```
mount -t ldiskfs /dev/{ostdev} /mnt/ost
```

2 Check the current:

```
od -Ax -td8 /mnt/ost/O/0/LAST_ID
```

3 Be very safe, only work on backups:

```
cp /mnt/ost/O/0/LAST_ID /tmp/LAST_ID
```

4 Convert binary to text:

```
xxd /tmp/LAST_ID /tmp/LAST_ID.asc
```

5 Fix:

```
vi /tmp/LAST_ID.asc
```

6 Convert to binary:

```
xxd -r /tmp/LAST_ID.asc /tmp/LAST_ID.new
```

7 Verify:

```
od -Ax -td8 /tmp/LAST_ID.new
```

8 Replace:

```
cp /tmp/LAST_ID.new  /mnt/ost/O/0/LAST_ID
```

9 Clean up:

```
umount /mnt/ost
```

Why can't I run an OST and a client on the same machine?

Consider the case of a "client" with dirty file system pages in memory and memory pressure. A kernel thread is woken to flush dirty pages to the file system, and it writes to local OST. The OST needs to do an allocation in order to complete the write. The allocation is blocked, waiting for the above kernel thread to complete the write and free up some memory. This is a deadlock.

Also, if the node with both a client and OST crash, then the OST waits, during recovery, for the client that was mounted on that node to recover. However, since the client crashed, it is considered a new client to the OST, and is blocked from mounting until recovery completes. As a result, this is currently considered a double failure and recovery cannot complete successfully.

Glossary

A

ACL (Access Control List). An extended attribute associated with a file which contains authorization directives.

Administrative OST failure – A configuration directive given to a cluster to declare that an OST has failed, so errors can be immediately returned.

C

CFS – Cluster File Systems, Inc., a United States corporation founded in 2001 by Peter J. Braam to develop, maintain and support Lustre.

CMD – Clustered metadata, a collection of metadata targets implementing a single file system namespace.

CMOBD – Cache Management OBD. A special device which implements remote cache flushed and migration among devices.

COBD – Caching OBD. A driver which decides when to use a proxy or a locally-unning cache and when to go to a master server. Formerly, this abbreviation was used for the term 'collaborative cache'.

Collaborative Cache – A read cache instantiated on nodes that can be clients or dedicated systems. It enables client-to-client data transfer, thereby enabling enormous scalability benefits for mostly read-only situations. A collaborative cache is not currently implemented in Lustre.

Completion Callback – An RPC made by an OST or MDT to another system, usually a client, to indicate that the lock request is now granted.

Configlog – An llog file used in a node, or retrieved from a management server over the network with configuration instructions for Lustre systems at startup time.

Configuration lock – A lock held by every node in the cluster to control configuration changes. When callbacks are received, the nodes quiesce their traffic, cancel the lock and await configuration changes after which they reacquire the lock before resuming normal operation.

D

Default stripe pattern – Information in the LOV descriptor that describes the default stripe count used for new files in a file system. This can be amended by using a directory stripe descriptor or a per-file stripe descriptor.

Direct I/O – A mechanism which can be used during read and write system calls. It bypasses the kernel I/O cache to memory copy of data between kernel and application memory address spaces.

Directory stripe descriptor – An extended attribute that describes the default stripe pattern for files underneath that directory.

E

EA – See Extended Attribute.

Eviction – The process of eliminating server state for a client that is not returning to the cluster after a timeout or if server failures have occurred.

Export – The state held by a server for a client that is sufficient to transparently recover all in-flight operations when a single failure occurs.

Extended Attribute (EA) – A small amount of data which can be retrieved through a name associated with a particular inode. Examples of extended attributes are ACLs, striping information, and crypto keys.

Extent Lock – A lock used by the OSC to protect an extent in a storage object for concurrent control of read/write, file size acquisition and truncation operations.

F

Failback – The failover process in which the default active server regains control over the service.

