VMS Software

VSI OpenVMS

Volume Shadowing Guide

Operating System and Version: VSI OpenVMS IA-64 Version 8.4-1H1 or higher
VSI OpenVMS Alpha Version 8.4-2L1 or higher
VSI OpenVMS x86-64 Version 9.2-1 or higher

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Volume Shadowing Guide

Legal Notice

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Preface

This manual explains how to use VSI Volume Shadowing for OpenVMS to replicate data transparently on multiple disks and to provide high data availability.

1. About VSI

VMS Software, Inc. (VSI) is an independent software company licensed by Hewlett Packard Enterprise to develop and support the OpenVMS operating system.

2. Intended Audience

This book is intended for system managers and system users who want to:

- Understand how Volume Shadowing for OpenVMS works
- Configure shadowed data storage subsystems to maximize data availability
- Set up and manage shadow sets
- Enhance shadow set performance

Although you do not need any previous volume shadowing experience to use the volume shadowing software or this documentation, you do need a familiarity with the OpenVMS operating system, the OpenVMS Mount utility or OpenVMS system services, and setting system parameters.

3. Document Structure

The manual consists of the following chapters and appendices:

Chapter	Contents
Chapter 1, "Introduction to Volume Shadowing for OpenVMS"	Introduces Volume Shadowing for OpenVMS and describes how it provides high data availability.
Chapter 2, "Configuring Your System for High Data Availability"	Illustrates various shadow set configurations.
Chapter 3, "Preparing to Use Volume Shadowing"	Describes how to set up a volume shadowing environment, including information about setting shadowing system parameters, booting a system that uses a system disk in a shadow set, and booting satellite nodes from a shadowed system disk.
Chapter 4, "Creating and Managing Shadow Sets Using DCL Commands"	Describes how to use DCL commands to create, mount, dismount, and dissolve shadow sets. The chapter also describes how to use the `SHOW DEVICES`**`SHOW DEVICES`** command, the System Dump Analyzer, and the F$GETDVI lexical function to obtain information about shadow sets on a running system.
Chapter 5, "Creating and Managing Shadow Sets with System Services"	Describes how to use the OpenVMS system services in a user-written program to create and manage shadow sets. The chapter also describes how to use the $GETDVI system service to obtain information about shadow sets.

Chapter	Contents
Chapter 6, "Ensuring Shadow Set Consistency"	Describes how the copy and merge operations maintain data consistency and availability during changes in shadow set membership.
Chapter 7, "Using Minicopy for Backing Up Data"	Describes how the minicopy operation can be used, in a carefully controlled environment, to reduce the time required for a member to be returned to a shadow set. Typically, the member is removed for backing up data.
Chapter 8, "Host-Based Minimerge (HBMM)"	Describes how to use host-based minimerge (HBMM) to shorten the time of a merge operation.
Chapter 9, "Performing System Management Tasks on Shadowed Systems"	Describes how to perform system management tasks on shadow sets, including performing backup and upgrade operations, performing shadowing operations in OpenVMS Cluster systems, and handling crash dumps on the shadow set.
Chapter 10, "Performance Information for Volume Shadowing"	Includes helpful information and guidelines for achieving better performance from shadow sets.
Appendix A, "Messages"	Lists messages related to volume shadowing that are returned by the Mount utility and the VOLPROC, shadow server, and OPCOM facilities.

4. Related Documents

The following documents contain information related to this manual:

- *VSI OpenVMS License Management Utility Guide*
- *VSI OpenVMS Cluster Systems Manual*
- *Guidelines for OpenVMS Cluster Configurations*
- *VSI OpenVMS DCL Dictionary: A–M*

  VSI OpenVMS DCL Dictionary: N–Z
- *VSI OpenVMS System Manager's Manual, Volume 1: Essentials*

  VSI OpenVMS System Manager's Manual, Volume 2: Tuning, Monitoring, and Complex Systems
- *VSI OpenVMS System Management Utilities Reference Manual, Volume 1: A-L*

  VSI OpenVMS System Management Utilities Reference Manual, Volume 2: M-Z
- *VSI OpenVMS System Analysis Tools Manual*
- *VSI OpenVMS System Services Reference Manual: A–GETUAI*

  VSI OpenVMS System Services Reference Manual: GETUTC–Z

5. VSI Encourages Your Comments

You may send comments or suggestions regarding this manual or any VSI document by sending electronic mail to the following Internet address: <docinfo@vmssoftware.com>. Users who have

VSI OpenVMS support contracts through VSI can contact <support@vmssoftware.com> for help with this product.

6. OpenVMS Documentation

The full VSI OpenVMS documentation set can be found on the VMS Software Documentation webpage at https://docs.vmssoftware.com.

7. Typographical Conventions

The following conventions may be used in this manual:

Convention	Meaning
Ctrl/ *x*	A sequence such as **Ctrl/** *x* indicates that you must hold down the key labeled Ctrl while you press another key or a pointing device button.
PF1 *x*	A sequence such as PF1 *x* indicates that you must first press and release the key labeled PF1 and then press and release another key or a pointing device button.
Return	In examples, a key name enclosed in a box indicates that you press a key on the keyboard. (In text, a key name is not enclosed in a box.)
. . .	A horizontal ellipsis in examples indicates one of the following possibilities: • Additional optional arguments in a statement have been omitted. • The preceding item or items can be repeated one or more times. • Additional parameters, values, or other information can be entered.
. . .	A vertical ellipsis indicates the omission of items from a code example or command format; the items are omitted because they are not important to the topic being discussed.
( )	In command format descriptions, parentheses indicate that you must enclose the options in parentheses if you choose more than one.
[ ]	In command format descriptions, brackets indicate optional choices. You can choose one or more items or no items. Do not type the brackets on the command line. However, you must include the brackets in the syntax for OpenVMS directory specifications and for a substring specification in an assignment statement.
[|]	In command format descriptions, vertical bars separate choices within brackets or braces. Within brackets, the choices are options; within braces, at least one choice is required. Do not type the vertical bars on the command line.
{ }	In command format descriptions, braces indicate required choices; you must choose at least one of the items listed. Do not type the braces on the command line.
bold text	This typeface represents the introduction of a new term. It also represents the name of an argument, an attribute, or a reason.
italic text	Italic text indicates important information, complete titles of manuals, or variables. Variables include information that varies in system output (Internal error *number*), in command lines (/PRODUCER= *name*), and in command parameters in text (where *dd* represents the predefined code for the device type).

