Veritas Storage Foundation™ Cluster File System Administrator's Guide

HP-UX

5.0.1

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Chapter 1

Technical overview

This chapter includes the following topics:

- Storage Foundation Cluster File System architecture
- About Veritas File System features supported in cluster file systems
- Storage Foundation Cluster File System benefits and applications

Storage Foundation Cluster File System architecture

The Veritas Storage Foundation Cluster File System (SFCFS) allows clustered servers to mount and use a file system simultaneously as if all applications using the file system were running on the same server. The Veritas Volume Manager cluster functionality (CVM) makes logical volumes and raw device applications accessible throughout a cluster.

This section includes the following topics:

- About the symmetric architecture
- About Storage Foundation Cluster File System primary/secondary failover
- About single-host file system semantics using Group Lock Manager

About the symmetric architecture

SFCFS uses a symmetric architecture in which all nodes in the cluster can simultaneously function as metadata servers. SFCFS still has some remnants of the old master/slave or primary/secondary concept. The first server to mount each cluster file system becomes its primary; all other nodes in the cluster become secondaries. Applications access the user data in files directly from the server on which they are running. Each SFCFS node has its own intent log. File system operations, such as allocating or deleting files, can originate from any node in the cluster.

About Storage Foundation Cluster File System primary/secondary failover

If the server on which the SFCFS primary is running fails, the remaining cluster nodes elect a new primary. The new primary reads the intent log of the old primary and completes any metadata updates that were in process at the time of the failure.

If a server on which an SFCFS secondary is running fails, the primary reads the intent log of the failed secondary and completes any metadata updates that were in process at the time of the failure.

About single-host file system semantics using Group Lock Manager

SFCFS uses the Veritas Group Lock Manager (GLM) to reproduce UNIX single-host file system semantics in clusters. This is most important in write behavior. UNIX file systems make writes appear to be atomic. This means that when an application writes a stream of data to a file, any subsequent application that reads from the same area of the file retrieves the new data, even if it has been cached by the file system and not yet written to disk. Applications can never retrieve stale data, or partial results from a previous write.

To reproduce single-host write semantics, system caches must be kept coherent and each must instantly reflect any updates to cached data, regardless of the cluster node from which they originate. GLM locks a file so that no other node in the cluster can update it simultaneously, or read it before the update is complete.

About Veritas File System features supported in cluster file systems

The Veritas Storage Foundation Cluster File System is based on the Veritas File System (VxFS).

Most of the major features of VxFS local file systems are available on cluster file systems, including the following features:

- Extent-based space management that maps files up to a terabyte in size
- Fast recovery from system crashes using the intent log to track recent file system metadata updates
- Online administration that allows file systems to be extended and defragmented while they are in use

The list of supported features and commands that operate on SFCFS. Every VxFS manual page has a section on Storage Foundation Cluster File System Issues with information on whether the command functions on a cluster-mounted file system and indicates any difference in behavior from local mounted file systems.

Veritas File System features in cluster file systems

Table 1-1 describes the VxFS supported features and commands for SFCFS.

Table 1-1 Veritas File System features in cluster file systems

Features	Description
Storage Checkpoints	Storage Checkpoints are supported on cluster file systems, but are licensed only with other Veritas products.
Snapshots	Snapshots are supported on cluster file systems.
Quotas	Quotas are supported on cluster file systems.
NFS mounts	You can mount cluster file systems to NFS.
Nested Mounts	You can use a directory on a cluster mounted file system as a mount point for a local file system or another cluster file system.
Freeze and thaw	Synchronizing operations, which require freezing and thawing file systems, are done on a cluster-wide basis.
Memory mapping	Shared memory mapping established by the `mmap`() function is supported on SFCFS. See the `mmap`(2) manual page.
Disk layout versions	SFCFS supports only disk layout Version 6 and 7. Cluster mounted file systems can be upgraded, a local mounted file system can be upgraded, unmounted, and mounted again as part of a cluster. Use the `fstyp -v` special_device command to ascertain the disk layout version of a VxFS file system. Use the `vxupgrade` command to update the disk layout version.
Locking	Advisory file and record locking are supported on SFCFS. For the F_GETLK command, if there is a process holding a conflicting lock, the `l_pid` field returns the process ID of the process holding the conflicting lock. The nodeid-to-node name translation can be done by examining the `/etc/llthosts` file or with the `fsclustadm` command. Mandatory locking, and deadlock detection supported by traditional `fcntl` locks, are not supported on SFCFS. See the `fcntl`(2) manual page.

Veritas File System features not in cluster file systems

Table 1-2 describes functionality as not supported and may not be expressly prevented from operating on cluster file systems, but the actual behavior is indeterminate.

It is not advisable to use unsupported functionality on SFCFS, or to alternate mounting file systems with these options as local and cluster mounts.

Table 1-2 Veritas File System features not in cluster file systems

Unsupported features	Comments
qlog	Quick log is not supported.
Swap files	Swap files are not supported on cluster mounted file system.
mknod	The `mknod` command cannot be used to create devices on a cluster mounted file system.
Cache advisories	Cache advisories are set with the mount command on individual file systems, but are not propagated to other nodes of a cluster.
Cached Quick I/O	This Quick I/O for Databases feature that caches data in the file system cache is not supported.
Commands that depend on file access times	File access times may appear different across nodes because the `atime` file attribute is not closely synchronized in a cluster file system. So utilities that depend on checking access times may not function reliably.

Storage Foundation Cluster File System benefits and applications

This section describes the SFCFS benefits and applications.

This section includes the following topics:

- How Storage Foundation Cluster File System works
- When to use Storage Foundation Cluster File System

How Storage Foundation Cluster File System works

SFCFS simplifies or eliminates system administration tasks that result from the following hardware limitations:

- The SFCFS single file system image administrative model simplifies administration by making all file system management operations and resizing and reorganization (defragmentation) can be performed from any node.
- You can create and manage terabyte-sized volumes, so partitioning file systems to fit within disk limitations is usually not necessary.
- SFCFS can support file systems with up to 256 terabyte in size, so only extremely large data farms must be partitioned because of file system addressing limitations.
- Because all servers in a cluster have access to SFCFS cluster-shareable file systems, keeping data consistent across multiple servers is automatic. All cluster nodes have access to the same data, and all data is accessible by all servers using single server file system semantics.
- Because all files can be accessed by all servers, applications can be allocated to servers to balance load or meet other operational requirements. Similarly, failover becomes more flexible because it is not constrained by data accessibility.
- Because each SFCFS file system can be on any node in the cluster, the file system recovery portion of failover time in an *n*-node cluster can be reduced by a factor of *n* by distributing the file systems uniformly across cluster nodes.
- Enterprise RAID subsystems can be used more effectively because all of their capacity can be mounted by all servers, and allocated by using administrative operations instead of hardware reconfigurations.
- Larger volumes with wider striping improve application I/O load balancing. Not only is the I/O load of each server spread across storage resources, but with SFCFS shared file systems, the loads of all servers are balanced against each other.
- Extending clusters by adding servers is easier because each new server's storage configuration does not need to be set up—new servers simply adopt the cluster-wide volume and file system configuration.

When to use Storage Foundation Cluster File System

You should use SFCFS for any application that requires the sharing of files, such as for home directories and boot server files, Web pages, and for cluster-ready applications. SFCFS is also applicable when you want highly available standby data, in predominantly read-only environments where you just need to access data, or when you do not want to rely on NFS for file sharing.

Almost all applications can benefit from SFCFS. Applications that are not "cluster-aware" can operate on and access data from anywhere in a cluster. If multiple cluster applications running on different servers are accessing data in a cluster file system, overall system I/O performance improves due to the load balancing effect of having one cluster file system on a separate underlying volume. This is automatic; no tuning or other administrative action is required.

Many applications consist of multiple concurrent threads of execution that could run on different servers if they had a way to coordinate their data accesses. SFCFS provides this coordination. Such applications can be made cluster-aware allowing their instances to co-operate to balance client and data access load, and thereby scale beyond the capacity of any single server. In such applications, SFCFS provides shared data access, enabling application-level load balancing across cluster nodes.

SFCFS provides the following features:

- For single-host applications that must be continuously available, SFCFS can reduce application failover time because it provides an already-running file system environment in which an application can restart after a server failure.
- For parallel applications, such as distributed database management systems and Web servers, SFCFS provides shared data to all application instances concurrently. SFCFS also allows these applications to grow by the addition of servers, and improves their availability by enabling them to redistribute load in the event of server failure simply by reassigning network addresses.
- For workflow applications, such as video production, in which very large files are passed from station to station, the SFCFS eliminates time consuming and error prone data copying by making files available at all stations.
- For backup, the SFCFS can reduce the impact on operations by running on a separate server, accessing data in cluster-shareable file systems.

The following are examples of applications and how they might work with SFCFS:

- Using Storage Foundation Cluster File System on file servers

  Two or more servers connected in a cluster configuration (that is, connected to the same clients and the same storage) serve separate file systems. If one of the servers fails, the other recognizes the failure, recovers, assumes the primaryship, and begins responding to clients using the failed server's IP addresses.
- Using Storage Foundation Cluster File System on web servers

  Web servers are particularly suitable to shared clustering because their application is typically read-only. Moreover, with a client load balancing front end, a Web server cluster's capacity can be expanded by adding a server and another copy of the site. A SFCFS-based cluster greatly simplifies scaling and administration for this type of application.

Storage Foundation Cluster File System architecture

This chapter includes the following topics:

Storage Foundation Cluster File System architecture overview

SFCFS includes Veritas Cluster Server (VCS), Veritas File System (VxFS), and Veritas Volume Manager (VxVM). The Veritas Cluster Server (VCS) provides the communication, configuration, and membership services required to create a cluster. VCS is the first component installed and configured to set up a cluster file system.

About Veritas Cluster Server architecture

The Group Membership and Atomic Broadcast (GAB) and Low Latency Transport (LLT) are VCS-specific protocols implemented directly on Ethernet data link. They run on redundant data links that connect the nodes in a cluster. VCS requires redundant cluster communication links to avoid single points of failure.

GAB provides membership and messaging for the cluster and its applications. GAB membership also provides orderly startup and shutdown of a cluster. The `/etc/gabtab` file is used to configure GAB. This file contain the `gabconfig` command run by GAB on startup. For example, the `-n` option of the command specifies the number of nodes in the cluster. GAB is configured automatically when you run the SFCFS installation script, but you may have to reconfigure GAB when adding nodes to a cluster.

See the `gabconfig`(1M) manual page.

LLT provides kernel-to-kernel communications and monitors network communications. The LLT `/etc/llthosts` and `/etc/llttab` files are configured to set system IDs within a cluster, set cluster IDs for multiple clusters, and tune network parameters such as heartbeat frequency. LLT is implemented so that cluster membership changes are reflected quickly, which in turn enables fast responses.

As with GAB, LLT is configured automatically when you run the VCS installation script. The `/etc/llttab` and `/etc/llthosts` files contain information you provide during installation. You may also have to reconfigure LLT when adding nodes to a cluster.

See the `llttab`(4) and the `llthosts`(4) manual pages.

See the *Veritas Cluster Server User's Guide*.

Each component in SFCFS registers with a GAB membership port. The port membership identifies nodes that have formed a cluster for the individual components.

Table 2-1 describes the port memberships.

Table 2-1 Port memberships

Port	Description
port a	heartbeat membership
port b	I/O fencing membership
port f	Cluster File system membership
port h	Veritas Cluster Server communication between GAB and High Availability Daemon (HAD)
port u	Temporarily used by CVM
port v	Cluster Volume Manager membership
port w	Cluster Volume Manager daemons on different nodes communicate with one another using this port, but receive cluster membership information through GAB (port v)

Veritas Volume Manager cluster functionality

The Veritas Volume Manager cluster functionality (CVM) makes logical volumes accessible throughout a cluster. CVM enables multiple hosts to concurrently access the logical volumes under its control. A VxVM cluster comprises nodes sharing a set of devices. The nodes are connected across a network. If one node fails, other nodes can access the devices. The VxVM cluster feature presents the same logical view of the device configurations, including changes, on all nodes. You configure CVM shared storage after VCS sets up a cluster configuration.

When the Storage Foundation Cluster File System primary fails

If the server on which the SFCFS primary is running fails, the remaining cluster nodes elect a new primary. The new primary reads the file system intent log and completes any metadata updates that were in process at the time of the failure. Application I/O from other nodes may block during this process and cause a delay. When the file system is again consistent, application processing resumes.

Because nodes using a cluster file system in secondary node do not update file system metadata directly, failure of a secondary node does not require metadata repair. SFCFS recovery from secondary node failure is therefore faster than from primary node failure.

See "Distribute a load on a cluster " on page 25.

About Storage Foundation Cluster File System and the Group Lock Manager

SFCFS uses the Veritas Group Lock Manager (GLM) to reproduce UNIX single-host file system semantics in clusters. UNIX file systems make writes appear atomic. This means when an application writes a stream of data to a file, a subsequent application reading from the same area of the file retrieves the new data, even if it has been cached by the file system and not yet written to disk. Applications cannot retrieve stale data or partial results from a previous write.

To reproduce single-host write semantics, the file system must keep system caches coherent, and each must instantly reflect updates to cached data, regardless of the node from which the updates originate.

About asymmetric mounts

A VxFS file system mounted with the `mount -o cluster` option is a cluster, or shared mount, as opposed to a non-shared or local mount. A file system mounted in shared mode must be on a VxVM shared volume in a cluster environment. A local mount cannot be remounted in shared mode and a shared mount cannot be remounted in local mode when you use the `mount -o remount` option. A single clustered file system can be mounted with different read/writes options on different nodes. These are called asymmetric mounts.

Asymmetric mounts allow shared file systems to be mounted with different read/write capabilities. For example, one node in the cluster can mount read/write, while other nodes mount read-only.

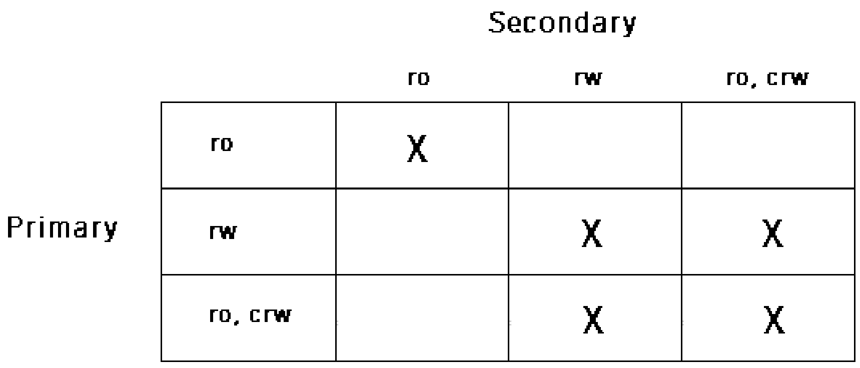
When a primary mounts "ro", this means that neither this node nor any other node is allowed to write the file system. Secondaries can only mount "ro", if the primary mounts "ro". Otherwise, the primary mounts either "rw" or "ro,crw", and the secondaries have the same choice.

You can specify the cluster read-write (`crw`) option when you first mount the file system, or the options can be altered when doing a remount (`mount -o remount`).

See the `mount_vxfs`(1M) manual page.

Figure 2-1 describes the first column showing the mode in which the primary is mounted:

Figure 2-1 Primary and secondary mounts



		Secondary		
		ro	rw	ro, crw
Primary	ro	X		
	rw		X	X
	ro, crw		X	X

The check marks indicate the mode secondary mounts can use for a given mode of the primary.

Mounting the primary with only the `-o cluster,ro` option prevents the secondaries from mounting in a different mode; that is, read-write.

Note: `rw` implies read-write capability throughout the cluster.

Parallel I/O

Some distributed applications read and write to the same file concurrently from one or more nodes in the cluster; for example, any distributed application where one thread appends to a file and there are one or more threads reading from various regions in the file. Several high-performance compute (HPC) applications can also benefit from this feature, where concurrent I/O is performed on the same file. Applications do not require any changes to use parallel I/O.

Traditionally, the entire file is locked to perform I/O to a small region. To support parallel I/O, SFCFS locks ranges in a file that correspond to I/O requests. Two I/O requests conflict if at least one is a write request, and the I/O range of the request overlaps the I/O range of the other.

The parallel I/O feature enables I/O to a file by multiple threads concurrently, as long as the requests do not conflict. Threads issuing concurrent I/O requests could be executing on the same node, or on different nodes in the cluster.

An I/O request that requires allocation is not executed concurrently with other I/O requests. Note that when a writer is extending the file and readers are lagging behind, block allocation is not necessarily done for each extending write.

Predetermine the file size and preallocate the file to avoid block allocations during I/O. This improves the concurrency of applications performing parallel I/O to the file. Parallel I/O also avoids unnecessary page cache flushes and invalidations using range locking, without compromising the cache coherency across the cluster.

For applications that update the same file from multiple nodes, the `-nomtime` mount option provides further concurrency. Modification and change times of the file are not synchronized across the cluster, which eliminates the overhead of increased I/O and locking. The timestamp seen for these files from a node may not have the time updates that happened in the last 60 seconds.

Storage Foundation Cluster File System namespace

The mount point name must remain the same for all nodes mounting the same cluster file system. This is required for the VCS mount agents (online, offline, and monitoring) to work correctly.

Storage Foundation Cluster File System backup strategies

The same backup strategies used for standard VxFS can be used with SFCFS because the APIs and commands for accessing the namespace are the same. File System checkpoints provide an on-disk, point-in-time copy of the file system. Because performance characteristics of a checkpointed file system are better in certain I/O patterns, they are recommended over file system snapshots (described below) for obtaining a frozen image of the cluster file system.

File System snapshots are another method of a file system on-disk frozen image. The frozen image is non-persistent, in contrast to the checkpoint feature. A snapshot can be accessed as a read-only mounted file system to perform efficient online backups of the file system. Snapshots implement “copy-on-write” semantics that incrementally copy data blocks when they are overwritten on the snapped file system. Snapshots for cluster file systems extend the same copy-on-write mechanism for the I/O originating from any cluster node.

Mounting a snapshot filesystem for backups increases the load on the system because of the resources used to perform copy-on-writes and to read data blocks from the snapshot. In this situation, cluster snapshots can be used to do off-host backups. Off-host backups reduce the load of a backup application from the primary server. Overhead from remote snapshots is small when compared to overall snapshot overhead. Therefore, running a backup application by mounting a snapshot from a relatively less loaded node is beneficial to overall cluster performance.

The following are several characteristics of a cluster snapshot:

- A snapshot for a cluster mounted file system can be mounted on any node in a cluster. The file system can be a primary, secondary, or secondary-only. A stable image of the file system is provided for writes from any node.
  See the `mount_vxfs` manual page for more information on secondary-only (seconly) is a CFS mount option.
- Multiple snapshots of a cluster file system can be mounted on the same or different cluster nodes.
- A snapshot is accessible only on the node mounting the snapshot. The snapshot device cannot be mounted on two nodes simultaneously.
- The device for mounting a snapshot can be a local disk or a shared volume. A shared volume is used exclusively by a snapshot mount and is not usable from other nodes as long as the snapshot is mounted on that device.
- On the node mounting a snapshot, the snapped file system cannot be unmounted while the snapshot is mounted.
- A SFCFS snapshot ceases to exist if it is unmounted or the node mounting the snapshot fails. However, a snapshot is not affected if another node leaves or joins the cluster.
- A snapshot of a read-only mounted file system cannot be taken. It is possible to mount a snapshot of a cluster file system only if the snapped cluster file system is mounted with the `crw` option.

In addition to frozen images of file systems, there are volume-level alternatives available for shared volumes using mirror split and rejoin. Features such as Fast Mirror Resync and Space Optimized snapshot are also available.

See the *Veritas Volume Manager System Administrator's Guide*.

Synchronize time on Cluster File Systems

SFCFS requires that the system clocks on all nodes are synchronized using some external component such as the Network Time Protocol (NTP) daemon. If the nodes are not in sync, timestamps for inode (`ctime`) and data modification (`mtime`) may not be consistent with the sequence in which operations actually happened.

Distribute a load on a cluster

You can use the `fsclustadm` to designate a SFCFS primary. The `fsclustadm setprimary` mount point can be used to change the primary. This change to the primary is not persistent across unmounts or reboots. The change is in effect as long as one or more nodes in the cluster have the file system mounted. The primary selection policy can also be defined by a VCS attribute associated with the SFCFS mount resource.