Failout OST – An OST which is not expected to recover if it fails to answer client requests. A failout OST can be administratively failed, thereby enabling clients to return errors when accessing data on the failed OST without making additional network requests.

Failover – The process by which a standby computer server system takes over for an active computer server after a failure of the active node. Typically, the standby computer server gains exclusive access to a shared storage device between the two servers.

FID (Lustre File Identifier). A collection of integers which uniquely identify a file or object. The FID structure contains a sequence, identity and version number.

Fileset – A group of files that are defined through a directory that represents a file system's start point.

FLDB (FID Location Database). This database maps a sequence of FIDs to a server which is managing the objects in the sequence.

Flight Group – Group or I/O transfer operations initiated in the OSC, which is simultaneously going between two endpoints. Tuning the flight group size correctly leads to a full pipe.

G

Glimpse callback – An RPC made by an OST or MDT to another system, usually a client, to indicate to tthat an extent lock it is holding should be surrendered if it is not in use. If the system is using the lock, then the system should report the object size in the reply to the glimpse callback. Glimpses are introduced to optimize the acquisition of file sizes.

GNS (Global Namespace). A GNS enables clients to access files without knowing their location. It also enables an administrator to aggregate file storage across distributed storage devices and manage it as a single file system.

Group Lock –

Group upcall –

GSS (Group Sweeping Scheduling). A disk sched uling strategy in which requests are served in cycles, in a round-robin manner.

H

Htree – An indexing system for large directories used by ext3. Originally implemented by Daniel Phillips and completed by CFS.

I

Import – The state held by a client to fully recover a transaction sequence after a server failure and restart.

Intent Lock – A special locking operation introduced by Lustre into the Linux kernel. An intent lock combines a request for a lock, with the full information to perform the operation(s) for which the lock was requested. This offers the server the option of granting the lock or performing the operation and informing the client of the operation result without granting a lock. The use of intent locks enables metadata operations (even complicated ones), to be implemented with a single RPC from the client to the server.

IOV – I/O vector. A buffer destined for transport across the network which contains a collection (a/k/a as a vector) of blocks with data.

J

Join File –

K

Kerberos – An authentication mechanism, optionally available in Lustre 1.8 as a GSS backend.

L

LAID – Lustre RAID. A mechanism whereby the LOV stripes I/O over a number of OSTs with redundancy. This functionality is expected to be introduced in Lustre 2.0.

LBUG – A bug that Lustre writes into a log indicating a serious system failure.

LDLM (Lustre Distributed Lock Manager).

lfind – A subcommand of lfs to find inodes associated with objects.

lfs – A Lustre file system utility named after fs (AFS), cfs (Coda), and ifs (Intermezzo).

lfsck (Lustre File System Check). A distributed version of a disk file system checker. Normally, lfsck does not need to be run, except when file systems are damaged through multiple disk failures and other means that cannot be recovered using file system journal recovery.

liblustre (Lustre library). A user-mode Lustre client linked into a user program for Lustre fs access. liblustre clients cache no data, do not need to give back locks on time, and can recover safely from an eviction. They should not participate in recovery.

Llite (Lustre lite). This term is in use inside the code and module names to indicate that code elements are related to the Lustre file system.

Llog (Lustre log). A log of entries used internally by Lustre. An llog is suitable for rapid transactional appends of records and cheap cancellation of records through a bitmap.

Llog Catalog (Lustre log catalog). An llog with records that each point at an llog. Catalogs were introduced to give llogs almost infinite size. llogs have an originator which writes records and a replicator which cancels record (usually through an RPC), when the records are not needed.

LMV (Logical Metadata Volume). A driver to abstract in the Lustre client that it is working with a metadata cluster instead of a single metadata server.

LND (Lustre Network Driver). A code module that enables LNET support over a particular transport, such as TCP and various kinds of InfiniBand, Elan or Myrinet.

LNET (Lustre Networking). A message passing network protocol capable of running and routing through various physical layers. LNET forms the underpinning of LNETrpc.