Convention	Meaning
UPPERCASE TEXT	Uppercase text indicates a command, the name of a routine, the name of a file, or the abbreviation for a system privilege.
`Monospace type`	Monospace type indicates code examples and interactive screen displays. In the C programming language, monospace type in text identifies the following elements: keywords, the names of independently compiled external functions and files, syntax summaries, and references to variables or identifiers introduced in an example.
`Bold monospace type`	Bold monospace type indicates DCL commands and qualifiers that can be entered at the command prompt.
-	A hyphen at the end of a command format description, command line, or code line indicates that the command or statement continues on the following line.
numbers	All numbers in text are assumed to be decimal unless otherwise noted. Nondecimal radixes—binary, octal, or hexadecimal—are explicitly indicated.

Chapter 1. Introduction to Volume Shadowing for OpenVMS

This chapter introduces VSI Volume Shadowing for OpenVMS and describes how volume shadowing, sometimes referred to as disk mirroring, achieves high data availability.

1.1. Overview

VSI Volume Shadowing for OpenVMS ensures that data is available to your applications and end users by duplicating data on multiple disks. Because the same data is recorded on multiple disk volumes, if one disk fails, the remaining disk or disks can continue to service I/O requests. VSI Volume Shadowing for OpenVMS is available on VSI OpenVMS Integrity servers, OpenVMS Alpha, and OpenVMS x86 systems. All volume shadowing features are available on OpenVMS Integrity servers, OpenVMS Alpha, and OpenVMS x86 systems.

An implementation of RAID 1 (redundant arrays of independent disks) technology, Volume Shadowing for OpenVMS prevents a disk device failure from interrupting system and application operations. By duplicating data on multiple disks, volume shadowing transparently prevents your storage subsystems from becoming a single point of failure because of media deterioration or communication path failure, or through controller or device failure.

Any entity that is designated as a disk class device to OpenVMS is a device that can be used in a shadow set.

You can mount up to six compatible disk volumes, including the system disk, to form a **shadow set**.

VSI OpenVMS allows users to mount a maximum of six disk volumes. Each disk in the shadow set is a shadow set **member**. Volume Shadowing for OpenVMS logically binds the shadow set disks together and represents them as a single virtual device called a **virtual unit**, as shown in *Figure 1.1, "Virtual Unit"*. This means that the multiple members of the shadow set, represented by the virtual unit, appear to applications and users as a single, highly available disk.

Note that the term disk and device are used interchangeably throughout this manual to refer to a disk volume. A disk volume is a disk that was prepared for use by placing a new file structure on it.

Figure 1.1. Virtual Unit

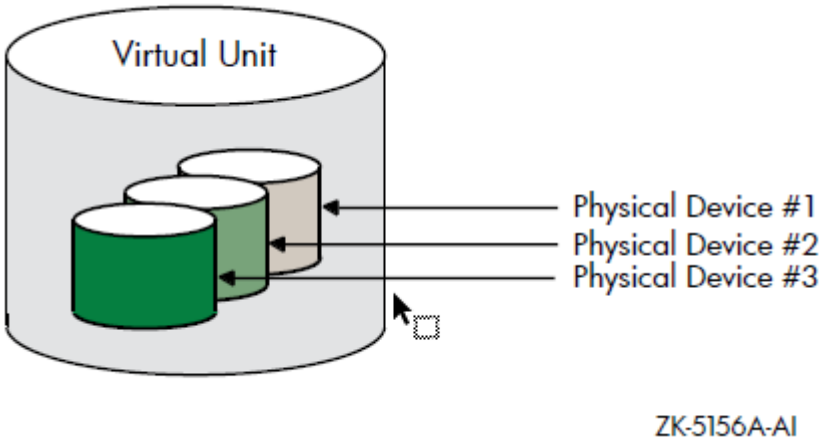
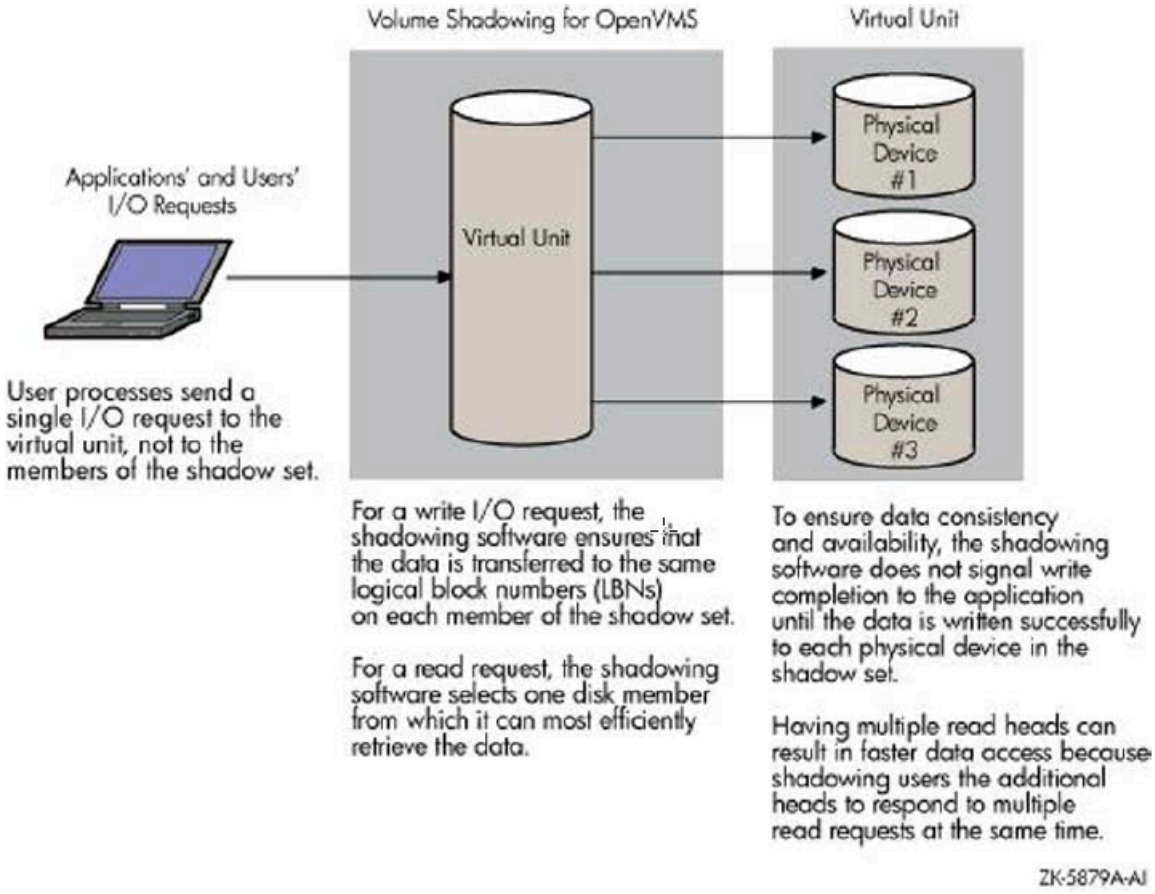