For example, if you have eight file systems and four nodes, designating two file systems per node as the primary is beneficial. The first node that mounts a file system becomes the primary for that file system.

File system tuneables

Using the `tunefstab` file will update the tuneable parameters at the time of mount. The file system `tunefstab` parameters are set to be identical on all nodes by propagating the parameters to each cluster node. When the file system is mounted on the node, the `tunefstab` parameters of the primary node are used. Symantec recommends that this file be identical on each node.

Split-brain and jeopardy handling

A split-brain occurs when the cluster membership view differs among the cluster nodes, increasing the chance of data corruption. With I/O fencing, the potential for data corruption is eliminated. I/O fencing requires disks that support SCSI-3 PGR.

Jeopardy state

In the absence of I/O fencing, SFCFS installation requires two heartbeat links. When a node is down to a single heartbeat connection, SFCFS can no longer discriminate between loss of a system and loss of the final network connection. This state is defined as jeopardy.

SFCFS detects jeopardy and responds to it in ways that prevent data corruption in some split-brain situations. However, data corruption can still occur in other situations:

- All links go down simultaneously.
- A node hangs and is unable to respond to heartbeat messages.

To eliminate the chance of data corruption in these scenarios, I/O fencing is required. With I/O fencing, the jeopardy state does not require special handling by the SFCFS stack.

Jeopardy handling

For installations that do not support SCSI-3 PGR, jeopardy handling prevents some potential split-brain conditions. If any cluster node fails following a jeopardy state notification, all cluster file systems that were mounted on the failed node or nodes are disabled on all remaining nodes. If a leave reconfiguration happens after jeopardy state notification, then the nodes which have received the jeopardy state notification leave the cluster.

Recovery from jeopardy

The disabled file system can be restored by a force unmount and the resource will be brought online without rebooting, which also brings the shared disk group resource online.

Note: If the jeopardy condition is not fixed, the nodes are susceptible to leaving the cluster again on subsequent node failure.

See the *Veritas Cluster Server User's Guide.*

Fencing

With the use of I/O fencing, all remaining cases with the potential to corrupt data (for which jeopardy handling cannot protect) are addressed.

Single network link and reliability

Certain environments may prefer using a single private link or a public network for connecting nodes in a cluster, despite the loss of redundancy for dealing with network failures. The benefits of this approach include simpler hardware topology and lower costs; however, there is obviously a tradeoff with high availability.

For the above environments, SFCFS provides the option of a single private link, or using the public network as the private link if I/O fencing is present. I/O fencing is used to handle split-brain scenarios. The option for single network is given during installation.

Configuring low priority a link

LLT can be configured to use a low-priority network link as a backup to normal heartbeat channels. Low-priority links are typically configured on the customer's public or administrative network. This typically results in a completely different network infrastructure than the cluster private interconnect, and reduces the chance of a single point of failure bringing down all links. The low-priority link is not used for cluster membership traffic until it is the only remaining link. In normal operation, the low-priority link carries only heartbeat traffic for cluster membership and link state maintenance. The frequency of heartbeats drops 50 percent to reduce network overhead. When the low-priority link is the only remaining network link, LLT also switches over all cluster status traffic. Following repair of any configured private link, LLT returns cluster status traffic to the high-priority link.

LLT links can be added or removed while clients are connected. Shutting down GAB or the high-availability daemon, had, is not required.

To add a link

- To add a link, type the following command:

  ```
  # lltconfig -d device -t device_tag
  ```

  where `device_tag` is a tag to identify particular link in subsequent commands, and is displayed by `lltstat`(1M).

To remove a link

- To remove a link, type the following command:

  ```
  # lltconfig -u device_tag
  ```

See the `lltconfig`(1M) manual page.

Changes take effect immediately and are lost on the next reboot. For changes to span reboots you must also update `/etc/llttab`.

Note: LLT clients do not recognize the difference unless only one link is available and GAB declares jeopardy.

I/O error handling policy

I/O errors can occur for several reasons, including failures of Fibre Channel links, host-bus adapters, and disks. SFCFS disables the file system on the node encountering I/O errors. The file system remains available from other nodes.

After the hardware error is fixed (for example, the Fibre Channel link is reestablished), the file system can be force unmounted and the mount resource can be brought online from the disabled node to reinstate the file system.

About Veritas Volume Manager cluster functionality

Veritas Volume Manager cluster functionality (CVM) allows up to 32 nodes in a cluster to simultaneously access and manage a set of disks under VxVM control (VM disks). The same logical view of the disk configuration and any changes are available on each node. When the cluster functionality is enabled, all cluster nodes can share VxVM objects. Features provided by the base volume manager, such as mirroring, fast mirror resync and dirty region logging are also supported in the cluster environment.

To implement cluster functionality, VxVM works together with the cluster monitor daemon provided by the host operating system or by VCS. The cluster monitor informs VxVM of changes in cluster membership. Each node starts up independently and has its own cluster monitor, plus its own copies of the operating system and CVM. When a node joins a cluster it gains access to shared disks. When a node leaves a cluster, it no longer has access to shared disks. A node joins a cluster when the cluster monitor is started on that node.

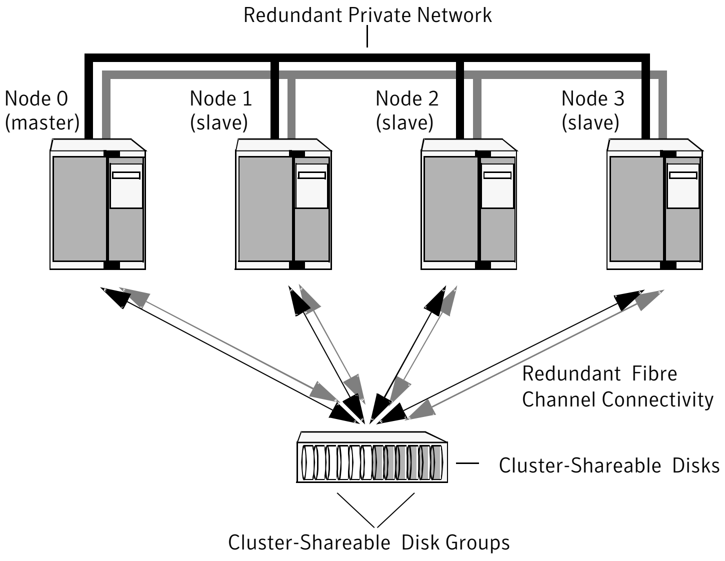
Note: RAID-5 volumes are not supported on a shared disk group.

Figure 2-2 illustrates a simple cluster arrangement consisting of four nodes with similar or identical hardware characteristics (CPUs, RAM and host adapters), and configured with identical software (including the operating system).

The nodes are fully connected by a private network and they are also separately connected to shared external storage (either disk arrays or JBODs: just a bunch of disks) via Fibre Channel. Each node has two independent paths to these disks, which are configured in one or more cluster-shareable disk groups.

The private network allows the nodes to share information about system resources and about each other's state. Using the private network, any node can recognize which nodes are currently active, which are joining or leaving the cluster, and which have failed. The private network requires at least two communication channels to provide redundancy against one of the channels failing. If only one channel were used, its failure would be indistinguishable from node failure—a condition known as network partitioning.

Figure 2-2 Example of a four node cluster


Redundant Private Network
Node 0 (master)
Node 1 (slave)
Node 2 (slave)
Node 3 (slave)
Redundant Fibre Channel Connectivity
Cluster-Shareable Disks
Cluster-Shareable Disk Groups

To the cluster monitor, all nodes are the same. VxVM objects configured within shared disk groups can potentially be accessed by all nodes that join the cluster. However, the cluster functionality of VxVM requires one node to act as the master node; all other nodes in the cluster are slave nodes. Any node is capable of being the master node, which is responsible for coordinating certain VxVM activities.

Note: You must run commands that configure or reconfigure VxVM objects on the master node. Tasks that must be initiated from the master node include setting up shared disk groups and creating and reconfiguring volumes.

VxVM designates the first node to join a cluster the master node. If the master node leaves the cluster, one of the slave nodes is chosen to be the new master. In the preceding example, node 0 is the master node and nodes 1, 2 and 3 are slave nodes.

Shared disk groups overview

This section provides an overview of shared disk groups.

This section includes the following topics:

- Private and shared disk groups
- Activation modes of shared disk groups
- Connectivity policy of shared disk groups
- Limitations of shared disk groups

Private and shared disk groups

Table 2-2 describes the disk group types.

Table 2-2 Disk group types

Disk group	Description
Private	Belongs to only one node. A private disk group is only imported by one system. Disks in a private disk group may be physically accessible from one or more systems, but import is restricted to one system only. The root disk group is always a private disk group.
Shared	Is shared by all nodes. A shared (or cluster-shareable) disk group is imported by all cluster nodes. Disks in a shared disk group must be physically accessible from all systems that may join the cluster.

In a cluster, most disk groups are shared. Disks in a shared disk group are accessible from all nodes in a cluster, allowing applications on multiple cluster nodes to simultaneously access the same disk. A volume in a shared disk group can be simultaneously accessed by more than one node in the cluster, subject to licensing and disk group activation mode restrictions.

You can use the `vxdg` command to designate a disk group as cluster-shareable. When a disk group is imported as cluster-shareable for one node, each disk header is marked with the cluster ID. As each node subsequently joins the cluster, it recognizes the disk group as being cluster-shareable and imports it. You can also import or deport a shared disk group at any time; the operation takes places in a distributed fashion on all nodes.

Each physical disk is marked with a unique disk ID. When cluster functionality for VxVM starts on the master, it imports all shared disk groups (except for any that have the `noautoimport` attribute set). When a slave tries to join a cluster, the master sends it a list of the disk IDs that it has imported, and the slave checks to see if it can access them all. If the slave cannot access one of the listed disks, it abandons its attempt to join the cluster. If it can access all of the listed disks, it imports the same shared disk groups as the master and joins the cluster. When a node leaves the cluster, it deports all its imported shared disk groups, but they remain imported on the surviving nodes.

Reconfiguring a shared disk group is performed with the co-operation of all nodes. Configuration changes to the disk group happen simultaneously on all nodes and the changes are identical. Such changes are atomic in nature, which means that they either occur simultaneously on all nodes or not at all.

Whether all members of the cluster have simultaneous read and write access to a cluster-shareable disk group depends on its activation mode setting.

The data contained in a cluster-shareable disk group is available as long as at least one node is active in the cluster. The failure of a cluster node does not affect access by the remaining active nodes. Regardless of which node accesses a cluster-shareable disk group, the configuration of the disk group looks the same.

Note: Applications running on each node can access the data on the VM disks simultaneously. VxVM does not protect against simultaneous writes to shared volumes by more than one node. It is assumed that applications control consistency (by using Veritas Storage Foundation Cluster File System or a distributed lock manager, for example).

Activation modes of shared disk groups

A shared disk group must be activated on a node in order for the volumes in the disk group to become accessible for application I/O from that node. The ability of applications to read from or to write to volumes is dictated by the activation mode of a shared disk group. Valid activation modes for a shared disk group are `exclusivewrite`, `readonly`, `sharedread`, `sharedwrite`, and `off` (inactive).

Note: The default activation mode for shared disk groups is `off` (inactive).

Special uses of clusters, such as high availability (HA) applications and off-host backup, can use disk group activation to explicitly control volume access from different nodes in the cluster.

Table 2-3 describes activation modes for shared disk groups.

Table 2-3 Activation modes for shared disk groups

Activation mode	Description
`exclusivewrite (ew)`	The node has exclusive write access to the disk group. No other node can activate the disk group for write access.
`readonly (ro)`	The node has read access to the disk group and denies write access for all other nodes in the cluster. The node has no write access to the disk group. Attempts to activate a disk group for either of the write modes on other nodes fail.
`sharedread (sr)`	The node has read access to the disk group. The node has no write access to the disk group, however other nodes can obtain write access.
`sharedwrite (sw)`	The node has write access to the disk group.
`off`	The node has neither read nor write access to the disk group. Query operations on the disk group are permitted.

Table 2-4 summarizes the allowed and conflicting activation modes for shared disk groups.

Table 2-4 Allowed and conflicting activation modes

Disk group activated in cluster as...	exclusive-write	readonly	sharedread	sharedwrite
exclusivewrite	Fails	Fails	Succeeds	Fails
readonly	Fails	Succeeds	Succeeds	Fails
sharedread	Succeeds	Succeeds	Succeeds	Succeeds
sharedwrite	Fails	Fails	Succeeds	Succeeds

To share disk groups

- Shared disk groups can be automatically activated in any mode during disk group creation or during manual or auto-import. To control auto-activation of shared disk groups, the defaults file `/etc/default/vxdg` must be created. The defaults file `/etc/default/vxdg` must contain the following lines:

```
enable_activation=true
default_activation_mode=activation-mode
```

The activation-mode is one of `exclusivewrite`, `readonly`, `sharedread`, `sharedwrite`, or `off`.

When a shared disk group is created or imported, it is activated in the specified mode. When a node joins the cluster, all shared disk groups accessible from the node are activated in the specified mode.

The activation mode of a disk group controls volume I/O from different nodes in the cluster. It is not possible to activate a disk group on a given node if it is activated in a conflicting mode on another node in the cluster. When enabling activation using the defaults file, it is recommended that this file be made identical on all nodes in the cluster. Otherwise, the results of activation are unpredictable.

If the defaults file is edited while the `vxconfigd` daemon is already running, the `vxconfigd` process must be restarted for the changes in the defaults file to take effect.

If the default activation mode is anything other than `off`, an activation following a cluster join, or a disk group creation or import can fail if another node in the cluster has activated the disk group in a conflicting mode.

To display the activation mode for a shared disk group, use the `vxdg list` command.

You can also use the `vxdg` command to change the activation mode on a shared disk group.

See the *Veritas Volume Manager Administrator's Guide*.

Connectivity policy of shared disk groups

The nodes in a cluster must always agree on the status of a disk. In particular, if one node cannot write to a given disk, all nodes must stop accessing that disk before the results of the write operation are returned to the caller. Therefore, if a node cannot contact a disk, it should contact another node to check on the disk's status. If the disk fails, no node can access it and the nodes can agree to detach the disk. If the disk does not fail, but rather the access paths from some of the nodes fail, the nodes cannot agree on the status of the disk.

Table 2-5 describes the policies for resolving this type of discrepancy.

Table 2-5 Policies

Policy	Description
Global	The detach occurs cluster-wide (globally) if any node in the cluster reports a disk failure. This is the default policy.

Table 2-5 Policies *(continued)*

Policy	Description
Local	In the event of disks failing, the failures are confined to the particular nodes that saw the failure. However, this policy is not highly available because it fails the node even if one of the mirrors is available. Note that an attempt is made to communicate with all nodes in the cluster to ascertain the disks' usability. If all nodes report a problem with the disks, a cluster-wide detach occurs.

Limitations of shared disk groups

The cluster functionality of VxVM does not support RAID-5 volumes, or task monitoring for cluster-shareable disk groups. These features can, however, be used in private disk groups that are attached to specific nodes of a cluster. Online relayout is supported provided that it does not involve RAID-5 volumes.

The root disk group cannot be made cluster-shareable. It must be private.

Only raw device access may be performed via the cluster functionality of VxVM. It does not support shared access to file systems in shared volumes unless the appropriate software, such as Veritas Storage Foundation Cluster File System, is installed and configured.

If a shared disk group contains unsupported objects, deport it and then re-import the disk group as private on one of the cluster nodes. Reorganize the volumes into layouts that are supported for shared disk groups, and then deport and re-import the disk group as shared.

Chapter 3

Storage Foundation Cluster File System administration

This chapter includes the following topics:

About Storage Foundation Cluster File System administration

The Veritas Storage Foundation Cluster File System is a shared file system that enables multiple hosts to mount and perform file operations concurrently on the same file. To operate in a cluster configuration, SFCFS requires the integrated set of Veritas products included in the Veritas Storage Foundation Cluster File System.

To configure a cluster, SFCFS requires the Veritas Cluster Server (VCS). VCS supplies two major components integral to SFCFS. The LLT package provides node-to-node communications and monitors network communications. The GAB package provides cluster state, configuration, and membership service, and monitors the heartbeat links between systems to ensure that they are active. There are several other packages supplied by VCS that provide application failover support when installing SFCFS HA.

See the *Veritas Storage Foundation Cluster File System Installation Guide*.

SFCFS also requires the cluster functionality (CVM) of the Veritas Volume Manager (VxVM) to create the shared volumes necessary for mounting cluster file systems.

For more information on these products, refer to the *Veritas Volume Manager* and *Veritas Cluster Server* documentation.

Veritas Cluster Server overview

The Veritas Cluster Server (VCS) provides the communication, configuration, and membership services required to create a cluster. VCS is the first component installed and configured to set up a cluster file system.

Group membership and atomic broadcast (GAB) and Low Latency Transport (LLT) are VCS-specific protocols implemented directly on an Ethernet data link or on a Fibre Channel fabric. Both GAB and LLT run over redundant data links that connect all the servers in a cluster. VCS requires redundant cluster communication links to minimize the possibility of cluster failure due to the failure of a single communication link.

About Group Membership and Atomic Broadcast

Group Membership and Atomic Broadcast (GAB) provides membership and messaging service, both for the cluster as a whole and for groups of applications running it. The GAB membership service provides orderly startup and shutdown of a cluster.

The file `/etc/gabtab` is used to configure GAB. Configuration is done with the `gabconfig` command. For example, the `-n` option of the command specifies the number of nodes in the cluster. GAB is configured automatically when you run the VCS installation script, but you may have to reconfigure GAB when you add a node to a cluster.

See the `gabconfig`(1M) manual page.

About Low Latency Transport

Low Latency Transport (LLT) provides kernel-to-kernel communications and monitors network communications. The LLT files `/etc/llthosts` and `/etc/llttab` can be configured to set system IDs within a cluster, set cluster IDs for multiple clusters, and tune network parameters such as heartbeat frequency. LLT is implemented so that events such as state changes are reflected quickly, which in turn enables fast responses.

As with GAB, LLT is configured automatically when you run the VCS installation script. The file `/etc/llttab` contains information derived from what you input during installation. You may also have to reconfigure LLT when you add a node to a cluster.

See the `llttab`(4) manual page.

Veritas Volume Manger cluster functionality overview

The cluster functionality (CVM) of the Veritas Volume Manager allows multiple hosts to concurrently access and manage a given set of logical devices under VxVM control. A VxVM cluster is a set of hosts sharing a set of devices; each host is a node in the cluster. The nodes are connected across a network. If one node fails, other nodes can still access the devices. The VxVM cluster feature presents the same logical view of the device configurations, including changes, on all nodes.

You configure CVM shared storage after VCS sets up a cluster configuration.

See "About Veritas Volume Manager cluster functionality administration" on page 91.

See the *Veritas Volume Manager Administrator's Guide*.

Storage Foundation Cluster File System overview

A file system cluster consists of one primary, and up to 15 secondaries. The primary-secondary terminology applies to one file system, not to a specific node (or hardware platform). You can have the same cluster node be primary for one shared file system, while at the same time it is secondary for another shared file system. Such distribution of file system primaryship to balance the load on a cluster is a recommended administrative policy.

See "Distribute the load on a cluster" on page 42.

For CVM, a single cluster node is the master for all shared disk groups and shared volumes in the cluster.

Setting the number of parallel fsck threads

This section describes how to set the number of parallel fsck threads.

The number of parallel fsck threads that could be active during recovery was set to 4. For example, if a node failed over 12 file systems, log replay for the 12 file systems will not complete at the same time. The number was set to 4 since parallel replay of a large number of file systems would put memory pressure on systems with less memory. However, on larger systems the restriction of 4 parallel processes replaying is not necessary.

This value gets tuned in accordance with available physical memory in the system.

To set the number of parallel fsck threads

◆ On all nodes in the cluster, edit the `/opt/VRTSvcs/bin/CFSfsckd/CFSfsckd.env` file and set `FSCKD_OPTS="-n` *`N`*`"`.

  where *N* is the number of parallel fsck threads desired and value of *N* has to be between 4 and 128.

Cluster and shared mounts

A VxFS file system that is mounted with the `mount -o cluster` option is called a cluster or shared mount, as opposed to a non-shared or local mount. A file system mounted in shared mode must be on a VxVM shared volume in a cluster environment. A local mount cannot be remounted in shared mode and a shared mount cannot be remounted in local mode. File systems in a cluster can be mounted with different read-write options. These are called asymmetric mounts.