LNETrpc – An RPC protocol layered on LNET. This protocol deals with stateful servers and has exactly-once semantics and built in support for recovery.

Load-balancing MDSs – A cluster of MDSs that perform load balancing of on system requests.

Lock Client – A module that makes lock RPCs to a lock server and handles revocations from the server.

Lock Server – A system that manages locks on certain objects. It also issues lock callback requests, calls while servicing or, for objects that are already locked, completes lock requests.

LOV (Logical Object Volume). The object storage analog of a logical volume in a block device volume management system, such as LVM or EVMS. The LOV is primarily used to present a collection of OSTs as a single device to the MDT and client file system drivers.

LOV descriptor – A set of configuration directives which describes which nodes are OSS systems in the Lustre cluster, providing names for their OSTs.

Lustre – The name of the project chosen by Peter Braam in 1999 for an object-based storage architecture. Now the name is commonly associated with the Lustre file system.

Lustre client – An operating instance with a mounted Lustre file system.

Lustre file – A file in the Lustre file system. The implementation of a Lustre file is through an inode on a metadata server which contains references to a storage object on OSSs.

Lustre Lite – A preliminary version of Lustre developed for LLNL in 2002. With the release of Lustre 1.0 in late 2003, Lustre Lite became obsolete.

Lvfs – A library that provides an interface between Lustre OSD and MDD drivers and file systems; this avoids introducing file system-specific abstractions into the OSD and MDD drivers.

M

Mballoc – An advanced block allocation protocol introduced by CFS into the ext3 disk file system. It is capable of efficiently managing the allocation of large (typically 1 MB), contiguous disk extents.

MDC (Metadata Client). A metadata code module which uses LNETrpc to interact with the MDT. Also, an instance of an object device operating on an MDT through the network protocol.

MDD (Metadata Device). Currently implemented using the directory structure and extended attributes of disk file systems.

MDS (Metadata Server). A computer system or software package that runs the Lustre metadata services.

MDS client – Same as MDC.

MDS server – Same as MDS.

MDT (Metadata Target). A metadata device made available through the Lustre meta-data network protocol.

Metadata Write-back Cache – A cache of metadata updates (mkdir, create, setattr, other operations) which an application has performed, but ave not yet been flushed to a storage device or server. InterMezzo is one of the first network file systems to have a metadata write-back cache.

MGS (Management Service). A software module that manages the startup configuration and changes to the configuration. Also, the server node on which this system runs.

Mount object –

Mountconf – The Lustre configuration protocol (introduced in version 1.6) which formats disk file systems on servers with the mkfs.lustre program, and prepares them for automatic incorporation into a Lustre cluster.

N

NAL – An older, obsolete term for LND.

NID (Network Identifier). Encodes the type, network number and network address of a network interface on a node for use by Lustre.

NIO API – A subset of the LNET RPC module that implements a library for sending large network requests, moving buffers with RDMA.

O

OBD (Object Device). The base class of layering software constructs that provides Lustre functionality.

OBD API – See Storage Object API.

OBD type – Module that can implement the Lustre object or metadata APIs. Examples of OBD types include the LOV, OSC and OSD.

Obdfilter – An older name for the OSD device driver.

OBDFS (Object Based File System). A now obsolete single node object file system that stores data and metadata on object devices.

Object device – An instance of a object that exports the OBD API.

Object storage – Refers to a storage-device API or protocol involving storage objects. The two most well known instances of object storage are the T10 iSCSI storage object protocol and the Lustre object storage protocol (a network implementation of the Lustre object API). The principal difference between the Lustre and T10 protocols is that Lustre includes locking and recovery control in the protocol and is not tied to a SCSI transport layer.

opencache – A cache of open file handles. This is a performance enhancement for NFS.