Figure 1.2, "Elements of a Shadow Set" shows how Volume Shadowing for OpenVMS propagates data through the virtual unit to three individual shadow set members.

Figure 1.2. Elements of a Shadow Set



An additional benefit of volume shadowing is its potential role in repairing data. For example, if data on a shadow set member becomes unreadable, the shadowing software can read the data from another member. Before the good data is returned to the process, it is written to the member that could not originally read it.

Note

Remember that volume shadowing protects against hardware problems that cause a disk volume to be a single point of failure for both applications and systems that use the disk. Volume shadowing does not provide for recovery from software-related incidents, such as the accidental deletion of files or errant software corrupting the contents of a disk file. Do not use volume shadowing as a substitute for regular backup or journaling.

Applications and users read and write data to and from a shadow set using the same commands and program language syntax and semantics that are used for non-shadowed I/O operations. System managers manage and monitor shadow sets using the same commands and utilities they use for non-shadowed disks. The only difference is that access is through the virtual unit, not to individual disk.

1.2. Volume Shadowing Tasks and Operations

The primary volume shadowing operations used to create shadow sets and to maintain consistent data on each member are mount, copy, minicopy, merge, and minimerge. When these operations are in progress, the system continues to process read and write requests, thus providing continuous availability.

All volume shadowing operations, except for merges and minimerges, are under the control of the system manager. Merges and minimerges are started automatically by the volume shadowing software if a hardware or software failure occurs that could affect the consistency of the data on the shadow set members. However, you can control the order of these merges by assigning different priorities to the shadow sets, as described in *Section 4.9, "Prioritizing Merge and Copy Operations"*. You can also change the default delays that affect merges and copies with the SHADOW_PSM_DLY and SHADOW_REC_DLY system parameters that are described in *Table 3.1, "Volume Shadowing Parameters"*.

System managers turn on volume shadowing with the SHADOWING system parameter.
They can control the number of concurrent merge or copy operations on a given node by the SHADOW_MAX_COPY system parameter. These volume shadowing system parameters, and all other system parameters used with volume shadowing, are described in *Section 3.3, "Volume Shadowing Parameters"* and in *Section 3.4, "Bitmap System Parameters"*.

Volume Shadowing for OpenVMS is never invoked directly. Instead, you invoke the DCL commands **MOUNT** and **DISMOUNT**. The **MOUNT** command works with the volume shadowing software to create shadow sets. The **DISMOUNT** command works with the volume shadowing software to remove shadow set members and to dissolve entire shadow sets.

Host-based minimerge (HBMM) enables minimerge operations on Fibre Channel and SCSI disk devices.

OpenVMS also provides a programming interface for creating and managing shadow sets with the $MOUNT, $DISMOU, and $GETDVI system services. This programming interface is described in *Chapter 5, "Creating and Managing Shadow Sets with System Services"*.

Table 1.1, "Main Volume Shadowing Tasks, Operation Name, and Related Software " shows the main volume shadowing tasks, the operations associated with them, and the software used to perform the operation. These operations are described in more detail in *Chapter 4, "Creating and Managing Shadow Sets Using DCL Commands"*, *Chapter 6, "Ensuring Shadow Set Consistency"*, and *Chapter 7, "Using Minicopy for Backing Up Data"*.

Table 1.1. Main Volume Shadowing Tasks, Operation Name, and Related Software

Task	Operation	Software Used
Create a shadow set.	Copy	**MOUNT/SHADOW** command with the SHADOWING system parameter set, which starts the copy automatically. When a second or third member is added, the shadowing software starts a copy operation.
Remove a member from a shadow set.	Dismount a disk	**DISMOUNT** command.
Dissolve a shadow set.	Dismount the shadow set (specify its virtual unit name)	**DISMOUNT** command.

Task	Operation	Software Used
Ensure that the data is identical on all shadow set members in the event of a hardware failure.	Merge or minimerge	Shadowing software does this automatically when it detects a hardware or software failure. If an HSJ or HSC controller is present in the configuration, a minimerge might be done.
Return a dismounted shadow set member to the shadow set.	Copy or minicopy	**MOUNT** command, with shadowing software that initiates either a copy or, if properly configured, a minicopy.