Determining or moving primaryship

The first node of a cluster file system to mount is called the primary node. Other nodes are called secondary nodes. If a primary node fails, an internal election process determines which of the secondaries becomes the primary file system.

To determine primaryship

- To determine primaryship, type the following command:

```
# fsclustadm -v showprimary mount_point
```

To give primaryship to a node

- To give primaryship to a node, type the following command:

```
# fsclustadm -v setprimary mount_point
```

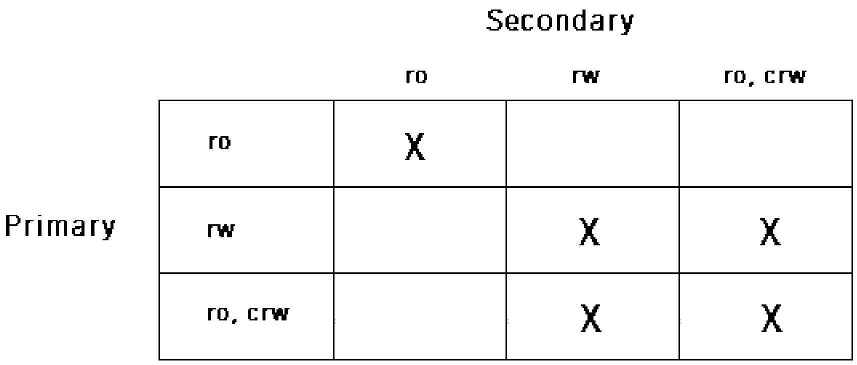
Asymmetric mounts

Asymmetric mounts allow shared file systems to be mounted with different read/write capabilities. So one node in the cluster can mount read-write, while other nodes mount read-only.

You can specify the cluster read-write (`crw`) option when you first mount the file system, or the options can be altered when doing a remount (`mount -o remount`). The first column in the following table shows the mode in which the primary is mounted. The check marks indicate the mode secondary mounts can use.

Asymmetric mounts describes the first column in the following table shows the mode in which the primary is mounted:

Figure 3-1 Primary and secondary mounts



		Secondary		
		ro	rw	ro, crw
Primary	ro	X		
	rw		X	X
	ro, crw		X	X

Only mounting the primary with `-o cluster,ro` prevents the secondaries from mounting in a different mode, that is, read-write mode. Note that `rw` implies read-write capability throughout the cluster.

See the `mount_vxfs`(1M) manual page.

Storage Foundation Cluster File System and Veritas Volume Manager cluster functionality agents

Agents are VCS processes that manage predefined resource types. SFCFS and CVM require agents to interact with VCS. Agents bring resources online, take resources offline, monitor resources, and report any state changes to VCS. VCS bundled agents are part of VCS and are installed when VCS is installed. The SFCFS and CVM agents are add-on resources to VCS specifically for the Veritas File System and Veritas Volume Manager.

See “About agents for Storage Foundation Cluster File System” on page 101.

Storage Foundation Cluster File System administration commands

This section describes some of the major aspects of cluster file system administration.

This section includes the following topics:

- Storage Foundation Cluster File System commands
- Veritas File System Commands

Storage Foundation Cluster File System commands

Table 3-1 describes the SFCFS commands.

Table 3-1 SFCFS commands

Commands	Description
cfscluster	Cluster configuration command
cfsmntadm	Adds, deletes, modifies, and sets policy on cluster mounted file systems
cfsdgadm	adds or deletes shared disk groups to/from a cluster configuration
cfsmount	mounts a cluster file system on a shared volume
cfsumount	unmounts a cluster file system on a shared volume

mount and fsclusteradm commands

The `mount` and `fsclustadm` commands are important for configuring cluster file systems.

mount

The `mount` command with the `-o cluster` option lets you access shared file systems.

See the `mount_vxfs`(1M) manual page.

fsclustadm

The `fsclustadm` command reports various attributes of a cluster file system. Using `fsclustadm` you can show and set the primary node in a cluster, translate node IDs to host names and vice versa, list all nodes that currently have a cluster mount of the specified file system mount point, and determine whether a mount is a local or cluster mount. The `fsclustadm` command operates from any node in a cluster on which the file system is mounted, and can control the location of the primary for a specified mount point.

See the `fsclustadm`(1M) manual page.

fsadm

The `fsadm` command can be invoked from the primary or secondary node.

See the `fsadm_vxfs`(1M) manual page.

Run commands safely in a cluster environment

Any UNIX command that can write to a raw device must be used carefully in a shared environment to prevent data from being corrupted. For shared VxVM volumes, SFCFS provides protection by reserving the volumes in a cluster to prevent VxFS commands, such as `fsck` and `mkfs`, from inadvertently damaging a mounted file system from another node in a cluster. However, commands such as `dd` execute without any reservation, and can damage a file system mounted from another node. Before running this kind of command on a file system, be sure the file system is not mounted on a cluster. You can run the `mount` command to see if a file system is a shared or local mount.

Time synchronization for Cluster File Systems

SFCFS requires that the system clocks on all nodes are synchronized using some external component such as the Network Time Protocol (NTP) daemon. If the nodes are not in sync, timestamps for creation (`ctime`) and modification (`mtime`) may not be consistent with the sequence in which operations actually happened.

Growing a Storage Foundation Cluster File System

There is a master node for CVM as well as a primary for SFCFS. When growing a file system, you grow the volume from the CVM master, and then grow the file system from any SFCFS node. The CVM master and the SFCFS node can be different nodes.

To determine the primary file system in a cluster

- To determine the primary file system in a cluster, type the following command:

  ```
  # fsclustadm -v showprimary mount_point
  ```

To determine that the current node is the master CVM node

- To determine if the current node is the master CVM node, type the following comannd:

  ```
  # vxdctl -c mode
  ```

To actually increase the size of the file system

1. On the master CVM node, type the following command:

   ```
   # vxassist -g shared_disk_group growto volume_name newlength
   ```

2. On any SFCFS node, type the following command:

   ```
   # fsadm -F vxfs -b newsize -r device_name mount_point
   ```

The fstab file

In the `/etc/fstab` file, do not specify any cluster file systems to mount-at-boot because mounts initiated from `fstab` occur before cluster configuration begins. For cluster mounts, use the VCS configuration file to determine which file systems to enable following a reboot.

Distribute the load on a cluster

Distributing the workload in a cluster provides performance and failover advantages.

For example, if you have eight file systems and four nodes, designating two file systems per node as the primary would be beneficial. Primaryship is determined by which node first mounts the file system. You can also use the `fsclustadm` to designate a SFCFS primary. The `fsclustadm setprimary` command can also define the order in which primaryship is assumed if the current primary fails. After setup, the policy is in effect as long as one or more nodes in the cluster have the file system mounted.

GUIs

Use the Veritas Enterprise Administrator (VEA) for various VxFS functions such as making and mounting file systems, on both local and cluster file systems.

With SFCFS HA, you can use the VCS Cluster Manager GUI to configure and monitor SFCFS. The VCS GUI provides log files for debugging LLT and GAB events.

Snapshots on Storage Foundation Cluster File System

A snapshot provides a consistent point-in-time image of a VxFS file system. A snapshot can be accessed as a read-only mounted file system to perform efficient online backups of the file system. Snapshots implement copy-on-write semantics that incrementally copy data blocks when they are overwritten on the snapped file system.

See the *Veritas File System Administrator's Guide*.

Snapshots for cluster file systems extend the same copy-on-write mechanism for the I/O originating from any node in the cluster.

Cluster snapshot characteristics

A cluster snapshot has the following characteristics:

- A snapshot for a cluster mounted file system can be mounted on any node in a cluster. The file system can be a primary, secondary, or secondary-only. A stable image of the file system is provided for writes from any node.
- Multiple snapshots of a cluster file system can be mounted on the same or a different node in a cluster.
- A snapshot is accessible only on the node mounting a snapshot. The snapshot device cannot be mounted on two different nodes simultaneously.
- The device for mounting a snapshot can be a local disk or a shared volume. A shared volume is used exclusively by a snapshot mount and is not usable from other nodes in a cluster as long as the snapshot is active on that device.
- On the node mounting a snapshot, the snapped file system cannot be unmounted while the snapshot is mounted.
- A SFCFS snapshot ceases to exist if it is unmounted or the node mounting the snapshot fails. A snapshot, however, is not affected if any other node leaves or joins the cluster.
- A snapshot of a read-only mounted file system cannot be taken. It is possible to mount snapshot of a cluster file system only if the snapped cluster file system is mounted with the `crw` option.

Performance considerations

Mounting a snapshot file system for backup increases the load on the system because of the resources used to perform copy-on-writes and to read data blocks from the snapshot. In this situation, cluster snapshots can be used to do off-host backups. Off-host backups reduce the load of a backup application from the primary server. Overhead from remote snapshots is small when compared to overall snapshot overhead. Therefore, running a backup application by mounting a snapshot from a relatively less loaded node is beneficial to overall cluster performance.

Creating a snapshot on a Storage Foundation Cluster File System

To create and mount a snapshot on a two-node cluster using SFCFS administrative interface commands.

To create a snapshot on a cluster file system

1. To create a VxFS file system on a shared VxVM volume, type the following command:

   ```
   # mkfs -F vxfs /dev/vx/rdsk/cfsdg/vol1
   ```

   ```
   version 7 layout
   15728640 sectors, 15728640 blocks of size 1024, log size 16384 blocks
   largefiles supported
   ```

2. To mount the file system on all nodes, type the following commands:

   ```
   # cfsmntadm add cfsdg vol1 /mnt1 all=cluster
   # cfsmount /mnt1
   ```

   The `cfsmntadm` command adds an entry to the cluster manager configuration, then the `cfsmount` command mounts the file system on all nodes.

3. Add the snapshot on a previously created volume (`snapvol` in this example) to the cluster manager configuration. For example:

   ```
   # cfsmntadm add snapshot cfsdg snapvol /mnt1 /mnt1snap system01=ro
   ```

   The snapshot of a cluster file system is accessible only on the node where it is created; the snapshot file system itself cannot be cluster mounted.

4 Create and locally mount the snapshot file system on system01, type the following command:

```
# cfsmount /mnt1snap
```

5 A snapped file system cannot be unmounted until all of its snapshots are unmounted. Unmount and destroy the snapshot before trying to unmount the snapped cluster file system, type the following command:

```
# cfsumount /mnt1snap
```

Adding a node to a cluster

If you want to add a new node to a multi-node cluster, first prepare the new system hardware. Physically connect the new node to the cluster using private networks and attach to any shared storage. Then install the required OS software. Install all the prerequisite patches.

Note: For a cluster to work correctly, all nodes must have the same time. If you are not running the Network Time Protocol (NTP) daemon, make sure the time on all the nodes comprising your cluster is synchronized.

To add a node to a cluster

1 Log into the new node as superuser.

2 Determine the block device file for the DVD drive:

```
# ioscan -fnC disk
```

Make a note of the device file as it applies to your node.

3 Run the following commands to start Portable File System (PFS):

```
# nohup pfs_mountd &
# nohup pfsd &
```

4 Create a directory in which to mount the software disc and mount the disc using the appropriate drive name. For example:

```
# mkdir -p /dvdrom
# /usr/sbin/mount -F cdfs /dev/dsk/c3t2d0 /dvdrom
```

5 Add `/opt/VRTS/bin` to your `PATH` and `/opt/VRTS/man` to your `MANPATH` environment variables.

6 Change to the SFCFS directory.

```
# cd sfcfs
```

7 Run the `installsfcfs` script with `-installonly` option to install all the required SFCFS packages on the new node.

```
# ./installsfcfs -installonly
```

8 Enter **y** to install SFCFS on these systems.

```
Do you want to install SFCFS on these systems? [y,n,q] (y)
```

9 Enter the system name of the new node to install SFCFS.

```
Enter the system names separted by spaces on which to install
SFCFS: system03
```

10 Enter a license key for the new node.

```
Enter a SFCFS license key for system03:[?]
XXXX-XXXX-XXXX-XXXX-XXXX-X
```

11 Enter **y** or **n** for another license key. You are prompted to press Return to continue.

```
Do you want to enter another license key for system03?
[y,n,q,?] (n)
```

12 Enter `1` or `2` to be installed on all systems.

```
Select the packages to be installed on all systems?
[1-2,q,?] (2)
```

13 Press Return to continue.

```
Press [Return] to continue:
```

Do not reboot the machine now.

14 Create the `/etc/llttab` file the same as it looks on another node in the cluster.

- Change the `set-node` line to the name of the new node, set the `set-cluster` line to the cluster ID, and specify that the LAN ports for the public and private networks are configured the same as on the other cluster nodes:

  ```
  set-node system03
  set-cluster 100

  link lan1 /dev/lan:1 - ether - -
  link lan2 /dev/lan:2 - ether - -
  ```

- Copy `/etc/llthosts` from one other node of the cluster and add a new line to it with the name of this node.
- Edit the `/etc/llthosts` file and add the new node to the file. For example:

  ```
  0 system01
  1 system02
  2 system03
  ```

- Copy the `/etc/llthosts` file from one of the existing systems over to the new system. The `/etc/llthosts` file must be identical on all nodes in the cluster.

15 Create an `/etc/gabtab` file and add the following command to the file:

```
/sbin/gabconfig -c -nN
```

Where *N* is the number of nodes in the cluster. For a three node cluster, *N* would equal 3.

16 There is no need to reboot the other nodes, just update the `/etc/gabtab` file on the other nodes in the cluster. Edit the `/etc/gabtab` file on each of the existing systems, changing the content to match the file on the new system.

17 Start VxVM on the system that has been added.

```
# vxinstall
```

18 After starting VxVM, proceed to Configuring Storage Foundation Cluster File System and Cluster Volume Manager agents on the new node.

Configuring Storage Foundation Cluster File System and Cluster Volume Manager agents on the new node

This section describes how to configure SFCFS and CVM agents on the new node.

To configure SFCFS and CVM agents on the new node

1. Verify if the `/etc/VRTSvcs/conf/config/.stale` file is present, before starting VCS.

   If the `/etc/VRTSvcs/conf/config/.stale` file is not present, enter:

   ```
   # touch /etc/VRTSvcs/conf/config/.stale
   ```

2. Start the VCS server and `vxfen` on the new node:

   - Start LLT and GAB on the new node:

     ```
     # /etc/init.d/llt start
     # /etc/init.d/gab start
     ```

   - For starting `vxfen` in the disable mode, run the following commands on system03:

     ```
     # echo vxfen_mode=disabled > /etc/vxfenmode
     # /sbin/init.d/vxfen start
     ```

   - For starting `vxfen` in the enabled mode:

     - Copy the following files from one of the existing cluster nodes to the new node:

       ```
       /etc/vxfenmode
       /etc/vxfendg
       ```

     - Run the following command:

       ```
       # /sbin/init.d/vxfen start
       ```

3. On the new node, verify that the GAB port memberships are `a` and `b`. Run the following command:

   ```
   # /sbin/gabconfig -a
   ```

4. Determine the CVM master node:

   ```
   # vxdctl -c mode
   ```

5. Make a backup copy of the `main.cf` file. Enter the following commands:

   ```
   # cd /etc/VRTSvcs/conf/config
   # cp main.cf main.cf.2node
   ```

6 Open the VCS configuration for writing and add the new node. For example:

```
# haconf -makerw
# hasys -add system03
```

7 Add the new node to the CVM system list and specify a failover priority of 2:

```
# hagrp -modify cvm SystemList -add system03 X
```

where *X* is one more than the index of the last system in System list of CVM service group in `/etc/VRTSvcs/conf/config/main.cf`.

8 Add the new node to the CVM AutoStartList:

```
# hagrp -modify cvm AutoStartList -add system03
```

9 Node ID can be obtained from `CVMNodeId` of `/etc/VRTSvcs/conf/config/main.cf`. Add the new node, `system03`, and its node ID, #, to the `cvm_clust` resource:

```
# hares -modify cvm_clust CVMNodeId -add system03 2
```

10 Write the new VCS configuration to disk:

```
# haconf -dump -makero
```

11 Verify the syntax of `main.cf` file:

```
# hacf -verify .
```

12 To enable the existing cluster to recognize the new node, execute on all the nodes in the cluster:

```
# /etc/vx/bin/vxclustadm -m vcs -t gab reinit
# /etc/vx/bin/vxclustadm nidmap
```

13 Start CVM on the newly added node.

- Determine the node ID:

  ```
  # cat /etc/llthosts
  ```

- Verify that this host ID is seen by the GAB module:

  ```
  # gabconfig -a
  ```

- Start the VCS engine.
  - If on the newly added node ports `f`, `u`, `v`, or `w` are present before `hastart`, then the newly added node must be rebooted to properly start VCS. To properly start VCS:

    ```
    # shutdown -r
    ```

  - If on the newly added node ports `f`, `u`, `v` or `w` were not present before `hastart`, then use the following command to start VCS:

    ```
    # hastart
    ```

14 Check the system status to see whether the new node is online:

```
# hastatus -sum
-- SYSTEM STATE
-- System          State        Frozen
A      system01   RUNNING      0
A      system02   RUNNING      0
A      system03   RUNNING      0

-- GROUP STATE
-- Group    System     Probed  AutoDisabled  State
B  cvm      system01   Y       N             ONLINE
B  cvm      system02   Y       N             ONLINE
B  cvm      system03   Y       N             ONLINE
```

15 Add shared disk groups to the cluster configuration:

```
# cfsdgadm add cfsdg system03=sw
```

16 Create a `/mnt` on system03 and run the following commands for the shared mount points:

```
# cfsmntadm modify /mnt add system03=rw
```

See `cfsmntadm`(1M) manual page.

17 Use the`cfsmount` command to cluster mount `/mnt` on the new node:

```
# cfsmount /mnt
```

Removing a node from a cluster

This section describes how to remove a node from a cluster. As in previous examples, the following removes the node system03 from a three-node cluster. The procedure can be done from any node remaining in the cluster or from a remote host.

To remove a node from a cluster

1. Log in as superuser on a node other than system03.
2. Use the `cfsumount` command to unmount the file system `/mnt` on all the nodes:

   ```
   # cfsumount /mnt system03
   ```

3. Stop all the cluster components:

   ```
   # cfscluster stop -f system03
   ```

4. Open the VCS configuration for writing:

   ```
   # haconf -makerw
   ```

5. Remove system03 from the system list attribute of the CVM and SFCFS service groups:

   ```
   # hagrp -modify service_group SystemList -delete system03
   # hagrp -modify cvm SystemList -delete system03
   ```

   where *service_group* is the name of the service group displayed by the `hagrp -dep cvm` command.
6. Write the new VCS configuration to disk:

   ```
   # haconf -dump -makero
   ```

7. Edit the `/etc/llthosts` file on the remaining nodes of the cluster, and remove the entry corresponding to the node being removed.
8. Edit the `/etc/gabtab` file on the remaining nodes of the cluster and edit the `gabconfig` command to reflect the correct and new number of nodes in the cluster.

9 Login to system03 and remove the following files:

```
# rm /etc/vxfenmode
# rm /etc/llthosts
# rm /etc/llttab
# rm /etc/gabtab
```

10 If fencing was enabled on the cluster, run the following commands:

```
# rm /etc/vxfentab
# rm /etc/vxfendg
```

11 If necessary, modify the `/etc/gabtab` file. No change is required to this file if the `/sbin/gabconfig` command has only the argument `-c`, although Symantec recommends using the `-nN` option, where *N* is the number of cluster nodes. If the command has the form `/sbin/gabconfig -c -nN`, where *N* is the number of cluster nodes, then make sure that *N* is not greater than the actual number of nodes in the cluster, or GAB does not automatically seed.

Modify `/etc/llthosts` file on each remaining nodes to remove the entry of the leaving node.

12 Reboot system03:

```
# /usr/sbin/shutdown -r now
```

13 Change to the `install` directory:

```
# cd /opt/VRTS/install
```

14 Run the `uninstallsfcfs` script and remove SFCFS on system03:

```
# ./uninstallsfcfs
```

If you do not want to remove the Veritas Cluster Server software, enter **n** when prompted to uninstall VCS.

See the *Veritas Cluster Server Installation Guide*.

Fencing administration

This chapter includes the following topics:

About I/O fencing

Symantec recommends configuring the cluster with I/O fencing enabled. I/O fencing requires shared devices to support SCSI-3 Persistent Reservations (PR). Enabling I/O fencing prevents data corruption caused by a split brain scenario.