Orphan objects – Storage objects for which there is no Lustre file pointing at them. Orphan objects can arise from crashes and are automatically removed by an llog recovery. When a client deletes a file, the MDT gives back a cookie for each stripe. The client then sends the cookie and directs the OST to delete the stripe. Finally, the OST sends the cookie back to the MDT to cancel it.

Orphan handling – A component of the metadata service which allows for recovery of open, unlinked files after a server crash. The implementation of this feature retains open, unlinked files as orphan objects until it is determined that no clients are using them.

OSC (Object Storage Client). The client unit talking to an OST (via an OSS).

OSD (Object Storage Device). A generic, industry term for storage devices with more extended interface than block-oriented devices, such as disks. Lustre uses this name to describe to a software module that implements an object storage API in the kernel. Lustre also uses this name to refer to an instance of an object storage device created by that driver. The OSD device is layered on a file system, with methods that mimic create, destroy and I/O operations on file inodes.

OSS (Object Storage Server). A system that runs an object storage service software stack.

OSS (Object Storage Server). A server OBD that provides access to local OST's.

OST (Object Storage Target). An OSD made accessible through a network protocol. Typically, an OST is associated with a unique OSD which, in turn is associated with a formatted disk file system on the server containing the storage objects.

P

Pdirops – A locking protocol introduced in the VFS by CFS to allow for concurrent operations on a single directory inode.

pool – A group of OSTs can be combined into a pool with unique access permissions and stripe characteristics. Each OST is a member of only one pool, while an MDT can serve files from multiple pools. A client accesses one pool on the the file system; the MDT stores files from / for that client only on that pool's OSTs.

Portal – A concept used by LNET. LNET messages are sent to a portal on a NID. Portals can receive packets when a memory descriptor is attached to the portal. Portals are implemented as integers.

Examples of portals are the portals on which certain groups of object, metadata, configuration and locking requests and replies are received.

Ptlrpc – An older term for LNETrpc.

R

Raw operations – VFS operations introduced by Lustre to implement operations such as mkdir, rmdir, link, rename with a single RPC to the server. Other file systems would typically use more operations. The expense of the raw operation is omitting the update of client namespace caches after obtaining a successful result.

Remote user handling –

Replay – The concept of re-executing a server request after the server lost information in its memory caches and shut down. The replay requests are retained by clients until the server(s) have confirmed that the data is persistent on disk. Only requests for which a client has received a reply are replayed.

Re-sent request – A request that has seen no reply can be re-sent after a server reboot.

Revocation Callback – An RPC made by an OST or MDT to another system, usually a client, to revoke a granted lock.

Rollback – The concept that server state is in a crash lost because it was cached in memory and not yet persistent on disk.

Root squash – A mechanism whereby the identity of a root user on a client system is mapped to a different identity on the server to avoid root users on clients gaining broad permissions on servers. Typically, for management purposes, at least one client system should not be subject to root squash.

routing – LNET routing between different networks and LNDs.

RPC (Remote Procedure Call). A network encoding of a request.

S

Storage Object API – The API that manipulates storage objects. This API is richer than that of block devices and includes the create / delete of storage objects, read / write of buffers from and to certain offsets, set attributes and other storage object metadata.

Storage objects – A generic concept that refers to data containers, similar or identical to file inodes.

Stride – A contiguous, logical extent of a Lustre file written to a single OST.

Stride size – The maximum size of a stride, typically 4 MB.

Stripe count – The number of OSTs holding objects for a RAID0-striped Lustre file.

Striping metadata – The extended attribute associated with a file that describes how its data is distributed over storage objects. See also **default stripe pattern**.

T

T10 object protocol – An object storage protocol tied to the SCSI transport layer.

W

Wide striping – Strategy of using many OSTs to store stripes of a single file. This obtains maximum bandwidth to a single file through parallel utilization of many OSTs.

Z

zeroconf – A method to start a client without an XML file. The mount command gets a client startup llog from a specified MDS. This is an obsolete method in Lustre 1.6 and later.

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