1.3. Hardware Environment

Hardware Environment Volume Shadowing for OpenVMS does not depend on specific hardware in order to operate. All shadowing functions can be performed on OpenVMS Integrity server systems, OpenVMS Alpha, and on OpenVMS x86 systems.

Volume shadowing requires a minimum of:

- One CPU
- One mass storage controller
- One of the following kinds of disk drives:
  - Serial Advanced Technology Attachment (SATA)
  - Small Computer Systems Interface (SCSI)
  - Fibre Channel

The following sections generically describe hardware support. See the most recent *Volume Shadowing for OpenVMS Software Product Description DO-VIBHAA-031* for more information.

1.3.1. Memory Requirements

The following additional memory is required to run Volume Shadowing for OpenVMS:

- 24 KB per node is required on Integrity server systems, OpenVMS Alpha systems, and OpenVMS x86 systems. These requirements are in effect even if you do not use Volume Shadowing for OpenVMS, unless you change the default setting.

  If this memory is not available, the node will not boot.

- 4.5 KB per shadow set per node is required.

  This amount of memory is required before a bitmap can be created. If this memory is not available, the mount fails (that is, the shadow set is not mounted on the node). The **MOUNT** command that fails will issue the following message:

  ```
  %MOUNT-F-INSFMEM, insufficient dynamic memory
  ```

- For every GB of storage of a shadow set member, 2.0 KB per node is required for the bitmaps for each shadow set mounted on a node. (Each shadow set can have up to six bitmaps. And, with HBMM support, a shadow set can have a maximum of 12 bitmaps.)

  When calculating memory requirements, note that a two-member shadow set with 50 GB per member counts as 50 GB, not 100 GB.

  For example, for a shadow set with 200 GB of storage per member, 400 KB of memory is required for its bitmaps for every node in the cluster. If this memory is not available on the node where the bitmap request occurs, the bitmap is not created.

  If the master bitmap is created but sufficient memory is not available on another node on which the shadow set is subsequently mounted, a local bitmap is not created. If the WBM_OPCOM_LVL system parameter is set to 1 (the default) or 2, the following OPCOM message is displayed:

  ```
  Unable to allocate local bitmap - running in degraded mode.
  ```

  Writes from nodes without local bitmaps are registered with the node on which the shadow set is first mounted.

These memory requirements are cumulative. For example, a system with 10 shadow sets mounted, with each shadow set consisting of 50-GB member disks, would require an additional 1,119 KB of memory. The calculation follows:

- 24 KB per node (regardless of whether you use volume shadowing)
- 45 KB (10 shadow sets × 4.5 KB per unit mounted on the system)
- 1050 KB (50 × 2.1 KB (per GB of disk size) × 10 shadow sets
- 1119 KB total memory required

1.4. Supported Configurations

Volume Shadowing for OpenVMS provides data availability across the full range of configurations — from single nodes to large OpenVMS Cluster systems — so you can provide data availability where you require it most.

There are no restrictions on the location of shadow set members beyond the valid disk configurations defined in the SPDs for the OpenVMS operating system and for OpenVMS Cluster systems:

- For the OpenVMS Operating System: *SPD DO-VIBHAA-005* for Integrity V8.4-1H1; *SPD DO-DVASPQ-001* for Alpha V8.4-2L1
- For OpenVMS Cluster Software: *SPD DO-VIBHAA-032*

If an individual disk volume is already mounted as a member of an active shadow set, the disk volume cannot be mounted as a standalone disk on another node.

1.4.1. Maximum Number of Shadow Sets

You can mount a maximum of 500 disks in shadow sets on a standalone system or in an OpenVMS Cluster system. A limit of 10,000 single-member shadow sets is allowed on a standalone system or in an OpenVMS cluster. Dismounted shadow sets, unused shadow sets, and shadow sets with no write bitmaps allocated to them are included in this total. These limits are independent of controller and disk type. The shadow sets can be mounted as public or private volumes.

The SHADOW_MAX_UNIT system parameter is responsible for the maximum number of shadow sets that can exist on a node. For more information about SHADOW_MAX_UNIT, see *Section 3.3.1, "Guidelines for Using Volume Shadowing Parameters"*.

1.4.2. Support for Six-Member Shadow Sets

VSI OpenVMS supports six-member shadow sets as compared to the previous three-member shadow sets. This is useful for multisite disaster-tolerant configurations. In a three-member shadow set, a three-site disaster tolerant configuration has only one shadow member per site. In this scenario, when two sites fail, the member left out in the surviving site becomes a single point of failure. With six-member shadow set support, you can have two members of a shadow set in each of the three sites providing high availability.

For example:

```
$ SHOW DEV DSA5678:
Device                  Device           Error    Volume     Free   Trans  Mnt
 Name                   Status           Count    Label     Blocks  Count  Cnt
DSA5678:                Mounted              0  SIXMEMBER   682944      1    1
$6$DKB0:     (WSC236)   ShadowSetMember      0  (member of DSA5678:)
$6$DKB100:   (WSC236)   ShadowSetMember      0  (member of DSA5678:)
$6$DKB200:   (WSC236)   ShadowSetMember      0  (member of DSA5678:)
$6$DKB300:   (WSC236)   ShadowSetMember      0  (member of DSA5678:)
$6$DKB400:   (WSC236)   ShadowSetMember      0  (member of DSA5678:)
$6$DKB500:   (WSC236)   ShadowSetMember      0  (member of DSA5678:)
```

1.4.3. Shadowing System Disks

You can shadow system disks as well as data disks. Thus, a system disk need not be a single point of failure for any system that boots from that disk. System disk shadowing becomes especially important for OpenVMS Cluster systems that use a common system disk from which multiple computers boot. Volume shadowing makes use of the OpenVMS distributed lock manager, and the quorum disk must be accessed before locking is enabled. Note that you cannot shadow quorum disks.

Integrity server, Alpha, and x86 systems can share data on shadowed data disks, but separate system disks are required — one for each architecture.