Storage Foundation Cluster File System is supported without I/O fencing enabled. However, without I/O fencing enabled, split brain scenarios can result in data corruption.

I/O fencing allows write access to members of the active cluster and blocks access to non-members. The physical components of I/O fencing are data disks and coordinator disks. Each has a unique purpose and uses different physical disk devices.

See the *Veritas Cluster Server Installation Guide*.

See the Hardware Compatibility List (HCL) at the following URL:

http://entsupport.symantec.com/docs/330441

Data disks

Data disks are standard disk devices used for data storage. These can be physical disks or RAID Logical Units (LUNs). These disks must support SCSI-3 PGR. Data disks are incorporated in standard VxVM/CVM disk groups. CVM is responsible for fencing data disks on a disk-group basis. Because VxVM enables I/O fencing, several other features are also provided. Disks added to a group are automatically fenced, as are new paths to a device.

Coordinator Disks

Coordinator disks are special-purpose disks. They comprise three (or an odd number greater than three) standard disks, or LUNs, set aside for use by I/O fencing during cluster reconfiguration.

The coordinator disks act as a global lock device during a cluster reconfiguration. This lock mechanism determines which node is allowed to fence off data drives from other nodes. From a high level, a system must eject a peer from the coordinator disks before it can fence the peer from the data drives. This concept of “racing” for control of coordinator disks is the key to understanding how fencing helps prevent split-brain.

Coordinator disks cannot be used for any other purpose. You cannot store data on them, or include them in a disk group for user data. They can be any three disks that support SCSI-3 PGR. Symantec recommends the coordinator disks use the smallest LUNs. Because coordinator disks do not store data, cluster nodes need only register with them, not reserve them.

Before you configure coordinator disks

I/O fencing requires coordinator disks to be configured in a disk group that each cluster system can access. The use of coordinator disks enables the `vxfen` driver to resolve potential split-brain conditions and prevent data corruption. A coordinator disk is not used for data storage, so it can be configured as the smallest LUN on a disk array to avoid wasting space.

Coordinator disks must meet the following requirements:

- There must be at least three coordinator disks and the total number of coordinator disks must be an odd number. This ensures a majority of disks can be achieved.
- Each of the coordinator disks must use a physically separate disk or LUN.
- Each of the coordinator disks should be on a different disk array, if possible.
- Coordinator disks in a disk array should use hardware-based mirroring.
- The coordinator disks must support SCSI-3 PR.

Note: The use of the `vxfentsthdw` utility to test for SCSI-3 PR support requires that disks be 1MB or greater. Smaller disks can be tested manually.

Contact Technical Support for the procedure.

See "Contacting Technical Support" on page 4.

Preparing to configure I/O fencing

Perform the following preparatory task to configure I/O fencing:

Initialize disks as VxVM disks	See "Initializing disks as VxVM disks" on page 55.
Requirements for testing the coordinator disk group	See "Requirements for testing the coordinator disk group" on page 57.
Testing the disks using vxfentsthdw utility	

Initializing disks as VxVM disks

This section describes how to initialize disk as VxVM disks.

Install the driver and HBA card. Refer to the documentation from the vendor for instructions.

After you physically add shared disks to the nodes, you must do the following:

- Initialize them as VxVM disks
- Verify that all the nodes see the same disk

See the *Veritas Volume Manager Administrator's Guide* for more information on how to add and configure disks.

To initialize disks as VxVM disks

1 Make the new disks recognizable. On each node, enter:

```
# ioscan -nfC disk
# insf -e
```

Warning: The HP-UX man page for the `insf` command instructs you to run the command in single-user mode only. You can run `insf -e` in multiuser mode only when no other user accesses any of the device files. This command can change the mode, owner, or group of an existing special (device) file, or unlink and recreate a file. The special files that are currently open may be left in an indeterminate state.

---

2 If the Array Support Library (ASL) for the array that you add is not installed, obtain and install it on each node before proceeding.

The ASL for the supported storage device that you add is available from the disk array vendor or Symantec technical support.

3 Verify that the ASL for the disk array is installed on each of the nodes. Run the following command on each node and examine the output to verify the installation of ASL.

The following output is a sample:

```
# vxddladm listsupport all
LIBNAME                      VID
==============================================================

libvxautoraid.sl             HP
libvxCLARiiON.sl             DGC
libvxemc.sl                  EMC
```

4 Scan all disk drives and their attributes, update the VxVM device list, and reconfigure DMP with the new devices. Type:

```
# vxdisk scandisks
```

See the Veritas Volume Manager documentation for details on how to add and configure disks.

5 To initialize the disks as VxVM disks, use one of the following methods:

- Use the interactive vxdiskadm utility to initialize the disks as VxVM disks. For more information see the *Veritas Volume Managers Administrator's Guide*.

- Use the `vxdisksetup` command to initialize a disk as a VxVM disk.

  ```
  vxdisksetup -i device_name
  ```

  The example specifies the CDS format:

  ```
  # vxdisksetup -i c2t13d0
  ```

  Repeat this command for each disk you intend to use as a coordinator disk.

Requirements for testing the coordinator disk group

Review the requirments for testing the coordinator disk group.

Run the vxfentsthdw utility

Review the following guidelines on testing support for SCSI-3:

- The utility requires that the coordinator disk group be accessible from two systems. For example, if you have a four-system cluster, select any two systems for the test.
- If you configured ssh (SSH client) for the cluster nodes, `vxfentsthdw` can be used as long as `ssh` commands between nodes can execute without password prompting and confirmation.
  If you did not configure ssh, enable each node to have remote rsh access to the other nodes during installation and disk verification. On each node, placing a "+" character in the first line of the `/.rhosts` file gives remote access to the system running the install program. You can limit the remote access to specific nodes. Refer to the manual page for the `/.rhosts` file for more information.
  Remove the remote rsh access permissions after the installation and disk verification process.
- ssh is used by default and rsh is only used if you do use the `vxfentsthdw -n` command.
- To ensure both nodes are connected to the same disk during the test, use the `vxfenadm -i diskpath` command to verify the disk serial number.
- The `vxfentsthdw` utility has additional options suitable for testing many disks. You can test disks without destroying data using the `-r` option. The options for testing disk groups (`-g`) and disks listed in a file (`-f`) are described in detail:

Setting up I/O fencing

Make sure you completed the preparatory tasks before you set up I/O fencing.

Tasks that are involved in setting up I/O fencing include:

Table 4-1 Tasks to set up I/O fencing

Action	Description
Setting up coordinator disk groups	See "Setting up coordinator disk groups" on page 58.
Configuring I/O fencing	See "Configuring I/O fencing" on page 59.
Modifying ProductNameShort configuration to use I/O fencing	See "Modifying VCS configuration to use I/O fencing" on page 60.
Start on all nodes	See "Starting I/O fencing, VCS, CVM, and CFS" on page 61.
Verifying GAB port membership	See "Verifying GAB port membership" on page 62.
Verifying I/O fencing configuration	See "Verifying I/O fencing configuration" on page 62.
Removing permissions for communication	See "Removing permissions for communication" on page 63.

Setting up coordinator disk groups

From one node, create a disk group named vxfencoorddg. This group must contain three disks or LUNs. If you use VxVM 5.0 or later, you must also set the coordinator attribute for the coordinator disk group. VxVM uses this attribute to prevent the reassignment of coordinator disks to other disk groups.

Note that if you create a coordinator disk group as a regular disk group, you can turn on the coordinator attribute in Volume Manager.

Refer to the *Veritas Volume Manager Administrator's Guide* for details on how to create disk groups.

The following example procedure assumes that the disks have the device names c1t0d0 , c2t1d0, and c3t1d0.

To create the vxfencoorddg disk group

1. On any node, create the disk group by specifying the device names:

   ```
   # vxdg init vxfencoorddg c1t0d0
   ```

   ```
   # vxdg -g vxfencoorddg adddisk c2t1d0
   ```

   ```
   # vxdg -g vxfencoorddg adddisk c3t1d0
   ```

2. If you use VxVM 5.0 or later, set the coordinator attribute value as "on" for the coordinator disk group.

   ```
   # vxdg -g vxfencoorddg set coordinator=on
   ```

Configuring I/O fencing

After you set up the coordinator disk group, you must do the following to configure I/O fencing:

- Create the I/O fencing configuration `/etc/vxfendg` file
- Update the I/O fencing configuration `/etc/vxfenmode` file

To update the I/O fencing files and start I/O fencing

1. Deport the coordinator disk group:

   ```
   # vxdg deport vxfencoorddg
   ```

2. Import the disk group with the `-t` option to avoid automatically importing it when the nodes restart:

   ```
   # vxdg -t import vxfencoorddg
   ```

3. Deport the disk group. Deporting the disk group prevents the coordinator disks from serving other purposes:

   ```
   # vxdg deport vxfencoorddg
   ```

4. On each nodes, type:

   ```
   # echo "vxfencoorddg" > /etc/vxfendg
   ```

   Do not use spaces between the quotes in the "vxfencoorddg" text.

   This command creates the `/etc/vxfendg` file that includes the name of the coordinator disk group.

5 Update the `/etc/vxfenmode` file to specify to use the SCSI-3 dmp disk policy. On all cluster nodes, type:

```
# cp /etc/vxfen.d/vxfenmode_scsi3_dmp /etc/vxfenmode
```

6 To check the updated `/etc/vxfenmode` configuration, enter the following command on one of the nodes. For example:

```
# more /etc/vxfenmode
```

Modifying VCS configuration to use I/O fencing

After you add coordinator disks and configure I/O fencing, add the UseFence = SCSI3 cluster attribute to the VCS configuration `/etc/VRTSvcs/conf/config/main.cf` file. If you reset this attribute to UseFence = None, VCS does not make use of I/O fencing abilities while failing over service groups. However, I/O fencing needs to be disabled separately.

To modify VCS configuration to enable I/O fencing

1 Save the existing configuration:

```
# haconf -dump -makero
```

2 Stop VCS on all nodes:

```
# hastop -all
```

3 If the I/O fencing driver vxfen is already running, on each node stop the I/O fencing driver.

```
# /sbin/init.d/vxfen stop
```

4 On all nodes, make a backup copy of the `main.cf` file:

```
# cd /etc/VRTSvcs/conf/config
# cp main.cf main.orig
```

5 On one node, use vi or another text editor to edit the `main.cf` file. To modify the list of cluster attributes, add the `UseFence` attribute and assign its value as `SCSI3`.

```
cluster clus1(
UserNames = { admin = "cDRpdxPmHpzS." }
Administrators = { admin }
HacliUserLevel = COMMANDROOT
CounterInterval = 5
UseFence = SCSI3
)
```

6 Save and close the file.

7 Verify the syntax of the `/etc/VRTSvcs/conf/config/main.cf` file:

```
# hacf -verify /etc/VRTSvcs/conf/config
```

8 Using rcp or another utility, copy the VCS configuration file from a node (for example, galaxy) to the remaining cluster nodes.

For example, on each remaining node, enter:

```
# rcp galaxy:/etc/VRTSvcs/conf/config/main.cf \
/etc/VRTSvcs/conf/config
```

Starting I/O fencing, VCS, CVM, and CFS

You must start I/O fencing, VCS, CVM, and CFS on all nodes in the cluster.

To start VCS, CVM, and CFS on a node

1 Start the I/O fencing driver. Run the following command on each node:

```
# /sbin/init.d/vxfen start
```

The vxfen startup script also invokes the `vxfenconfig` command that configures the vxfen driver to start and use the coordinator disks that are listed in `/etc/vxfentab` file.

2 With the configuration file in place on each system, start VCS, CVM, and CFS:

```
# hastart
```

Verifying GAB port membership

After setting up I/O fencing and starting VCS, CVM, and CFS on each node, verify GAB port membership.

To verify GAB port membership

- Run the `gabconfig -a` command.

  For example:

```
galaxy# gabconfig -a
GAB Port Memberships
===============================================================
Port a gen  ada401 membership 01
Port b gen  ada40d membership 01
Port d gen  ada409 membership 01
Port f gen  ada41c membership 01
Port h gen  ada40f membership 01
Port v gen  ada416 membership 01
Port w gen  ada418 membership 01
```

Verifying I/O fencing configuration

Verify from the vxfenadm output that the SCSI-3 disk policy reflects the configuration in the `/etc/vxfenmode` file.

To verify I/O fencing configuration

◆ On one of the nodes, type:

```
# vxfenadm -d

I/O Fencing Cluster Information:
================================

Fencing Protocol Version: 201
Fencing Mode: SCSI3
Fencing SCSI3 Disk Policy: dmp
Cluster Members:

   * 0 (galaxy)
   1 (nebula)

RFSM State Information:
   node 0 in state 8 (running)
   node 1 in state 8 (running)
```

Removing permissions for communication

Make sure you completed the installation of SFCFS and the verification of disk support for I/O fencing. If you used `remsh`, remove the temporary `remsh` access permissions that you set for the nodes and restore the connections to the public network.

If the nodes use `ssh` for secure communications, and you temporarily removed the connections to the public network, restore the connections.

Adding or removing coordinator disks

Before adding coordinator disks, verify the disks support SCSI-3 persistent reservations.

To add and remove coordinator disks

1. Log in as `root` on any cluster node.
2. Import the coordinator disk group. The file `/etc/vxfendg` includes the name of the disk group containing the coordinator disks. Type:

   ```
   # vxdg -tfC import `cat /etc/vxfendg`
   ```

   where:

-t	Specifies that the disk group is imported only until the system reboots.
-f	Specifies that the import is to be done forcibly, which is necessary if one or more disks is inaccessible.
-C	Specifies any import blocks are removed.

3. To add disks to, or remove them from, the disk group, use the VxVM disk administrator utility, `vxdiskadm`.
4. After disks are added or removed, deport the disk group:

   ```
   # vxdg deport `cat /etc/vxfendg`
   ```

5. Reboot each system in the cluster to make the coordinator disks accessible.

Verifying fenced configurations

Administrators can use the `vxfenadm` command to test and troubleshoot fenced configurations. The `vxfenadm` command includes the following options:

-d	Display current I/O fencing mode
-g	Read and display keys
-i	Read SCSI inquiry information from device
-m	Register with disks
-n	make a reservation with disks
-p	Remove registrations made by other systems
-r	Read reservations
-x	Remove registrations

Formatting the registration key

The key defined by VxVM associated with a disk group consists of seven bytes maximum. This key becomes unique among the systems when the VxVM prefixes it with the ID of the system. The key used for I/O fencing, therefore, consists of eight bytes.

Table 4-3 describes the keys currently assigned to the disks.

Table 4-2 The keys currently assigned to the disks

0	1	2	3	4	5	6	7
Node ID	VxVM Defined	VxVM Defined	VxVM Defined	VxVM Defined	VxVM Defined	VxVM Defined	VxVM Defined

To display keys currently assigned to disks

- To display keys currently assigned to disks from the system with node ID 1, type the following command:

```
# vxfenadm -g /dev/device_name
Reading SCSI Registration Keys...
Device Name: device_name
Total Number of Keys: 1
key[0]:
Key Value [Numeric Format]: 65,80,71,82,48,48,48,48
```

The `-g` option of `vxfenadm` displays the eight bytes of a key value in two formats. In the numeric format, the first byte, representing the node ID, contains the system ID plus 65. The remaining bytes contain the ASCII values of the key's letters. In this case, "PGR0000." In the next line, the node ID 0 is expressed as "A" and node ID 1 would be "B."

Disabling I/O fencing

You may have to disable fencing in the following cases:

- The cluster has been upgraded to the latest SFCFS stack and the storage does not support the SCSI-3 PGR feature.
- During installation fencing was turned on but later disabled.

By default, the VxFEN driver operates with I/O fencing enabled. To disable this feature without removing the coordinator disks, you must create the file `/etc/vxfenmode` and include a string within the file to notify the VxFEN driver.

To stop and restart the driver

1. To stop and restart the driver, type the following commands:

```
# echo "vxfen_mode=disabled" > /etc/vxfenmode

# /sbin/init.d/vxfen stop
# /sbin/init.d/vxfen start
```

2. Additionally, Veritas recommends removing the `/etc/vxfendg` file if fencing is to be later reenabled.

How I/O fencing works during different events

The following table describes how I/O fencing works to prevent data corruption during different failure scenarios. For each event, corrective actions are indicated.

Table 4-3 describes corrective actions to prevent data corruption.

Table 4-3 Corrective actions to prevent data corruption

Event	Node A: What Happens?	Node B: What Happens?	Action
All private networks fail.	Node A races for majority of coordinator disks. If Node A wins race for coordinator disks, Node A ejects Node B from the shared disks and continues.	Node B races for majority of coordinator disks. If Node B loses the race for the coordinator disks, Node B removes itself from the cluster.	When Node B is ejected from cluster, repair the private networks before attempting to bring Node B back.
All private networks function again after event above.	Node A continues to work.	Node B has crashed. It cannot start the database since it is unable to write to the data disks.	Reboot Node B after private networks are restored.
One private network fails.	Node A prints message about an IOFENCE on the console but continues.	Node B prints message on the console about jeopardy and continues.	Repair private network. After network is repaired, both nodes automatically use it.

Table 4-3 Corrective actions to prevent data corruption *(continued)*

Event	Node A: What Happens?	Node B: What Happens?	Action
Node A hangs.	Node A is extremely busy for some reason or is in the kernel debugger. When Node A is no longer hung or in the kernel debugger, any queued writes to the data disks fail because Node A is ejected. When Node A receives message from GAB about being ejected, it removes itself from the cluster.	Node B loses heartbeats with Node A, and races for a majority of coordinator disks. Node B wins race for coordinator disks and ejects Node A from shared data disks.	Verify private networks function and reboot Node A.
Nodes A and B and private networks lose power. Coordinator and data disks retain power. Power returns to nodes and they reboot, but private networks still have no power.	Node A reboots and I/O fencing driver (vxfen) detects Node B is registered with coordinator disks. The driver does not see Node B listed as member of cluster because private networks are down. This causes the I/O fencing device driver to prevent Node A from joining the cluster. Node A console displays: Potentially a preexisting split brain. Dropping out of the cluster. Refer to the user documentation for steps required to clear preexisting split brain.	Node B reboots and I/O fencing driver (vxfen) detects Node A is registered with coordinator disks. The driver does not see Node A listed as member of cluster because private networks are down. This causes the I/O fencing device driver to prevent Node B from joining the cluster. Node B console displays: Potentially a preexisting split brain. Dropping out of the cluster. Refer to the user documentation for steps required to clear preexisting split brain.	Refer to section in Troubleshooting chapter for instructions on resolving preexisting split brain condition.

Table 4-3 Corrective actions to prevent data corruption *(continued)*

Event	Node A: What Happens?	Node B: What Happens?	Action
Node A crashes while Node B is down. Node B comes up and Node A is still down.	Node A is crashed.	Node B reboots and detects Node A is registered with the coordinator disks. The driver does not see Node A listed as member of the cluster. The I/O fencing device driver prints message on console: Potentially a preexisting split brain. Dropping out of the cluster. Refer to the user documentation for steps required to clear preexisting split brain.	Refer to section in Troubleshooting chapter for instructions on resolving preexisting split brain condition.
The disk array containing two of the three coordinator disks is powered off.	Node A continues to operate as long as no nodes leave the cluster. Node A races for a majority of coordinator disks. Node A fails because only one of three coordinator disks is available. Node A removes itself from the cluster.	Node B continues to operate as long as no nodes leave the cluster. Node B leaves the cluster.	Power on failed disk array and restart I/O fencing driver to enable Node A to register with all coordinator disks.
Node B leaves the cluster and the disk array is still powered off.			

Troubleshooting fenced configurations

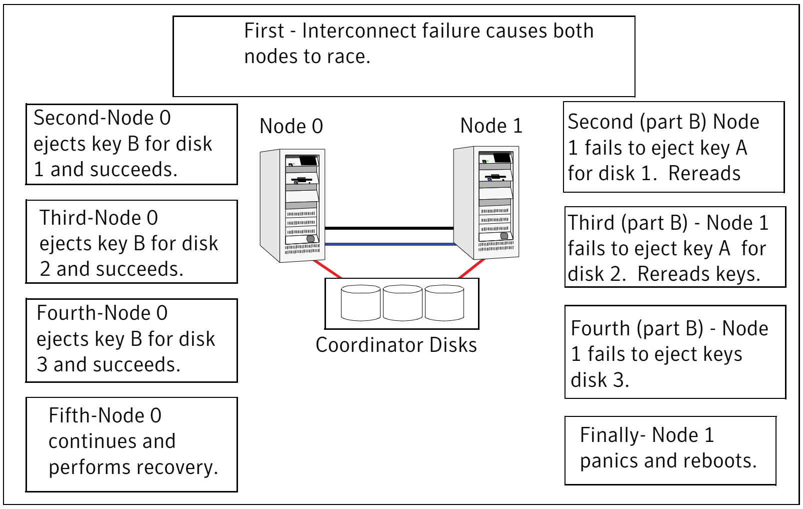
The following information describes network partitioning in a fenced environment.

See the *Veritas Cluster Server User's Guide*.

Example of a preexisting network partition (split-brain)

Figure 4-1 shows a two-node cluster in which the severed cluster interconnect poses a potential split-brain condition.

Figure 4-1 Preexisting network partition (split-brain)


First - Interconnect failure causes both nodes to race.
Second-Node 0 ejects key B for disk 1 and succeeds.
Third-Node 0 ejects key B for disk 2 and succeeds.
Fourth-Node 0 ejects key B for disk 3 and succeeds.
Fifth-Node 0 continues and performs recovery.
Node 0
Node 1
Coordinator Disks
Second (part B) Node 1 fails to eject key A for disk 1. Rereads
Third (part B) - Node 1 fails to eject key A for disk 2. Rereads keys.
Fourth (part B) - Node 1 fails to eject keys disk 3.
Finally- Node 1 panics and reboots.

Because the fencing module operates identically on each system, both nodes assume the other is failed, and carry out fencing operations to insure the other node is ejected. The VCS GAB module on each node determines the peer has failed due to loss of heartbeats and passes the membership change to the fencing module.

Each side “races” to gain control of the coordinator disks. Only a registered node can eject the registration of another node, so only one side successfully completes the command on each disk.

The side that successfully ejects the peer from a majority of the coordinator disks wins. The fencing module on the winning side then passes the membership change up to VCS and other higher-level packages registered with the fencing module, allowing VCS to invoke recovery actions. The losing side forces a kernel panic and reboots.

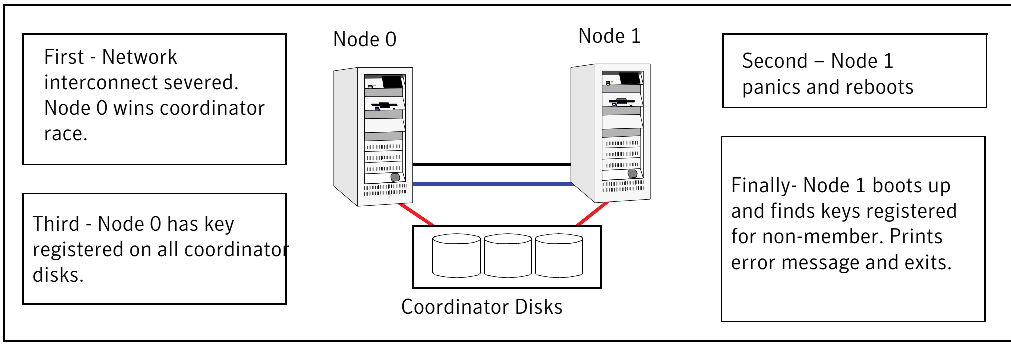
Recovering from a preexisting network partition (split-brain)

The fencing module `vxfen` prevents a node from starting up after a network partition and subsequent panic and reboot of a node.

Example Scenario I

Figure 4-2 scenario could cause similar symptoms on a two-node cluster with one node shut down for maintenance. During the outage, the private interconnect cables are disconnected.

Figure 4-2 Example scenario I


First - Network interconnect severed. Node 0 wins coordinator race.
Third - Node 0 has key registered on all coordinator disks.
Node 0
Node 1
Coordinator Disks
Second – Node 1 panics and reboots
Finally- Node 1 boots up and finds keys registered for non-member. Prints error message and exits.

In example scenario I, the following occurs:

- Node 0 wins a coordinator race following to a network failure.
- Node 1 panics and reboots.
- Node 0 has keys registered on the coordinator disks. When Node 1 boots up, it sees the Node 0 keys, but cannot see Node 0 in the current GAB membership. It senses a potential preexisting split brain and causes the vxfen module to print an error message to the console. The vxfen module prevents fencing from starting, which, in turn, prevents VCS from coming online.

  Suggested solution: Shut down Node 1, reconnect the cables, and restart Node 1.

Example Scenario II

Suggested solution: Shut down both nodes, reconnect the cables, restart the nodes.

Example Scenario III

Similar to example scenario II, if private interconnect cables are disconnected in a two-node cluster, Node 1 is fenced out of the cluster, panics, and reboots. If before the private interconnect cables are fixed and Node 1 rejoins the cluster, Node 0 panics due to hardware failure and cannot come back up, Node 1 cannot rejoin.

Suggested solution: Shut down Node 1, reconnect the cables, restart the node. You must then clear the registration of Node 0 from the coordinator disks.

To fix scenario III

1 On Node 1, type the following command:

```
# /opt/VRTSvcs/vxfen/bin/vxfenclearpre
```

2 Restart the node.

Chapter 5

Using Veritas Extension for Oracle Disk Manager

This chapter includes the following topics:

About Oracle Disk Manager

Veritas Extension for Oracle Disk Manager is specifically designed for Oracle9i or later to enhance file management and disk I/O throughput. The features of Oracle Disk Manager are best suited for databases that reside in a file system contained in Veritas File System. Oracle Disk Manager allows Oracle9i or later users to improve database throughput for I/O intensive workloads with special I/O optimization.

Veritas Extension for Oracle Disk Manager supports Oracle Resilvering. With Oracle Resilvering, the storage layer receives information from the Oracle database as to which regions or blocks of a mirrored datafile to resync after a system crash. Oracle Resilvering avoids overhead from the VxVM DRL, which increases performance.

Oracle Disk Manager reduces administrative overhead by providing enhanced support for Oracle Managed Files. Veritas Extension for Oracle Disk Manager has Quick I/O-like capabilities, but is transparent to the user. Unlike Veritas Quick I/O, files managed using Veritas Extension for Oracle Disk Manager do not require special file naming conventions. The Oracle Disk Manager interface uses regular database files. If you are upgrading to Oracle9i or later, you should convert from Quick I/O to Oracle Disk Manager.

Database administrators can choose the datafile type used with the Oracle product. Historically, choosing between file system files and raw devices was based on manageability and performance. The exception to this is a database intended for use with Oracle Parallel Server, which requires raw devices on most platforms. If performance is not as important as administrative ease, file system files are typically the preferred file type. However, while an application may not have substantial I/O requirements when it is first implemented, I/O requirements may change. If an application becomes dependent upon I/O throughput, converting datafiles from file system to raw devices is often necessary.

Oracle Disk Manager was designed to work with Oracle9i or later to provide both performance and manageability. Oracle Disk Manager provides support for Oracle's file management and I/O calls for database storage on VxFS file systems and on raw volumes or partitions. This feature is provided as a dynamically-loaded shared library with which Oracle binds when it is loaded. The Oracle Disk Manager library works with an Oracle Disk Manager driver that is loaded in the kernel to perform its functions.

If you are upgrading to Oracle9i or later, you should convert from Quick I/O to Oracle Disk Manager.

The benefits of using Oracle Disk Manager are as follows:

- True kernel asynchronous I/O for files and raw devices
- Reduced system call overhead
- Improved file system layout by preallocating contiguous files on a VxFS file system
- Performance on file system files that is equivalent to raw devices
- Transparent to users
- Contiguous datafile allocation

How Oracle Disk Manager improves database performance

Oracle Disk Manager improves database I/O performance to VxFS file systems by:

- Supporting kernel asynchronous I/O
- Supporting direct I/O and avoiding double buffering
- Avoiding kernel write locks on database files
- Supporting many concurrent I/Os in one system call
- Avoiding duplicate opening of files per Oracle instance
- Allocating contiguous datafiles

About kernel asynchronous I/O support

Asynchronous I/O performs non-blocking system level reads and writes, allowing the system to perform multiple I/O requests simultaneously. Kernel asynchronous I/O is better than library asynchronous I/O because the I/O is queued to the disk device drivers in the kernel, minimizing context switches to accomplish the work.

About direct I/O support and avoiding double buffering

I/O on files using read() and write() system calls typically results in data being copied twice: once between the user and kernel space, and the other between kernel space and the disk. In contrast, I/O on raw devices is copied directly between user space and disk, saving one level of copying. As with I/O on raw devices, Oracle Disk Manager I/O avoids the extra copying. Oracle Disk Manager bypasses the system cache and accesses the files with the same efficiency as raw devices. Avoiding double buffering reduces the memory overhead on the system. Eliminating the copies from kernel to user address space significantly reduces kernel mode processor utilization freeing more processor cycles to execute the application code.

About avoiding kernel write locks on database files

When database I/O is performed by way of the write() system call, each system call acquires and releases a kernel write lock on the file. This lock prevents simultaneous write operations on the same file. Because database systems usually implement their own locks for managing concurrent access to files, write locks unnecessarily serialize I/O writes. Oracle Disk Manager bypasses file system locking and lets the database server control data access.

About supporting many concurrent I/Os in one system call

When performing asynchronous I/O, an Oracle process may try to issue additional I/O requests while collecting completed I/Os, or it may try to wait for particular I/O requests synchronously, as it can do no other work until the I/O is completed. The Oracle process may also try to issue requests to different files. All this activity can be accomplished with one system call when Oracle uses the Oracle Disk Manager I/O interface. This interface reduces the number of system calls performed to accomplish the same work, reducing the number of user space/kernel space context switches.

About avoiding duplicate file opens

Oracle Disk Manager allows files to be opened once, providing a “file identifier.” This is called “identifying” the files. The same file identifiers can be used by any other processes in the Oracle instance. The file status is maintained by the Oracle Disk Manager driver in the kernel. The reduction in file open calls reduces processing overhead at process initialization and termination, and it reduces the number of file status structures required in the kernel.

About allocating contiguous datafiles

Oracle Disk Manager can improve performance for queries, such as sort and parallel queries, that use temporary tablespaces. Without Oracle Disk Manager, Oracle does not initialize the datafiles for the temporary tablespaces. Therefore, the datafiles become sparse files and are generally fragmented. Sparse or fragmented files lead to poor query performance. When using Oracle Disk Manager, the datafiles are initialized for the temporary tablespaces and are allocated in a contiguous fashion, so that they are not sparse.

About Oracle Disk Manager and Storage Foundation Cluster Files System

Oracle Disk Manager supports access to clustered files in the SFCFS environment. With a Veritas Storage Foundation Cluster File System license, ODM supports SFCFS files in a serially-exclusive mode which allows access to each SFCFS file by one node at a time, but does not allow simultaneous access from multiple nodes.

See the `mount_odm`(1) man page for more information on its cluster support modes.

About Oracle Disk Manager and Oracle Managed Files

Oracle9i or later offers a feature known as Oracle Managed Files (OMF). OMF manages datafile attributes such as file names, file location, storage attributes, and whether or not the file is in use by the database. OMF is only supported for databases that reside in file systems. OMF functionality is greatly enhanced by Oracle Disk Manager.

The main requirement for OMF is that the database be placed in file system files. There are additional prerequisites imposed upon the file system itself.

OMF is a file management feature that:

- Eliminates the task of providing unique file names
- Offers dynamic space management by way of the tablespace auto-extend functionality of Oracle9i or later

OMF should only be used in file systems that reside within striped logical volumes, which support dynamic file system growth. File systems intended for OMF use must also support large, extensible files in order to facilitate tablespace auto-extension. Raw partitions cannot be used for OMF.

By default, OMF datafiles are created with auto-extend capability. This attribute reduces capacity planning associated with maintaining existing databases and implementing new applications. Due to disk fragmentation that occurs as the tablespace grows over time, database administrators have been somewhat cautious when considering auto-extensible tablespaces. Oracle Disk Manager eliminates this concern.

When Oracle Disk Manager is used in conjunction with OMF, special care is given within Veritas Extension for Disk Manager to ensure that contiguous disk space is allocated to datafiles, including space allocated to a tablespace when it is auto-extended. The table and index scan throughput does not decay as the tablespace grows.

How Oracle Disk Manager works with Oracle Managed Files

The following example illustrates the relationship between Oracle Disk Manager and Oracle Managed Files (OMF). The example shows the `init.ora` contents and the command for starting the database instance. To simplify Oracle UNDO management, the new Oracle9i or later `init.ora` parameter `UNDO_MANAGEMENT` is set to `AUTO`. This is known as System-Managed Undo.

Note: Before building an OMF database, you need the appropriate `init.ora` default values. These values control the location of the `SYSTEM` tablespace, online redo logs, and control files after the `CREATE DATABASE` statement is executed.

```
$ cat initPROD.ora
UNDO_MANAGEMENT = AUTO
DB_CREATE_FILE_DEST = '/PROD'
DB_CREATE_ONLINE_LOG_DEST_1 = '/PROD'
db_block_size = 4096
db_name = PROD
$ sqlplus /nolog
SQL> connect / as sysdba
SQL> startup nomount pfile= initPROD.ora
```

The Oracle instance starts.

```
Total System Global Area 93094616 bytes
Fixed Size 279256 bytes
Variable Size 41943040 bytes
Database Buffers 50331648 bytes
Redo Buffers 540672 bytes
```

To implement a layout that places files associated with the `EMP_TABLE` tablespace in a directory separate from the `EMP_INDEX` tablespace, use the `ALTER SYSTEM` statement. This example shows how OMF handles file names and storage clauses and paths. The layout allows you to think of the tablespaces as objects in a file system as opposed to a collection of datafiles. Since OMF uses the Oracle Disk Manager file resize function, the tablespace files are initially created with the default size of 100MB and grow as needed. Use the `MAXSIZE` attribute to limit growth.

The following example shows the commands for creating an OMF database and for creating the `EMP_TABLE` and `EMP_INDEX` tablespaces in their own locale.

Note: The directory must exist for OMF to work, so the `SQL*Plus HOST` command is used to create the directories:

```
SQL> create database PROD;
```

The database is created.

```
SQL> HOST mkdir /PROD/EMP_TABLE;
SQL> ALTER SYSTEM SET DB_CREATE_FILE_DEST = '/PROD/EMP_TABLE';
```

The system is altered.

```
SQL> create tablespace EMP_TABLE DATAFILE AUTOEXTEND ON MAXSIZE \
500M;
```

A tablespace is created.

```
SQL> ALTER SYSTEM SET DB_CREATE_FILE_DEST = '/PROD/EMP_INDEX';
```

The system is altered.

```
SQL> create tablespace EMP_INDEX DATAFILE AUTOEXTEND ON MAXSIZE \
100M;
```

A tablespace is created.

Use the `ls` command to show the newly created database:

```
$ ls -lFR
total 638062
drwxr-xr-x 2 oracle9i dba 96 May  3 15:43 EMP_INDEX/
drwxr-xr-x 2 oracle9i dba 96 May  3 15:43 EMP_TABLE/
-rw-r--r-- 1 oracle9i dba 104858112 May 3 17:28 ora_1_BEhYgc0m.log
-rw-r--r-- 1 oracle9i dba 104858112 May 3 17:27 ora_2_BEhYu4NA.log
-rw-r--r-- 1 oracle9i dba 806912 May 3 15:43 ora_BEahlfUX.ctl
-rw-r--r-- 1 oracle9i dba 10489856 May 3 15:43 ora_sys_undo_BEajPSVq.dbf
-rw-r--r-- 1 oracle9i dba 104861696 May 3 15:4 ora_system_BEaiFE8v.dbf
-rw-r--r-- 1 oracle9i dba 186 May 3 15:03 PROD.ora

./EMP_INDEX:
total 204808
-rw-r--r-- 1 oracle9i dba 104861696 May 3 15:43
ora_emp_inde_BEakGfun.dbf

./EMP_TABLE:
total 204808
-rw-r--r-- 1 oracle9i dba 104861696 May 3 15:43
ora_emp_tabl_BEak1LqK.dbf
```

Setting up Veritas Extension for Oracle Disk Manager

Veritas Extension for Oracle Disk Manager is part of Veritas Storage Foundation for Oracle. Veritas Extension for Oracle Disk Manager is enabled once Veritas Storage Foundation for Oracle and Oracle9i or later are installed, and the Veritas

Extension for Oracle Disk Manager library is linked to the library in the `{ORACLE_HOME}/lib` directory.

Before setting up Veritas Extension for Oracle Disk Manager, the following conditions must be met:

Prerequisites	■ Veritas Storage Foundation for Oracle must be installed on your system. ■ Oracle9i, or later, must be installed on your system. ■ If Cached Quick I/O is available, do not enable Oracle Disk Manager when Cached Quick I/O is enabled for datafiles.
Usage Notes	■ When the Quick I/O feature is available, Oracle Disk Manager uses the Quick I/O driver to perform asynchronous I/O. Do not turn off the Quick I/O mount option, which is the default. ■ Oracle uses default file access methods if Oracle9i or later or Veritas Storage Foundation for Oracle is not installed, or VxFS 5.0 is not available in the kernel.

How to prepare existing database storage for Oracle Disk Manager

Non-Quick I/O files in a VxFS file system work with Oracle Disk Manager without any changes. The files are found and identified for Oracle Disk Manager I/O by default. To take full advantage of Oracle Disk Manager datafiles, files should not be fragmented.

If you are using Quick I/O files in a VxFS file system and you want to move to Oracle Disk Manager, convert the Quick I/O files to normal files using the `qio_convertdbfiles -u` command.

You must be running Oracle9i or later to use Oracle Disk Manager.

Converting Quick I/O files to Oracle Disk Manager files

If you plan to run Veritas Storage Foundation for Db with Oracle9i or later, and you have been using Quick I/O files, it is recommended that you convert your Quick I/O files to regular files. This should be done after you upgrade Veritas Storage Foundation for Db.

Note: If you are running an earlier version of Oracle (Oracle 8.x or lower), you should not convert your Quick I/O files because Oracle Disk Manager is for Oracle9i or later only.

Because Oracle Disk Manager uses the Quick I/O driver to perform asynchronous I/O, do not turn off the Quick I/O mount option, which is the default.

To convert Quick I/O files to Oracle Disk Manager files

1. Run `qio_getdbfiles` to retrieve a list of all datafiles.

   ```
   # /opt/VRTS/bin/qio_getdbfiles -T ora -a
   ```

   The list is compiled in a file named `mkqio.dat`.
2. Shutdown the database.
3. Run `qio_convertdbfiles` in the directory containing the `mkqio.dat` file. The `qio_convertdbfiles`script converts all Quick I/O files to ODM files.

   ```
   # /opt/VRTS/bin/qio_convertdbfiles -T ora -u
   ```

4. Restart the database instance.

Verifying that Oracle Disk Manager is configured

Before verifying that Oracle Disk Manager is configured, make sure that the following conditions are met:

Prerequisites	■ `/opt/VRTSodm/lib/libodm.sl` must exist. ■ If you are using Oracle9i, `$ORACLE_HOME/lib/libodm9.sl` is linked to `/opt/VRTSodm/lib/libodm.sl`. ■ If you are using Oracle 10g, `$ORACLE_HOME/lib/libodm10.sl` is linked to `/opt/VRTSodm/lib/libodm.sl`. ■ The `VRTSdbed` license must be valid. ■ The `VRTSodm` package must be installed.

Note: In addition to the following procedure, you can instead check the conditoins using the `dbed_checkconfig` command, which is installed with Veritas Storage Foundation for Oracle.

See the `dbed_checkconfig`(1M) manual page for more information.

To verify that Oracle Disk Manager is configured

1 Check the `VRTSdbed` license:

```
# /opt/VRTS/bin/vxlictest -n "VERITAS Storage Foundation for Oracle" \
-f "ODM"

ODM feature is licensed
```

2 Check that the `VRTSodm` package is installed:

```
(root@slias19)[/] swlist VRTSodm
# Initializing...
# Contacting target "slias19"...
#
# Target:  slias19:/
#

# VRTSodm                5.0.31.5.%20090322 Veritas Oracle Disk Manager
  VRTSodm.ODM-KRN        5.0.31.5.%20090322 Veritas ODM kernel files
  VRTSodm.ODM-MAN        5.0.31.5.%20090322 Veritas ODM manual pages
  VRTSodm.ODM-RUN        5.0.31.5.%20090322 Veritas ODM commands
```

3 Check that `libodm.sl` is present.

```
# ls -lL /opt/VRTSodm/lib/libodm.sl
-rw-r--r-- 1 root sys 14336 Apr 25 18:42
/opt/VRTSodm/lib/libodm.sl
```

See “Checking the database configuration environment using dbed_checkconfig” on page 83.