1.4.4. EFI Shell Precautions on Shadowed System Disks

On each Integrity server and x86 system disk, there can exist up to two File Allocation Table (FAT)s partitions that contain OpenVMS boot loaders, Extensible Firmware Interface (EFI) applications, and hardware diagnostics. The OpenVMS bootstrap partition and, when present, the diagnostics partition are respectively mapped to the following container files on the OpenVMS system disk:

```
SYS$LOADABLE_IMAGES:SYS$EFI.SYS
SYS$MAINTENANCE:SYS$DIAGNOSTICS.SYS
```

The contents of the FAT partitions appear as `fs`*n*`:` devices at the console EFI `Shell>` prompt. The `fs`*n*`:` devices can be directly modified by the user command input at EFI `Shell>` prompt and by the EFI console or EFI diagnostic applications. Neither OpenVMS nor any EFI console environments that might share the system disk are notified of partition modifications; OpenVMS and console environments are unaware of console modifications. You must ensure the proper coordination and proper synchronization of the changes with OpenVMS and with any other EFI consoles that might be in use.

You must take precautions when modifying the console in configurations using either or both of the following:

- OpenVMS host-based volume shadowing for the OpenVMS Integrity server and x86 system disk;
- Shared system disks and parallel EFI console access across Integrity server and x86 environments sharing a common system disk.

You must preemptively reduce the OpenVMS system disk environments to a single-member host-based volume shadow set or to a non-shadowed system disk, and you must externally coordinate access to avoid parallel EFI shell sessions whenever making shell-level modifications to the `fs`*`n`*`: devices`, such as:

- Installing or operating diagnostics within the diagnostics partition.
- Allowing diagnostics in the partition (or running from removable media) to modify the boot or the diagnostic partition on an OpenVMS Integrity server and x86 system disk.
- Modifying directly or indirectly the boot or the diagnostics partition within these environments from the EFI `Shell>` prompt.

If you do not take these precautions, any modifications made within the fsn: device associated with the boot partition or the device associated with the diagnostic partition can be overwritten and lost immediately or after the next OpenVMS host-based volume shadowing full-merge operation.

For example, when the system disk is shadowed and changes are made by the EFI console shell to the contents of these container files on one of the physical members, the volume shadowing software is unaware that a write is done to a physical device. If the system disk is a multiple-member shadow set, you must make the same changes to all of the other physical devices that are the current shadow set members. If this is not done, when a full merge operation is next performed on that system disk, the contents of these files might regress. The merge operation might occur many days or weeks after any EFI changes are made.

Furthermore, if a full merge is active on the shadowed system disk, you must not make changes to either file using the console EFI shell.

To suspend a full merge operation that is in progress or to determine the membership of a shadow set, see *Chapter 8, "Host-Based Minimerge (HBMM)"*.

The precautions are applicable only for the Integrity server and x86 system disks that are configured for host-based volume shadowing, or are configured and shared across multiple OpenVMS Integrity server and OpenVMS x86 systems.

1.4.5. Using Minicopy in a Mixed-Version OpenVMS Cluster System

To use the minicopy feature in a mixed-version OpenVMS Cluster system, every node in the cluster must use a version of OpenVMS that supports this feature.

1.4.6. Shadow Sets, Bound Volume Sets, and Stripe Sets

Shadow sets also can be constituents of a bound volume set or a stripe set. A bound volume set consists of one or more disk volumes that have been bound into a volume set by specifying the **/BIND** qualifier

with the **MOUNT** command. *Section 1.5, "Shadowing Disks Across an OpenVMS Cluster System"* describes shadowing across OpenVMS Cluster systems. *Chapter 10, "Performance Information for Volume Shadowing"* contains more information about striping and how it relates to volume shadowing.

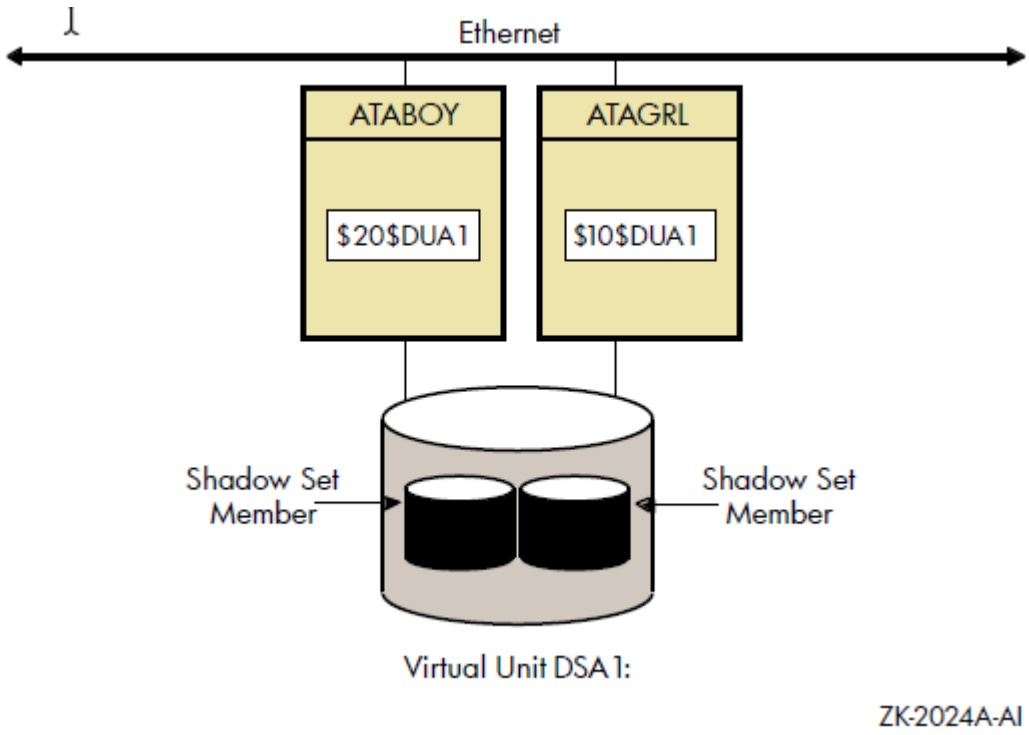
1.5. Shadowing Disks Across an OpenVMS Cluster System

The host-based implementation of volume shadowing allows disks that are connected to multiple physical controllers to be shadowed in an OpenVMS Cluster system. There is no requirement that all members of a shadow set be connected to the same controller. Controller independence allows you to manage shadow sets regardless of their controller connection or their location in the OpenVMS Cluster system and helps provide improved data availability and flexible configurations.

For clusterwide shadowing, members can be located anywhere in an OpenVMS Cluster system and served by MSCP servers across any supported OpenVMS Cluster interconnect, including the Ethernet, Digital Storage Systems Interconnect (DSSI), and Fiber Distributed Data Interface (FDDI). For example, OpenVMS Cluster systems using IPCI and wide area network services can be hundreds of miles apart, which further increases the availability and disaster tolerance of a system.

Figure 1.3, "Shadow Sets Accessed Through the MSCP Server" shows how shadow-set members are on line to local adapters located on different nodes. In the figure, a disk volume is local to each of the nodes ATABOY and ATAGRL. The MSCP server provides access to the shadow set members over the Ethernet. Even though the disk volumes are local to different nodes, the disks are members of the same shadow set. A member that is local to one node can be accessed by the remote node via the MSCP server.

Figure 1.3. Shadow Sets Accessed Through the MSCP Server



The shadowing software maintains shadow sets in a distributed fashion on each node that mounts the shadow set in the OpenVMS Cluster system. In an OpenVMS Cluster environment, each node creates

and maintains shadow sets independently. The shadowing software on each node maps each shadow set, represented by its virtual unit name, to its respective physical units. Shadow sets are not served to other nodes. When a shadow set must be accessed by multiple nodes, each node creates an identical shadow set. The shadowing software maintains clusterwide membership coherence for shadow sets mounted on multiple nodes. For shadow sets that are mounted on an OpenVMS Cluster system, mounting or dismounting a shadow set on one node in the cluster does not affect applications or user functions executing on other nodes in the system. For example, you can dismount the shadow set from one node in an OpenVMS Cluster system and leave the shadow set operational on the remaining nodes on which it is mounted.

1.6. Installation

Volume Shadowing for OpenVMS is a System Integrated Product (SIP) that you install at the same time that you install the operating system. On OpenVMS Integrity server systems, the license for Volume Shadowing is included in the Enterprise Operating Environment and in the Mission Critical Operating Environment. It is not included in the Foundation Operating Environment but can be purchased separately. On OpenVMS Alpha, Volume Shadowing for OpenVMS requires its own license that is separate from the OpenVMS base operating system license. To use the volume shadowing software, it must be licensed either as part of an OpenVMS Integrity server operating environment or by a separate license, as described. All nodes booting from shadowed system disks must have shadowing licensed and enabled. See the instructions included in your current OpenVMS upgrade and installation manual.

See *Section 3.2, "Licensing Volume Shadowing for OpenVMS"* for more information about licensing Volume Shadowing for OpenVMS.

Chapter 2. Configuring Your System for High Data Availability

System availability is a critical requirement in most computing environments. A dependable environment enables users to interact with their system when they want and in the way they want.

2.1. Levels of High Data Availability Using Volume Shadowing

A key component of overall system availability is availability or accessibility of data. Volume Shadowing for OpenVMS provides high levels of data availability by allowing shadow sets to be configured on a single-node system or on an OpenVMS Cluster system, so that continued access to data is possible despite failures in the disk media, disk drive, or disk controller. For shadow sets whose members are local to different OpenVMS Cluster nodes, if one node serving a shadow set member shuts down, the data is still accessible through an alternate node.