To verify that Oracle Disk Manager is running

1 Start the Oracle database.

2 Check that the instance is using the Oracle Disk Manager function:

```
# cat /dev/odm/stats
# echo $?
0
```

3 Verify that the Oracle Disk Manager is loaded:

```
# /usr/sbin/kcmodule -P state odm
state loaded
```

4 In the alert log, verify the Oracle instance is running. The log should contain output similar to the following:

```
Oracle instance running with ODM: Veritas #.# ODM Library,
Version #.#
```

Checking the database configuration environment using dbed_checkconfig

You can use the command to verify and report on the database environment from the command line.

Before checking the configuration environment, the following conditions must be met:

Prerequisites	■ You must be logged on as the database administrator (typically, the user ID `oracle`
Usage notes	■ The `dbed_checkconfig` command is used to verify various elements of the database environment. The utility attempts to use certain basic rules on database settings, file system and volume parameters and layout options to verify how resilient and well configured a configuration is. The information provided is valid for the supplied database. ■ See the `dbed_checkconfig`(1M) manual page.

To check the database configuration environment

◆ Use the command as follows:

```
$ /opt/VRTS/bin/dbed_checkconfig-S FLAS11r1 -H $ORACLE_HOME
```

```
VRTSodm             5.0.31.5.%20090524 Veritas Oracle Disk Manager
Examining file system attributes.
All file systems are VxFS.
Examining Quick I/O settings.
```

```
0 files are configured to use Quick I/O files.
It appears that your system is ODM enabled.
0 Quick I/O files should be converted to regular
files to use ODM feature.

Examining Cached Quick I/O settings.
No file systems have Cached Quick I/O enabled.
Examining File System tunable settings.

Parameters for all VxFS file systems used by FLAS11r1.
Filesystem i/o parameters for /snap_data11r1
read_pref_io = 2097152
read_nstream = 1
read_unit_io = 2097152
write_pref_io = 2097152
write_nstream = 1
write_unit_io = 2097152
pref_strength = 10
buf_breakup_size = 2097152
discovered_direct_iosz = 262144
max_direct_iosz = 1048576
default_indir_size = 8192
qio_cache_enable = 0
write_throttle = 0
max_diskq = 33554432
initial_extent_size = 8
max_seqio_extent_size = 2048
max_buf_data_size = 8192
hsm_write_prealloc = 0
read_ahead = 1
inode_aging_size = 0
inode_aging_count = 0
fcl_maxalloc = 317750272
fcl_keeptime = 0
fcl_winterval = 3600
fcl_ointerval = 600
oltp_load = 0
Examining Oracle volume and file system layout.

Data for database FLAS11r1 is contained in one volume group.
Examining Oracle internal information.

Oracle Version is 11.1.0.6.0.
Control file /snap_data11r1/FLAS11r1/control01.ctl is on file system
```

```
/snap_data11r1.
SFORA dbed_checkconfig WARNING V-81-999 Control file is on a VxVM
volume set

Control file /snap_data11r1/FLAS11r1/control02.ctl is on file system
/snap_data11r1.
SFORA dbed_checkconfig WARNING V-81-999 Control file is on a VxVM
volume set

Control file /snap_data11r1/FLAS11r1/control03.ctl is on file system
/snap_data11r1.
SFORA dbed_checkconfig WARNING V-81-999 Control file is on a VxVM
volume set

Total of 3 control files over 1 file systems.
SFORA dbed_checkconfig WARNING V-81-3122 Control files are not spread
over multiple file systems. Spread control files over multiple file
systems for better redundancy.

Examining Oracle automatic extension of datafiles.

Total of 1009 datafiles are configured to auto extend.
Total of 1015 datafiles are defined to the database.
Examining Oracle log modes.

The database is running in archivelog mode.
The database is running in automatic log archiving mode.
```

To check the database configuration environment and not update the repository

◆ Use the `dbed_checkconfig` command with the `-v` and `-n` options as follows:

  ```
  $ /opt/VRTS/bin/dbed_checkconfig -S FLAS11r1 \
  -H $ORACLE_HOME -v -n
  ```

  where:

  - `-v` lists all files.
  - `-n` stops the repository from being updated.

```
VRTSodm              5.0.31.5.%20090524 Veritas Oracle Disk Manager
Examining file system attributes.

All file systems are VxFS.

Examining Quick I/O settings.
```

```
0 files are configured to use Quick I/O files.
It appears that your system is ODM enabled.

Examining Cached Quick I/O settings.

No file systems have Cached Quick I/O enabled.

Examining File System tunable settings.

Parameters for all VxFS file systems used by FLAS11r1.
Filesystem i/o parameters for /snap_data11r1
read_pref_io = 2097152
read_nstream = 1
read_unit_io = 2097152
write_pref_io = 2097152
write_nstream = 1
write_unit_io = 2097152
pref_strength = 10
buf_breakup_size = 2097152
discovered_direct_iosz = 262144
max_direct_iosz = 1048576
default_indir_size = 8192
qio_cache_enable = 0
write_throttle = 0
max_diskq = 33554432
initial_extent_size = 8
max_seqio_extent_size = 2048
max_buf_data_size = 8192
hsm_write_prealloc = 0
read_ahead = 1
inode_aging_size = 0
inode_aging_count = 0
fcl_maxalloc = 317750272
fcl_keeptime = 0
fcl_winterval = 3600
fcl_ointerval = 600
oltp_load = 0

Examining Oracle volume and file system layout.

Data for database FLAS11r1 is contained in one volume group.
```

```
Examining Oracle internal information.

Oracle Version is 11.1.0.6.0.
Control file /snap_data11r1/FLAS11r1/control01.ctl is on file system
/snap_data11r1.
SFORA dbed_checkconfig WARNING V-81-999 Control file is on a
VxVM volume set

Control file /snap_data11r1/FLAS11r1/control02.ctl is on file system
/snap_data11r1.
SFORA dbed_checkconfig WARNING V-81-999 Control file is on a
VxVM volume set

Control file /snap_data11r1/FLAS11r1/control03.ctl is on file system
/snap_data11r1.
SFORA dbed_checkconfig WARNING V-81-999 Control file is on a
VxVM volume set

Total of 3 control files over 1 file systems.
SFORA dbed_checkconfig WARNING V-81-3122 Control files are not spread
over multiple file systems. Spread control files over multiple file
systems for better redundancy.

Examining Oracle automatic extension of datafiles.

Total of 1009 datafiles are configured to auto extend.
The following datafiles are not configured to autoextend:
/snap_data11r1/FLAS11r1/test_big.dbf
/snap_data11r1/FLAS11r1/undotbs02.dbf
/snap_data11r1/FLAS11r1/tde_tbs1.dbf
/snap_data11r1/FLAS11r1/tde_tbs2.dbf
/snap_data11r1/FLAS11r1/16k_file.dbf
/snap_data11r1/FLAS11r1/32k_file.dbf

Total of 1015 datafiles are defined to the database.

Examining Oracle log modes.

The database is running in archivelog mode.
The database is running in automatic log archiving mode.
```

Disabling the Oracle Disk Manager feature

Since the Oracle Disk Manager feature uses regular files, you can access these files as regular VxFS files as soon as the feature is disabled.

Note: To convert to VxFS with Quick I/O, disable Oracle Disk Manager using the following procedure, then convert the files to Quick I/O files.

See "Converting Quick I/O files to Oracle Disk Manager files" on page 80.

Before disabling the Oracle Disk Manager feature, you may want to back up your files.

To disable the Oracle Disk Manager feature in an Oracle instance

1. Shut down the database instance.
2. Use the `rm` and `ln` commands to remove the link to the Oracle Disk Manager Library.

   For HP-UX PA

   For Oracle 11g, enter:

   ```
   # rm ${ORACLE_HOME}/lib/libodm11.sl
   # ln -s ${ORACLE_HOME}/lib/libodmd11.sl \
   ${ORACLE_HOME}/lib/libodm11.sl
   ```

   For Oracle 10g, enter:

   ```
   # rm ${ORACLE_HOME}/lib/libodm10.sl
   # ln -s ${ORACLE_HOME}/lib/libodmd10.sl \
   ${ORACLE_HOME}/lib/libodm10.sl
   ```

   For Oracle9i, enter:

   ```
   # rm ${ORACLE_HOME}/lib/libodm9.sl
   # ln -s ${ORACLE_HOME}/lib/libodmd9.sl \
   ${ORACLE_HOME}/lib/libodm9.sl
   ```

   For HP-UX IA

   For Oracle 11g, enter:

   ```
   # rm ${ORACLE_HOME}/lib/libodm11.so
   # ln -s ${ORACLE_HOME}/lib/libodmd11.sl \
   ${ORACLE_HOME}/lib/libodm11.so
   ```

   For Oracle 10g, enter:

   ```
   # rm ${ORACLE_HOME}/lib/libodm10.so
   # ln -s ${ORACLE_HOME}/lib/libodmd10.sl \
   ${ORACLE_HOME}/lib/libodm10.so
   ```

   For Oracle9i, enter:

   ```
   # rm ${ORACLE_HOME}/lib/libodm9.so
   # ln -s ${ORACLE_HOME}/lib/libodmd9.sl \
   ${ORACLE_HOME}/lib/libodm9.so
   ```

3. Restart the database instance.

Chapter 6

Veritas Volume Manager cluster functionality administration

This chapter includes the following topics:

About Veritas Volume Manager cluster functionality administration

A cluster consists of a number of hosts or nodes that share a set of disks. The main benefits of cluster configurations are:

Availability	If one node fails, the other nodes can still access the shared disks. When configured with suitable software, mission-critical applications can continue running by transferring their execution to a standby node in the cluster. This ability to provide continuous uninterrupted service by switching to redundant hardware is commonly termed failover. Failover is transparent to users and high-level applications for database and file-sharing. You must configure cluster management software, such as VCS, to monitor systems and services, and to restart applications on another node in the event of either hardware or software failure. VCS also allows you to perform general administration tasks such as making nodes join or leave a cluster.

Off-host processing	Clusters can reduce contention for system resources by performing activities such as backup, decision support and report generation on the more lightly loaded nodes of the cluster. This allows businesses to derive enhanced value from their investment in cluster systems.

The CVM allows up to 32 nodes in a cluster to simultaneously access and manage a set of disks under VxVM control (VM disks). The same logical view of disk configuration and any changes to this is available on all the nodes. When the cluster functionality is enabled, all the nodes in the cluster can share VxVM objects. This chapter discusses the cluster functionality that is provided with VxVM.

See the *Veritas Volume Manager Administrator's Guide* for more information on VxVM and CVM.

See the *Veritas Cluster Server User's Guide* for more information on VCS.

Overview of Cluster Volume Management

Tightly coupled cluster systems have become increasingly popular in enterprise-scale mission-critical data processing. The primary advantage of clusters is protection against hardware failure. If the primary node fails or otherwise becomes unavailable, applications can continue to run by transferring their execution to standby nodes in the cluster. This ability to provide continuous availability of service by switching to redundant hardware is commonly termed failover.

Another major advantage of clustered systems is their ability to reduce contention for system resources caused by activities such as backup, decision support and report generation. Enhanced value can be derived from cluster systems by performing such operations on lightly loaded nodes in the cluster instead of on the heavily loaded nodes that answer requests for service. This ability to perform some operations on the lightly loaded nodes is commonly termed load balancing.

To implement cluster functionality, VxVM works together with the cluster monitor daemon that is provided by the host operating system or by VCS. The cluster monitor informs VxVM of changes in cluster membership. Each node starts up independently and has its own cluster monitor plus its own copies of the operating system and VxVM with support for cluster functionality. When a node joins a cluster, it gains access to shared disks. When a node leaves a cluster, it no longer has access to shared disks. A node joins a cluster when the cluster monitor is started on that node.

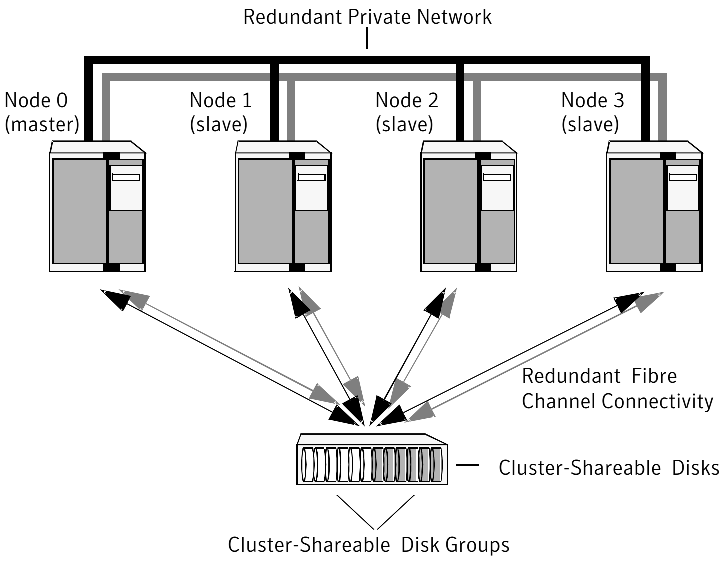
Note: The cluster functionality of VxVM is supported only when used in conjuction with a cluster monitor that has been configured correctly to work with VxVM.

Figure 6-1 illustrates a simple cluster arrangement consisting of four nodes with similar or identical hardware characteristics (CPUs, RAM and host adapters), and configured with identical software (including the operating system).

The nodes are fully connected by a private network and they are also separately connected to shared external storage (either disk arrays or JBODs: just a bunch of disks) via Fibre Channel. Each node has two independent paths to these disks, which are configured in one or more cluster-shareable disk groups.

The private network allows the nodes to share information about system resources and about each other's state. Using the private network, any node can recognize which other nodes are currently active, which are joining or leaving the cluster, and which have failed. The private network requires at least two communication channels to provide redundancy against one of the channels failing. If only one channel were used, its failure would be indistinguishable from node failure—a condition known as network partitioning.

Figure 6-1 Example of a four node cluster


Redundant Private Network
Node 0 (master)
Node 1 (slave)
Node 2 (slave)
Node 3 (slave)
Redundant Fibre Channel Connectivity
Cluster-Shareable Disks
Cluster-Shareable Disk Groups

To the cluster monitor, all nodes are the same. VxVM objects configured within shared disk groups can potentially be accessed by all nodes that join the cluster. However, the cluster functionality of VxVM requires that one node act as the master node; all other nodes in the cluster are slave nodes. Any node is capable of being the master node, and it is responsible for coordinating certain VxVM activities.

Note: You must run commands that configure or reconfigure VxVM objects on the master node. Tasks that must be initiated from the master node include setting up shared disk groups, creating and reconfiguring volumes, and performing snapshot operations.

VxVM designates the first node to join a cluster performs the function of the master node. If the master node leaves the cluster, one of the slave nodes is chosen to be the new master.

Private and shared disk groups

The following types of disk groups are defined:

Private disk groups	Belong to only one node. A private disk group is only imported by one system. Disks in a private disk group may be physically accessible from one or more systems, but access is restricted to one system only. The boot disk group (usually aliased by the reserved disk group name bootdg) is always a private disk group.
Shared disk groups	Shared by all nodes. A shared (or cluster-shareable) disk group is imported by all cluster nodes. Disks in a shared disk group must be physically accessible from all systems that may join the cluster.

In a cluster, most disk groups are shared. Disks in a shared disk group are accessible from all nodes in a cluster, allowing applications on multiple cluster nodes to simultaneously access the same disk. A volume in a shared disk group can be simultaneously accessed by more than one node in the cluster, subject to licensing and disk group activation mode restrictions.

You can use the `vxdg` command to designate a disk group as cluster-shareable.

See the *Veritas Volume Manager Administrator's Guide*.

When a disk group is imported as cluster-shareable for one node, each disk header is marked with the cluster ID. As each node subsequently joins the cluster, it recognizes the disk group as being cluster-shareable and imports it. You can also import or deport a shared disk group at any time; the operation takes places in a distributed fashion on all nodes.

Each physical disk is marked with a unique disk ID. When cluster functionality for VxVM starts on the master, it imports all shared disk groups (except for any that have the `noautoimport` attribute set). When a slave tries to join a cluster, the master sends it a list of the disk IDs that it has imported, and the slave checks to see if it can access them all. If the slave cannot access one of the listed disks, it abandons its attempt to join the cluster. If it can access all of the listed disks, it imports the same shared disk groups as the master and joins the cluster. When a node leaves the cluster, it deports all its imported shared disk groups, but they remain imported on the surviving nodes.

Reconfiguring a shared disk group is performed with the co-operation of all nodes. Configuration changes to the disk group happen simultaneously on all nodes and the changes are identical. Such changes are atomic in nature, which means that they either occur simultaneously on all nodes or not at all.

Whether all members of the cluster have simultaneous read and write access to a cluster-shareable disk group depends on its activation mode setting.

See Activating modes of shared disk groups.

The data contained in a cluster-shareable disk group is available as long as at least one node is active in the cluster. The failure of a cluster node does not affect access by the remaining active nodes. Regardless of which node accesses a cluster-shareable disk group, the configuration of the disk group looks the same.

Note: Applications running on each node can access the data on the VM disks simultaneously. VxVM does not protect against simultaneous writes to shared volumes by more than one node. It is assumed that applications control consistency (by using a distributed lock manager, for example).

Activating modes of shared disk groups

A shared disk group must be activated on a node for the volumes in the disk group to become accessible for I/O from that node. The ability of applications to read from or to write to volumes is determined by the activation mode of a shared disk group. Valid activation modes for a shared disk group are `exclusive-write`, `read-only`, `shared-read`, `shared-write`, and `off` (inactive).

Note: The default activation mode for shared disk groups is `off`.

Applications such as high availability and off-host backup can use disk group activation to explicitly control volume access from different nodes in the cluster.

The activation mode of a disk group controls volume I/O from different nodes in the cluster. It is not possible to activate a disk group on a given node if it is activated in a conflicting mode on another node in the cluster.

Table 6-1 describes Activation modes for disk groups.

Table 6-1 Activation modes for shared disk groups

Activation mode	Description
exclusive-write (ew)	The node has exclusive write access to the disk group. No other node can activate the disk group for write access.
read-only (ro)	The node has read access to the disk group and denies write access for all other nodes in the cluster. The node has no write access to the disk group. Attempts to activate a disk group for either of the write modes on other nodes fail.
shared-read (sr)	The node has read access to the disk group. The node has no write access to the disk group, however other nodes can obtain write access.
shared-write (sw)	The node has write access to the disk group.
off	The node has neither read nor write access to the disk group. Query operations on the disk group are permitted.

Table 6-2 summarizes allowed and conflicting activation modes or shared disk groups:

Table 6-2 Allowed and conflicting activation modes

Disk group activated in cluster as...	exclusive-write	read-only	shared-read	shared-write
exclusive-write	Fails	Fails	Succeeds	Fails
read-only	Fails	Succeeds	Succeeds	Fails
shared-read	Succeeds	Succeeds	Succeeds	Succeeds
shared-write	Fails	Fails	Succeeds	Succeeds

Shared disk groups can be automatically activated in any mode during disk group creation or during manual or auto-import.

To control auto-activation of shared disk groups

1 To create the defaults file `/etc/default/vxdg`.

2 The defaults file `/etc/default/vxdg` must contain the following lines:

```
enable_activation=true
default_activation_mode=activation-mode
```

The `activation-mode` is one of `exclusive-write`, `read-only`, `shared-read`, `shared-write`, or `off`.

When enabling activation using the defaults file, it is advisable that the defaults file be identical on all nodes in the cluster. Otherwise, the results of activation are unpredictable.

When a shared disk group is created or imported, it is activated in the specified mode. When a node joins the cluster, all shared disk groups accessible from the node are activated in the specified mode.

If the defaults file is edited while the `vxconfigd` daemon is already running, the `vxconfigd` process must be restarted for the changes in the defaults file to take effect.

Note: If the default activation mode is anything other than `off`, an activation following a cluster join, or a disk group creation or import can fail if another node in the cluster has activated the disk group in a conflicting mode.