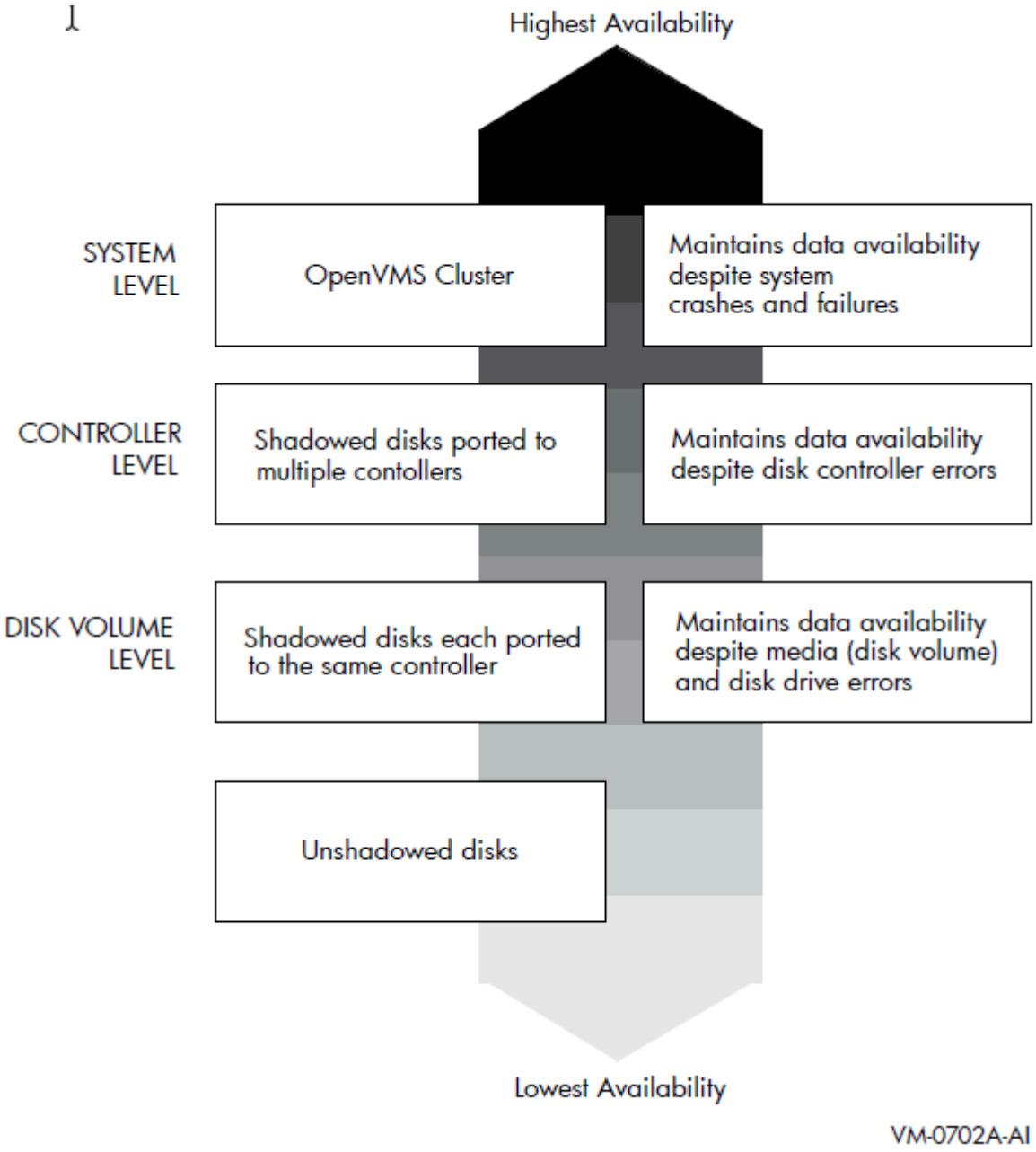
You can create a virtual unit, the system representation of a shadow set, that consists of only one disk volume. However, you must mount two or more disk volumes in order to “shadow,” that is, to maintain multiple copies of the same data. This configuration protects against either failure of a single disk drive or deterioration of a single volume. For example, if one member fails out of a shadow set, the remaining member can be used as a source device whose data can be accessed by applications at the same time the data is being copied to a newly mounted target device. Once the data is copied, both devices contain identical information and the target device becomes a source member of the shadow set. (Disks of different sizes can be combined into a shadow set, as described in *Section 7.5, "Write Bitmaps and Dissimilar Device Shadowing Caution"*.)

Using two controllers provides a further guarantee of data availability in the event of a single-controller failure. When setting up a system with volume shadowing, you should connect each disk drive to a different controller I/O channel whenever possible. Separate connections help protect against either failure of a single controller or of the communication path used to access it.

Using an OpenVMS Cluster system (as opposed to a single-node environment) and multiple controllers provides the greatest data availability. Disks that are connected to different local controllers and disks that are MSCP-served by other OpenVMS systems can be combined into a single shadow set, provided the disks are compatible and no more than three are combined.

Figure 2.1, "Levels of Availability " provides a qualitative, high-level classification of how you can achieve increasing levels of physical data availability in different types of configurations.

Figure 2.1. Levels of Availability



Section 2.2, "Repair and Recovery from Failures" describes how you can configure your shadowed system to achieve high data availability despite physical failures.

2.2. Repair and Recovery from Failures

Volume shadowing failures, some of which are automatically recoverable by the volume shadowing software, are grouped into the following categories:

- Controller errors
- Device errors
- Data errors

- Connectivity failures

The handling of shadow set recovery and repair depends on the type of failure that occurred and the hardware configuration. In general, devices that are inaccessible tend to fail over to other controllers whenever possible. Otherwise, they are removed from the shadow set. Errors that occur as a result of media defects can often be repaired automatically by the volume shadowing software.

Table 2.1, "Types of Failures " describes these failure types and recovery mechanisms.

Table 2.1. Types of Failures

Type	Description
Controller error	Results from a failure in the controller. If the failure is recoverable, processing continues and data availability is not affected. If the failure is nonrecoverable, shadow set members connected to the controller are removed from the shadow set, and processing continues with the remaining members. In configurations where disks are dual-pathed between two controllers, and one controller fails, the shadow set members fail over to the remaining controller and processing continues.
Device error	Signifies that the mechanics or electronics in the device failed. If the failure is recoverable, processing continues. If the failure is nonrecoverable, the node that detects the error removes the device from the shadow set.
Data errors	Results when a device detects corrupt data. Data errors usually result from media defects that do not cause the device to be removed from a shadow set. Depending on the severity of the data error (or the degree of media deterioration), the controller: ● Corrects the error and continues. ● Corrects the data and, depending on the device and controller implementation, may revector it to a new logical block number (LBN). When data cannot be corrected by the controller, volume shadowing replaces the lost data by retrieving it from another shadow set member and writing the data to a different LBN of the member with the incorrect data. This repair operation is synchronized within the cluster and with the application I/O stream.
Connectivity failures	When a connectivity failure occurs, the first node to detect the failure must decide how to recover from the failure in a manner least likely to affect the availability or consistency of the data. As each node discovers the recoverable device failure, it determines its course of action as follows: ● If at least one member of the shadow set is accessible by the node that detected the error, that node will attempt to recover from the failure. The node repeatedly attempts to access the failed shadow set member within the period of time specified by the system parameter SHADOW_MBR_TMO. (This time period could be either the default setting or a different value previously set by the system manager.) If access to the failed disk is not

Type	Description
	established within the time specified by SHADOW_MBR_TMO, the disk is removed from the shadow set. ● If no members of a shadow set can be accessed by the node, that node does not attempt to make any adjustments to the shadow set membership. Rather, it assumes that another node, which does have access to the shadow set, will make appropriate corrections. The node will attempt to access the shadow set members until the period of time designated by the system parameter MVTIMEOUT expires. This time period could be the default setting or a different value previously set by the system manager. After the time expires, all application I/O is returned with the following error status message: `-SYSTEM-F-VOLINV, Volume is not software enabled`

2.3. Shadow Set Configurations

To illustrate the various levels of data availability obtainable through Volume Shadowing for OpenVMS, this section provides a representative sample of hardware configurations. Figures *Figure 2.2, "OpenVMS Cluster System With Two FC Switches, Two Dual Controllers and Two Shadow Sets"* through *Figure 2.4, "Multiple-Site OpenVMS Cluster System With Four Systems, Four FC Switches, Four Controllers, and Two Shadow Sets"* show possible system configurations for shadow sets. The hardware used to describe the sample systems, while intended to be representative, is hypothetical; they must used only for general observations about availability and not as a suggestion for any specific configurations or products.