To display the activation mode for a shared disk group, use the `vxdg list diskgroup` command.

You can also use the `vxdg` command to change the activation mode on a shared disk group.

Connectivity policy of shared disk groups

The nodes in a cluster must always agree on the status of a disk. In particular, if one node cannot write to a given disk, all nodes must stop accessing that disk before the results of the write operation are returned to the caller. Therefore, if a node cannot contact a disk, it should contact another node to check on the disk's status. If the disk fails, no node can access it and the nodes can agree to detach the disk. If the disk does not fail, but rather the access paths from some of the nodes fail, the nodes cannot agree on the status of the disk.

Table 6-3 describes one of the following policies for resolving this type of discrepancy.

Table 6-3 Policies for resolving this type of discrepancy

Policy	Description
global	The detach occurs cluster-wide (globally) if any node in the cluster reports a disk failure. This is the default policy.

Table 6-3 Policies for resolving this type of discrepancy *(continued)*

Policy	Description
local	In the event of disks failing, the failures are confined to the particular nodes that saw the failure. Note that an attempt is made to communicate with all nodes in the cluster to ascertain the disks' usability. If all nodes report a problem with the disks, a cluster-wide detach occurs.

The `vxdg` command can be used to set the disk dettach and dg fail policy. The dgfailpolicy sets the disk group failure policy in the case that the master node loses connectivity to the configuration and log copies within a shared disk group. This attribute requires that the disk group version is 120 or greater.

Table 6-4 describes the supported policies.

Table 6-4 Supported policies

Policies	Description
dgdisable	The master node disables the diskgroup for all user or kernel initiated transactions. First write and final close fail. This is the default policy.
leave	The master node panics instead of disabling the disk group if a log update fails for a user or kernel initiated transaction (including first write or final close). If the failure to access the log copies is global, all nodes panic in turn as they become the master node.

Disk group failure policy

The local detach policy by itself is insufficient to determine the desired behavior if the master node loses access to all disks that contain copies of the configuration database and logs. In this case, the disk group is disabled. As a result, the other nodes in the cluster also lose access to the volume. In release 4.1, the disk group failure policy was introduced to determine the behavior of the master node in such cases.

Table 6-5 illustrates the policy's possible settings.

Table 6-5 Behavior of master node for different failure policies

Type of I/O failure	Leave (dgfailpolicy=leave)	Disable (dgfailpolicy=dgdisable)
Master node loses access to all copies of the logs.	The master node panics with the message “klog update failed” for a failed kernel-initiated transaction, or “cvm config update failed” for a failed user-initiated transaction.	The master node disables the disk group.

The behavior of the master node under the disk group failure policy is independent of the setting of the disk detach policy. If the disk group failure policy is set to `leave`, all nodes panic in the unlikely case that none of them can access the log copies.

Limitations of shared disk groups

The boot disk group (usually aliased as `bootdg`) cannot be made clustershareable. It must be private.

Only raw device access may be performed via the cluster functionality of VxVM. It does not support shared access to file systems in shared volumes unless the appropriate software, such as Veritas Storage Foundation Cluster File System, is installed and configured.

The cluster functionality of VxVM does not support RAID-5 volumes, or task monitoring for cluster-shareable disk groups. These features can, however, be used in private disk groups that are attached to specific nodes of a cluster.

If you have RAID-5 volumes in a private disk group that you wish to make shareable, you must first relayout the volumes as a supported volume type such as `stripe-mirror` or `mirror-stripe`. Online relayout is supported provided that it does not involve RAID-5 volumes.

If a shared disk group contains unsupported objects, deport it and then re-import the disk group as private on one of the cluster nodes. Reorganize the volumes into layouts that are supported for shared disk groups, and then deport and re-import the disk group as shared.

Chapter 7

Agents for Storage Foundation Cluster File System

This chapter includes the following topics:

About agents for Storage Foundation Cluster File System

Agents are processes that manage predefined resource types. When an agent is started, it obtains configuration information from the Veritas Cluster Server (VCS). It then periodically monitors the resources and updates VCS with the resource status.

Agents typically do the following:

- Bring resources online
- Take resources offline
- Monitor resources and report any state changes to VCS

VCS bundled agents are part of VCS and are installed when VCS is installed. The cluster functionality agents are add-on resources to VCS for the Veritas File System and Veritas Volume Manager (VxVM). Cluster functionality agents and resource types are part of the `VRTScavf` package and are configured when you run the`cfscluster config` command.

See the *Veritas Cluster Server Bundled Agents Reference Guide*.

This appendix includes the following topics:

- Storage Foundation Cluster File System agents
- Veritas Cluster Server cluster components
- Modifying the agents and their resources
- Storage Foundation Cluster File System administrative interface

Storage Foundation Cluster File System agents

SFCFS includes the following agents:

- CFSMount agent
- CFSfsckd agent
- CVMCluster agent
- CVMVolDg agent

Veritas Cluster Server cluster components

Resources, attributes, and service groups are components integral to cluster functionality.

See the *Veritas Cluster Server User's Guide*.

Resources

Resources are hardware or software entities, such as disks, volumes, file system mount points, network interface cards (NICs), IP addresses, applications, and databases. Resources work together to provide a service to clients in a client/server environment. Resource types are defined in the `types.cf` file by a collection of attributes. The VCS configuration file, `main.cf`, contains the values for the attributes of the resources. The `main.cf` file incorporates the resources listed in the `types.cf` by way of an `include` directive.

Attributes

Attributes contain data regarding the cluster, nodes, service groups, resources, resource types, and agents. A specified value for a given attribute configures the resource to function in a specific way. By modifying the value of an attribute of a resource, you change the way the VCS agent manages the resource. Each attribute has a definition and a value. You define an attribute by specifying its data type and dimension. Attributes also have default values that are assigned when a value is not specified.

Service groups

Service groups are comprised of related resources. When a service group is brought online, all the resources within the group are brought online.

Modifying the agents and their resources

You can use the VCS Cluster Manager GUI, or enter VCS commands (the "ha" commands such as `hastatus` and `haconf`) from the command line, to modify the configuration of the resources managed by an agent. You can also edit the `main.cf` file directly, but you must reboot your system for the changes to take effect. An example `main.cf` file is located in the `/etc/VRTSvcs/conf/sample_cvm` directory.

It is advisable to use the Veritas Cluster Server GUI to administer your cluster file system resources.

See *Veritas Cluster Server Installation Guide*.

Resources and service groups for File System cluster functionality

Managing cluster mounts through VCS requires various resources types, resources, and service groups.

The following VCS resource types required for Veritas Volume Manager cluster functionality (or CVM) are:

- CVMCluster
- CVMVolDg

CVMCluster controls the overall operation of CVM. The agents of CVMCluster bring up the CVM cluster. Only one CVMCluster resource is required in a VCS environment. It is advisable to use the standard configuration procedure for CVM to add the CVMCluster resource. The procedure creates a service group named `cvm` and adds the resources to the configuration.

See "Storage Foundation Cluster File System administrative interface" on page 105.

The following VCS resource types required for SFCFS functionality are:

- CFSfsckd
- CFSMount

CFSfsckd is a mandatory resource type for SFCFS functionality. CFSfsckd agents start the cluster file system check (`fsck` command) daemon, `vxfsckd`, which must be running for a cluster mount to succeed. As with CVMCluster, only one resource instance is required for CFSfsckd. You add these resources using the SFCFS configuration process, which adds the resources to the `cvm` service group.

See "The cfscluster command" on page 105.

Each CVMVolDg resource controls one shared disk group, and one or more shared volumes of that disk group. CVMVolDg resources enable the disk group and set the disk group activation mode. Each CFSMount resource controls the cluster mount of a shared volume on a specified mount point. CFSMount resources also keep track of mount options associated with the mount points.

These resource instances are not added automatically during the SFCFS configuration; you must add them as required using the SFCFS cluster administration commands.

Note: That the CFSMount and CVMVolDg resources are not added to the `cvm` service group; those should be added to a different service group.

See "The cfsmntadm command" on page 106.

Resource and service group dependencies

Dependencies between resources and service groups specify the order in which the resource and service group are brought online and taken offline, which must be done in correct sequence.

The various resources and service groups required for SFCFS must follow these dependency (or link) rules:

- A CFSMount resource must depend on the corresponding CVMVolDg resource

- A service group containing the CVMVolDg resource must depend on the `cvm` service group

Storage Foundation Cluster File System administrative interface

The SFCFS administrative interface provides an easy and convenient way to create resources required for SFCFS with the correct attributes and the correct links between them.

Storage Foundation Cluster File System resource management commands

As many as five VCS agents are required to manage cluster file system functionality. Each of these resources has several attributes and dependencies between them. To make resources easier to manage, five SFCFS administrative commands are provided. It is advisable to use only these commands to manage cluster file systems.

Table 7-1 describes the SFCFS commands.

Table 7-1 SFCFS commands

Commands	Description
cfscluster	Cluster configuration command
cfsmntadm	Adds, deletes, modifies, and sets policy on cluster mounted file systems
cfsdgadm	adds or deletes shared disk groups to and from a cluster configuration
cfsmount	mounts a cluster file system on a shared volume
cfsumount	unmounts a cluster file system on a shared volume

The cfscluster command

The `cfscluster` command is used primarily to configure and unconfigure CVM and SFCFS, and can be run from any node in the cluster. VCS must be started before you can run the `cfscluster config` command. The `cfscluster config` command adds all the resource type definitions and adds resource instances, one each of type CVMCluster and CFSfsckd. The `cfscluster config` command also brings the resources online, and `cfscluster status` can be used to query the status of VCS.

See "Resources and service groups for File System cluster functionality" on page 103.

The `cfscluster unconfig` command takes resources offline (except CFSMount resources) and removes all the resources and service groups that were used to manage the cluster file system.

See the `cfscluster`(1M) manual page.

You must manually take CFSMount resources offline (using the `cfsumount` command) before executing the `cfscluster unconfig` command.

The cfsmntadm command

One CVMVolDg and one CFSMount resource is required to control each cluster mount. You can use the `cfsmntadm add` to add these resources. The `cfsmntadm` command takes mount points, shared volumes, and shared disk groups as arguments. You can optionally specify a service group name. If a service group name is specified, the `cfsmntadm` command creates a new service group (if the service group is not already present) and makes it dependent on the `cvm` service group. If no service group name is specified, `cfsmntadm add` creates a default service group, `cfs`. The command next adds CVMVolDg to the specified service group and associates it with the specified disk group (if that kind of resource is not already present in the same service group). Subsequently, `cfsmntadm add` adds a CFSMount resource and links it with the CVMVolDg resource, then sets the appropriate values to the resource attributes. It is advisable to add all the mount points (that have their device in the same shared disk group) to the same service group.

See "Resources and service groups for File System cluster functionality" on page 103.

Using `cfsmntadm`, you can also add file system snapshots and Storage Checkpoints; delete, display, and modify resources; and set the primary election policy on a cluster mounted file system.

See the `cfsmntadm`(1M) manual page.

The cfsdgadm command

The `cfsdgadm` command is the administrative interface for shared disk groups. Using `cfsdgadm`, you can add a shared disk group to a cluster configuration, delete a shared disk group, modify the activation mode, or display the shared disk group's configuration information. A shared disk group must already exist before being specified with `cfsdgadm` command.

See the `cfsdgadm`(1M) manual page.

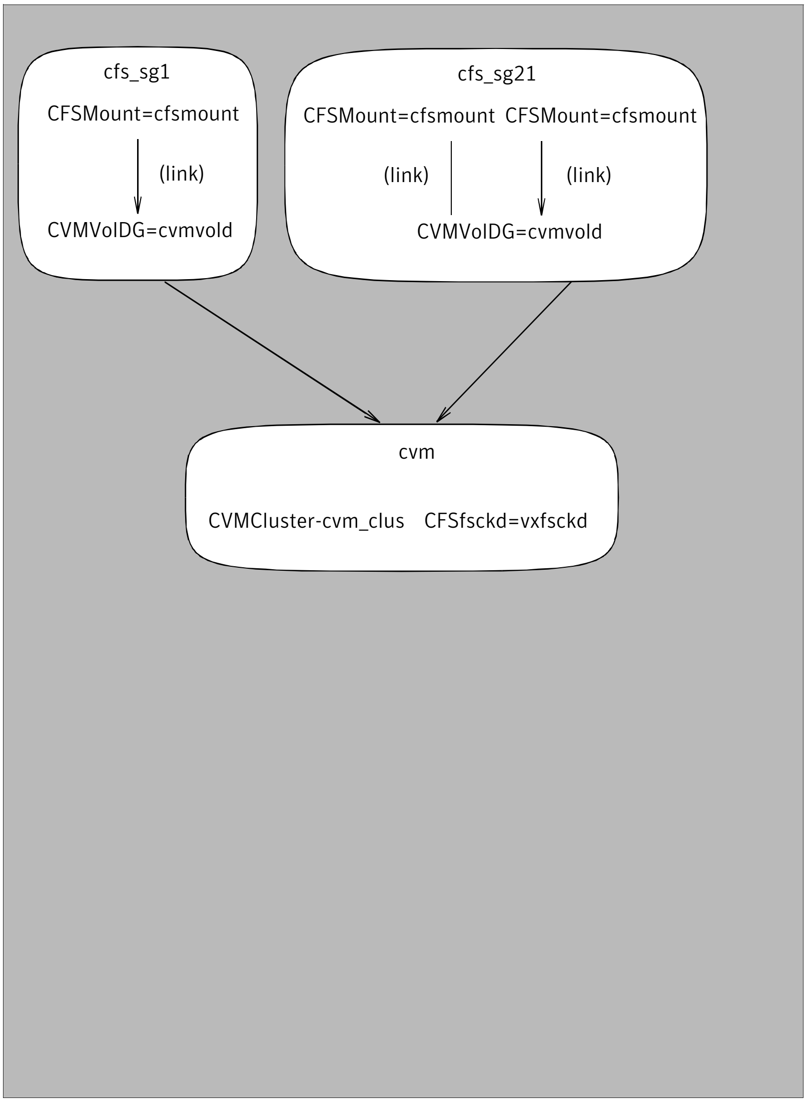
The cfsmount and cfsumount command

The `cfsmount` command mounts a cluster file system on a shared volume on one or more nodes. If no nodes are specified, the cluster file system is mounted on all associated nodes in the cluster. The cluster mount instance for the shared volume must be previously defined by the `cfsmntadm add` command before running `cfsmount`. The `cfsumount` command unmounts one or more shared volumes

See the `cfsmount`(1M) manual page.

Figure 7-1 describes the SFCFS service groups and resource dependencies.

Figure 7-1 SFCFS service groups and resource dependencies



Example main.cf file

This is a sample `main.cf` file:

```
include "types.cf"
include "CFSTypes.cf"
include "CVMTypes.cf"
cluster cfs_cluster (
    UserNames = { admin = HMNfMHmJNiNNlVNhMK }
    Administrators = { admin }
    CredRenewFrequency = 0
    HacliUserLevel = COMMANDROOT
    CounterInterval = 5
    )
system system01 (
    )
system system02 (
    )
group cvm (
    SystemList = { system01 = 0, system02 = 1 }
    AutoFailOver = 0
    Parallel = 1
    AutoStartList = { system01, system02 }
    )
    CFSfsckd vxfsckd (
        ActivationMode @system01 = { cfsdg = off }
        ActivationMode @system02 = { cfsdg = off }
        )
    CVMCluster cvm_clus (
        CVMClustName = omcluster
        CVMNodeId = { system01 = 0, system02 = 1 }
        CVMTransport = gab
        CVMTimeout = 200
        )
    CVMVxconfigd cvm_vxconfigd (
        Critical = 0
        CVMVxconfigdArgs = { syslog }
        )
    cvm_clus requires cvm_vxconfigd
    vxfsckd requires cvm_clus
    // resource dependency tree
    //
    //  group cvm
    //  {
    //  CFSfsckd vxfsckd
    //      {
    //      CVMCluster cvm_clus
    //          {
    //          CVMVxconfigd cvm_vxconfigd
    //          }
    //      }
    //  }
group vrts_vea_cfs_int_cfsmount1 (
    SystemList = { system01 = 0, system02 = 1 }
    AutoFailOver = 0
    Parallel = 1
    AutoStartList = { system01, system02 }
    )
    CFSMount cfsmount1 (
        Critical = 0
        MountPoint = "/mnt0"
        BlockDevice = "/dev/vx/dsk/cfsdg/vol1"
        NodeList = { system01 , system02 }
        RemountRes @system01 = DONE
        RemountRes @system02 = DONE
        )
    CVMVolDg cvmvoldg1 (
        Critical = 0
        CVMDiskGroup = cfsdg
        CVMActivation @system01 = off
        CVMActivation @system02 = off
        )
    requires group cvm online local firm
    cfsmount1 requires cvmvoldg1
    // resource dependency tree
    //
    //  group vrts_vea_cfs_int_cfsmount1
    //  {
    //  CFSMount cfsmount1
    //      {
    //      CVMVolDg cvmvoldg1
    //      }
    //  }
```

Example CVMTypes.cf file

This is a sample of the `CVMTypes.cf` file.

```
type CVMCluster (
    static int NumThreads = 1
    static int OnlineRetryLimit = 2
    static int OnlineTimeout = 400
    static str ArgList[] = { CVMTransport, CVMClustName, CVMNodeAddr,
 CVMNodeId, PortConfigd, PortKmsgd, CVMTimeout }
    str CVMClustName
    str CVMNodeAddr{}
    str CVMNodeId{}
    str CVMTransport
    int PortConfigd
    int PortKmsgd
    int CVMTimeout
)
type CVMVolDg (
    static keylist RegList = { CVMActivation }
    static str ArgList[] = { CVMDiskGroup, CVMVolume, CVMActivation
}
    str CVMDiskGroup
    keylist CVMVolume
    str CVMActivation
    temp int voldg_stat
)
type CVMVxconfigd (
    static int FaultOnMonitorTimeouts = 2
    static int RestartLimit = 5
    static str ArgList[] = { CVMVxconfigdArgs }
    static str Operations = OnOnly
    keylist CVMVxconfigdArgs
)
```

Example CFSTypes.cf file

This is a sample of the `CFSTypes.cf` file.

```
type CFSMount (
    static keylist RegList = { MountOpt, Policy, NodeList, ForceOff,
 SetPrimary }
    static int FaultOnMonitorTimeouts = 1

    static int OnlineRetryLimit = 16

    static int OnlineWaitLimit = 1
    static str ArgList[] = { MountPoint, BlockDevice, MountOpt }
    str MountPoint
    str MountType
    str BlockDevice
    str MountOpt
    keylist NodeList
    keylist Policy
    temp str Primary
    str SetPrimary
    str RemountRes
    str ForceOff
)
type CFSfsckd (
    static int RestartLimit = 1
    str ActivationMode{}
)
```

CFSMount agent

The CFSMount agent brings online, takes offline, and monitors a cluster file system mount point. The CFSMount agent executable is `/opt/VRTSvcs/bin/CFSMount/CFSMountAgent`. The type definition is in the `/etc/VRTSvcs/conf/config/CFSTypes.cf` file.

Table 7-2 describes the CFSMount agent entry points.

Table 7-2 CFSMount agent entry points

Entry Points	Description
Online	Mounts a block device or file system snapshot in cluster mode.
Offline	Unmounts the file system (doing a forced unmount if necessary).
Monitor	Determines if the file system is mounted. Checks mount status using the `fsclustadm` command.
Clean	A null operation for a cluster file system mount.
attr_change	Remounts file system with new mount option; sets new primary for file system; sets `fsclustadm` policy on file system.

Table 7-3 describes the CFSMount agent attributes.

Table 7-3 CFSMount agent attributes

Attributes	Type and Dimension	Definition
BlockDevice (required)	string-scalar	Block device for mount point.
MountPoint (required)	string-scalar	Directory for mount point.

Table 7-3 CFSMount agent attributes *(continued)*

Attributes	Type and Dimension	Definition
NodeList (required)	string-keylist	List of nodes on which to mount.
Policy (optional)	string-scalar	Node list for the primary file system selection policy.

MountOpt (optional)	string-scalar	Options for the `mount` command. To create a valid MountOpt attribute string:
		■ Use VxFS type-specific options only.
		■ Do not use the `-o` flag to specify the VxFS-specific options.
		■ Do not use the `-F vxfs` file system type option.
		■ The `cluster` option is not required.
		■ Specify options in a comma-separated list as in these examples:
		`ro`
		`ro,cluster`
		`blkclear,mincache=closesync`

MountType, Primary, SetPrimary, RemountRes, ForceOff (internal)		Not user configured used only by system.

CFSMount type definition

The CFSMount type definition:

```
type CFSMount (
        static keylist RegList = { MountOpt, Policy, NodeList, ForceOff,
SetPrimary }
        static int FaultOnMonitorTimeouts = 1
        static int OnlineWaitLimit = 1
        static str ArgList[] = { MountPoint, BlockDevice, MountOpt,
Primary }
        str MountPoint
        str MountType
        str BlockDevice
        str MountOpt
        keylist NodeList
        keylist Policy
        temp str Primary
        str SetPrimary
        temp str RemountRes
        str ForceOff
)
```

Sample of CFSMount configuration

This is a sample of CFSMount configuration:

```
CFSMount testdg_test01_fsetpri (
    Critical = 0
    mountPoint = "/mnt1"
    BlockDevice = "/dev/vx/dsk/testdg/test01"
    )
CFSMount testdg_test02_fsetpri (
    Critical = 0
    MountPoint = "/mnt2"
    BlockDevice = "/dev/vx/dsk/testdg/test02"
    MountOpt = "blkclear,mincache=closesync"
    )
```

CFSfsckd agent

The CFSfsckd agent starts, stops, and monitors the `vxfsckd` process. The CFSfsckd agent executable is `/opt/VRTSvcs/bin/CFSfsckd/CFSfsckdAgent`. The type definition is in the `/etc/VRTSvcs/conf/config/CFSTypes.cf` file. The configuration is added to the `main.cf` file after running the `cfscluster config` command.

Table 7-4 describes the CFSfsckd agent entry points.

Table 7-4 CFSfsckd agent entry points

Entry Points	Description
Online	Starts the vxfsckd process.
Offline	Kills the vxfsckd process.
Monitor	Checks whether the vxfsckd process is running.
Clean	A null operation for a cluster file system mount.

There are no required or optional attributes for the CFSfsckd agent.

CFSfsckd type definition

The CFSfsckd type definition:

```
type CFSfsckd (
        static int RestartLimit = 1
        str ActivationMode{}
)
```

Sample of CFSfsckd configuration

This is a sample of CFSfsckd configuration:

```
CFSfsckd vxfsckd (
)
```

CVMCluster agent

The CVMCluster agent controls node membership on the cluster port associated with CVM. The CVMCluster resource requires the CVMVxconfigd resource and must be configured to depend on CVMVxconfigd. The CVMCluster agent executable is `/opt/VRTSvcs/bin/CVMCluster/CVMClusterAgent`. The type definition is in the `/etc/VRTSvcs/conf/config/CVMTypes.cf` file. The configuration is added to the main.cf file after running the cfscluster config command.

Table 7-5 describes the CVMCluster agent entry points.

Table 7-5 CVMCluster agent entry points

Entry Points	Description
Online	Joins a node to the CVM cluster port.
Offline	Removes a node from the CVM cluster port.
Monitor	Monitors the node's CVM cluster membership state.
Clean	A null operation for a cluster file system mount.

Table 7-6 describes the CVMCluster agent attributes.

Table 7-6 CVMCluster agent attributes

Attributes	Type and Dimension	Definition
CVMClustName (required)	string-scalar	Name of the cluster.
CVMNodeAddr (required)	string-association	List of host names and IP addresses.
CVMNodeId (required)	string-association	List of host names and LLT node numbers.
CVMTransport (required)	string-association	The CVM transport mode, either `gab` or `udp`. For SFCFS, `gab` is the only valid transport mode.
PortConfigd (required)	integer-scalar	Port number used by CVM for vxconfigd-level communication.
PortKmsgd (required)	integer-scalar	Port number used by CVM for kernel-level communication.
CVMTimeout (required)	integer-scalar	Timeout used by CVM during cluster reconfigurations.

CVMCluster type definition

```
type CVMCluster (
        static int NumThreads = 1
        static int OnlineRetryLimit = 2
        static int OnlineTimeout = 400
        static str ArgList[] = { CVMTransport, CVMClustName, CVMNodeAddr,
CVMNodeId, PortConfigd, PortKmsgd, CVMTimeout }
        str CVMClustName
        str CVMNodeAddr{}
        str CVMNodeId{}
        str CVMTransport
        int PortConfigd
        int PortKmsgd
        int CVMTimeout
)
```

Sample of CVMCluster configuration

This is a sample of CVMCluster configuration:

```
CVMCluster cvm_clus (
        Critical = 0
        CVMClustName = vcs
        CVMNodeId = { system01 = 1, system02 = 2 }
        CVMTransport = gab
        CVMTimeout = 200
    )
```

CVMVolDg agent

The CVMVolDg agent brings online, takes offline, and monitors a VxVM shared volume in a disk group. The CVMVolDg agent executable is `/opt/VRTSvcs/bin/CVMVolDg/CVMVolDg`. The type definition is in the `/etc/VRTSvcs/conf/config/CVMTypes.cf` file.

Table 7-7 describes the CVMVolDg agent entry points.

Table 7-7 CVMVolDg agent entry points

Entry Points	Description
Online	Sets the activation mode of the shared disk group and brings volumes online.
Offline	Sets the activation mode of the shared disk group to “off.”
Monitor	Determines whether the disk group and volumes are online.
Clean	A null operation for a cluster file system mount.
attr_changed	Changes the activation mode of the shared disk groups specified.

Table 7-8 describes the CVMVolDg agent attributes.

Table 7-8 CVMVolDg agent attributes

Attributes	Type and Dimension	Definition
CVMDiskGroup (required)	string-scalar	Shared disk group name.
CVMVolume (required)	string-keylist	Shared Volume names. This list is used to check that the volumes are in the correct state before allowing the resource to come online, and that the volumes remain in an enabled state.

Table 7-8 CVMVolDg agent attributes *(continued)*

Attributes	Type and Dimension	Definition
CVMActivation (required)	string-scalar	Activation mode for the disk group. Must be set to shared-write (`sw`). This is a localized attribute.
CVMVolumeIoTest(optional)	string-keylist	List of volumes that will be periodically polled to test availability. The polling is in the form of a 1k read every monitor cycle to a maximum of 10 of the volumes in the list

CVMVolDg type definition

The CVMVolDg type definition:

```
type CVMVolDg (
        static keylist RegList = { CVMActivation, CVMVolume }
        static int OnlineRetryLimit = 2
        static int OnlineTimeout = 400
        static str ArgList[] = { CVMDiskGroup, CVMVolume, CVMActivation,
CVMStartVolumes, CVMDGAction }
        str CVMDiskGroup
        str CVMDGAction
        keylist CVMVolume
        str CVMActivation
        int CVMStartVolumes
        temp int voldg_stat
)
```

Sample of CVMVolDg configuration

This is a sample of CVMVolDg configuration:

```
CVMVolDg testdg (
    CVMDiskGroup = testdg
    CVMActivation @system01 = sw
    CVMActivation @system02 = sw
    )
```

Creating a starter database

This appendix includes the following topics:

Creating a database for Oracle 10g or 11g

Create a database tablespace for Oracle 10g or 11g using one of the two options:

- Option 1: on shared raw VxVM volumes
- Option 2: on cluster file system (CFS)

Before you begin, take note of the following prerequisites:

- CRS daemons must be running. To verify the status of CRS, enter:

  ```
  # $CRS_HOME/bin/crs_stat
  ```

- Use the `ping` command to verify that all private IP addresses on each node are up.

Creating database tablespace on shared raw VxVM volumes (option 1)

This section describes how to create database tablespace on shared raw VxVM volumes (option 1).

To create database tablespace on shared raw VxVM volumes (option 1)

1. Log in as `root`.
2. Find out the CVM master, enter the following command on any node:

   ```
   # vxdctl -c mode
   mode: enabled: cluster active - MASTER
   master: system01
   ```

   The above sample output indicates that `system01` is the CVM master.
3. On the CVM master, find out the spare disks that can be used for creating shared disk group for Oracle database tablespaces, enter:

   ```
   # vxdisk -o alldgs list
   DEVICE TYPE          DISK   GROUP     STATUS
   sda    auto:none     -      -         online invalid
   sdb    auto:none     -      -         online invalid
   sdc    auto:cdsdisk  -      tempdg    online shared
   sdd    auto:none     -      ocrvotedg online shared
   sde    auto:cdsdisk  -      -         online shared
   sdf    auto:cdsdisk  -      -         online shared
   ```

   The above sample output indicates that shared disks `sde` and `sdf` are free and can be used for Oracle database tablespaces.
4. On the CVM master node, create a shared disk group:

   ```
   # vxdg -s init oradatadg sde sdf
   ```

5. Create a volume in the shared group for each of the required tablespaces.

   See the *Oracle* documentation specific to the Oracle database release to determine the tablespace requirements.

   For example, enter:

   ```
   # vxassist -g oradatadg make VRT_system01 1000M
   # vxassist -g oradatadg make VRT_system02 10M
   .
   .
   .
   ```

6 Define the access mode and permissions for the volumes storing the Oracle data. For each volume listed in `$ORACLE_HOME/raw_config`, use the `vxedit` command:

```
# vxedit -g disk_group set group=group user=user mode=660 volume
```

See the `vxedit`(1M) manual page.

For example, enter:

```
# vxedit -g oradatadg set group=oinstall user=oracle mode=660 \
VRT_system01
```

In this example, `VRT_system01` is the name of one of the volumes. Repeat the command to define access mode and permissions for each volume in the `oradatadg`.

7 Create the database.

See the *Oracle* documentation.

Creating database tablespace on CFS (option 2)

This section describes how to create database tablespace on CFS (option 2). If you plan to use a cluster file system to store the Oracle database, use the following procedure to create the file system.

To creating database tablespace on CFS (option 2)

1 Log in as `root`.

2 Find out the CVM master, enter the following command on any node:

```
# vxdctl -c mode
mode: enabled: cluster active - MASTER
master: system01
```

The above sample output indicates that `system01` is the CVM master.

3. On the CVM master, find out the spare disks that can be used for creating shared disk group for Oracle database tablespaces, enter:

```
# vxdisk -o alldgs list
DEVICE TYPE          DISK   GROUP     STATUS
sda    auto:none     -      -         online invalid
sdb    auto:none     -      -         online invalid
sdc    auto:cdsdisk  -      tempdg    online shared
sdd    auto:none     -      ocrvotedg online shared
sde    auto:cdsdisk  -      -         online shared
sdf    auto:cdsdisk  -      -         online shared
```

   The above sample output indicates that shared disks `sde` and `sdf` are free and can be used for Oracle database tablespaces.

4. Create a shared disk group. For example, enter:

```
# vxdg -s init oradatadg sdd
```

5. Create a single shared volume that is large enough to contain a file system for all tablespaces.

   See the *Oracle* documentation specific to the Oracle database release for tablespace sizes.

   Assuming 6.8GB are required for the tablespaces, enter:

```
# vxassist -g oradatadg make oradatavol 6800M
```

6. Create a VxFS file system in this volume, enter:

```
# mkfs -F vxfs /dev/vx/rdsk/oradatadg/oradatavol
```

7. Create a mount point for the shared file system, enter:

```
# mkdir /oradata
```

8. From the same node, mount the file system, enter:

```
# mount -F vxfs -o cluster /dev/vx/dsk/oradatadg/oradatavol \
/oradata
```

9. Set `oracle` as the owner of the file system, and set `775` as the permissions:

```
# chown oracle:oinstall /oradata
# chmod 775 /oradata
```

10 On the other node(s), complete steps 7 through 9.

11 Create the Oracle database.

See the *Oracle* documentation.

Glossary

access control list (ACL)	The information that identifies specific users or groups and their access privileges for a particular file or directory.
agent	A process that manages predefined Veritas Cluster Server (VCS) resource types. Agents bring resources online, take resources offline, and monitor resources to report any state changes to VCS. When an agent is started, it obtains configuration information from VCS and periodically monitors the resources and updates VCS with the resource status.
allocation unit	A group of consecutive blocks on a file system that contain resource summaries, free resource maps, and data blocks. Allocation units also contain copies of the super-block.
API	Application Programming Interface.
asynchronous writes	A delayed write in which the data is written to a page in the system's page cache, but is not written to disk before the write returns to the caller. This improves performance, but carries the risk of data loss if the system crashes before the data is flushed to disk.
atomic operation	An operation that either succeeds completely or fails and leaves everything as it was before the operation was started. If the operation succeeds, all aspects of the operation take effect at once and the intermediate states of change are invisible. If any aspect of the operation fails, then the operation aborts without leaving partial changes.
Block-Level Incremental Backup (BLI Backup)	A Veritas backup capability that does not store and retrieve entire files. Instead, only the data blocks that have changed since the previous backup are backed up.
boot disk	A disk that is used for the purpose of booting a system.
boot disk group	A private disk group that contains the disks from which the system may be booted.
buffered I/O	A mode of I/O operation (where I/O is any operation, program, or device that transfers data to or from a computer) that first transfers data into the Operating System buffer cache.
bootdg	A reserved disk group name that is an alias for the name of the boot disk group.
cluster mounted file system	A shared file system that enables multiple hosts to mount and perform file operations on the same file. A cluster mount requires a shared storage device that can be accessed by other cluster mounts of the same file system. Writes to the

	shared device can be done concurrently from any host on which the cluster file system is mounted. To be a cluster mount, a file system must be mounted using the `mount -o cluster` option.
Cluster Services	The group atomic broadcast (GAB) module in the SFCFS stack provides cluster membership services to the file system. LLT provides kernel-to-kernel communications and monitors network communications.
contiguous file	A file in which data blocks are physically adjacent on the underlying media.
CVM	The cluster functionality of Veritas Volume Manager.
CVM Master	The cluster volume manager (CVM) has a master node that records changes to the volume configuration.
data block	A block that contains the actual data belonging to files and directories.
data synchronous writes	A form of synchronous I/O that writes the file data to disk before the write returns, but only marks the inode for later update. If the file size changes, the inode will be written before the write returns. In this mode, the file data is guaranteed to be on the disk before the write returns, but the inode modification times may be lost if the system crashes.
defragmentation	The process of reorganizing data on disk by making file data blocks physically adjacent to reduce access times.
direct extent	An extent that is referenced directly by an inode.
direct I/O	An unbuffered form of I/O that bypasses the kernel's buffering of data. With direct I/O, the file system transfers data directly between the disk and the user-supplied buffer.
discovered direct I/O	Discovered Direct I/O behavior is similar to direct I/O and has the same alignment constraints, except writes that allocate storage or extend the file size do not require writing the inode changes before returning to the application.
encapsulation	A process that converts existing partitions on a specified disk to volumes. If any partitions contain file systems, `/etc/fstab` entries are modified so that the file systems are mounted on volumes instead. Encapsulation is not applicable on some systems.
extent	A group of contiguous file system data blocks treated as a single unit. An extent is defined by the address of the starting block and a length.
extent attribute	A policy that determines how a file allocates extents.
external quotas file	A quotas file (named `quotas`) must exist in the root directory of a file system for quota-related commands to work.
file system block	The fundamental minimum size of allocation in a file system. This is equivalent to the fragment size on some UNIX file systems.

fileset	A collection of files within a file system.
fixed extent size	An extent attribute used to override the default allocation policy of the file system and set all allocations for a file to a specific fixed size.
fragmentation	The on-going process on an active file system in which the file system is spread further and further along the disk, leaving unused gaps or fragments between areas that are in use. This leads to degraded performance because the file system has fewer options when assigning a file to an extent.
GB	Gigabyte (2^{30} bytes or 1024 megabytes).
hard limit	The hard limit is an absolute limit on system resources for individual users for file and data block usage on a file system.
Heartbeats	Heartbeat messages are sent over the private link to obtain information on cluster membership changes. If a node does not send a heartbeat for 16 seconds, it is removed from the membership. The command lltconfig is used for information on the various heartbeat parameters. The low latency transport (LLT) module provides communication services across the cluster.
indirect address extent	An extent that contains references to other extents, as opposed to file data itself. A single indirect address extent references indirect data extents. A double indirect address extent references single indirect address extents.
indirect data extent	An extent that contains file data and is referenced via an indirect address extent.
inode	A unique identifier for each file within a file system that contains the data and metadata associated with that file.
inode allocation unit	A group of consecutive blocks containing inode allocation information for a given fileset. This information is in the form of a resource summary and a free inode map.
intent logging	A method of recording pending changes to the file system structure. These changes are recorded in a circular intent log file.
internal quotas file	VxFS maintains an internal quotas file for its internal usage. The internal quotas file maintains counts of blocks and indices used by each user.
K	Kilobyte (2^{10} bytes or 1024 bytes).
large file	A file larger than two terabytes. VxFS supports files up to 8 exabytes in size.
large file system	A file system larger than two terabytes. VxFS supports file systems up to 8 exabytes in size.
latency	For file systems, this typically refers to the amount of time it takes a given file system operation to return to the user.

local mounted file system	A file system mounted on a single host. The single host mediates all file system writes to storage from other clients. To be a local mount, a file system cannot be mounted using the `mount -o cluster` option.
metadata	Structural data describing the attributes of files on a disk.
MB	Megabyte (2^{20} bytes or 1024 kilobytes).
mirror	A duplicate copy of a volume and the data therein (in the form of an ordered collection of subdisks). Each mirror is one copy of the volume with which the mirror is associated.
multi-volume file system	A single file system that has been created over multiple volumes, with each volume having its own properties.
MVS	Multi-volume support.
node	One of the hosts in a cluster.
node abort	A situation where a node leaves a cluster (on an emergency basis) without attempting to stop ongoing operations.
node join	The process through which a node joins a cluster and gains access to shared disks.
object location table (OLT)	The information needed to locate important file system structural elements. The OLT is written to a fixed location on the underlying media (or disk).
page file	A fixed-size block of virtual address space that can be mapped onto any of the physical addresses available on a system.
preallocation	A method of allowing an application to guarantee that a specified amount of space is available for a file, even if the file system is otherwise out of space.
primary fileset	The files that are visible and accessible to the user.
quotas	Quota limits on system resources for individual users for file and data block usage on a file system.
quotas file	The quotas commands read and write the external quotas file to get or change usage limits. When quotas are turned on, the quota limits are copied from the external quotas file to the internal quotas file.
reservation	An extent attribute used to preallocate space for a file.
root disk group	A special private disk group that always exists on the system. The root disk group is named `rootdg`.
SFCFS	The Veritas Storage Foundation Cluster File System.
SFCFS Primary	There is a primary node for each file system in the cluster responsible for updating metadata in the file system.
shared disk group	A disk group in which the disks are shared by multiple hosts (also referred to as a cluster-shareable disk group).

shared volume	A volume that belongs to a shared disk group and is open on more than one node at the same time.
snapshot file system	An exact copy of a mounted file system at a specific point in time. Used to do online backups.
snapped file system	A file system whose exact image has been used to create a snapshot file system.
soft limit	The soft limit is lower than a hard limit. The soft limit can be exceeded for a limited time. There are separate time limits for files and blocks.
Storage Checkpoint	A facility that provides a consistent and stable view of a file system or database image and keeps track of modified data blocks since the last Storage Checkpoint.
structural fileset	The files that define the structure of the file system. These files are not visible or accessible to the user.
super-block	A block containing critical information about the file system such as the file system type, layout, and size. The VxFS super-block is always located 8192 bytes from the beginning of the file system and is 8192 bytes long.
synchronous writes	A form of synchronous I/O that writes the file data to disk, updates the inode times, and writes the updated inode to disk. When the write returns to the caller, both the data and the inode have been written to disk.
TB	Terabyte (2^{40} bytes or 1024 gigabytes).
transaction	Updates to the file system structure that are grouped together to ensure they are all completed.
throughput	For file systems, this typically refers to the number of I/O operations in a given unit of time.
unbuffered I/O	I/O that bypasses the kernel cache to increase I/O performance. This is similar to direct I/O, except when a file is extended; for direct I/O, the inode is written to disk synchronously, for unbuffered I/O, the inode update is delayed.
VCS	The Veritas Cluster Server.
volume	A virtual disk which represents an addressable range of disk blocks used by applications such as file systems or databases.
volume set	A container for multiple different volumes. Each volume can have its own geometry.
vxfs	The Veritas File System type. Used as a parameter in some commands.
VxFS	The Veritas File System.
VxVM	The Veritas Volume Manager.

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