In all the following examples, the shadow set members use the `$allocation-class$ddcu:` naming convention. The virtual unit uses the DSA `n:` format, where `n` represents a number between 0 and 9999. These naming conventions are described in more detail in *Section 4.2, "Creating a Shadow Set"*.

Figure 2.2, "OpenVMS Cluster System With Two FC Switches, Two Dual Controllers and Two Shadow Sets" shows an OpenVMS Cluster system consisting of two systems connected to the same two shadow sets. Each system has two host-based adapters (HBAs) connecting it to the same two Fibre Channel (FC) switches. In turn, the FC switches are connected to two dual controllers, which are connected to two shadow sets.

Each shadow set member is connected by two paths, one to each of the dual controllers of one storage system. Each shadow set member can fail over between controllers independently of each other. Each system can access both shadow sets by direct connections.

This configuration provides coverage against:

- Media errors
- Failure on one system
- Failure of one HBA per system
- Failure of one or more controllers

- Failure of one disk per shadow set

Figure 2.2. OpenVMS Cluster System With Two FC Switches, Two Dual Controllers and Two Shadow Sets

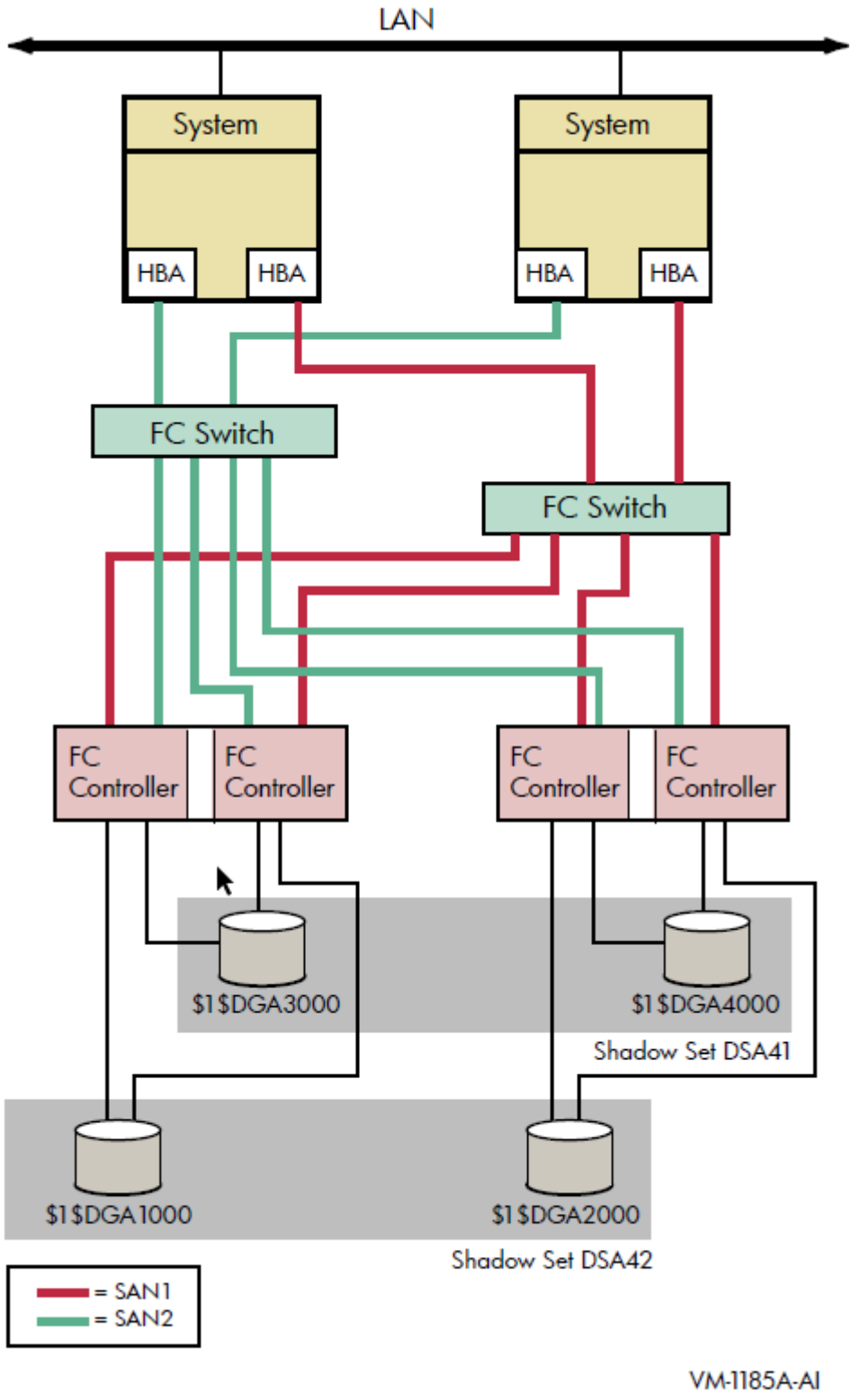


Figure 2.3, "OpenVMS Cluster System With Four Systems, Four FC Switches, Four Dual Controllers, and Two Shadow Sets" shows an OpenVMS Cluster system consisting of four systems. Each system in the cluster is identical to each system shown in *Figure 2.2, "OpenVMS Cluster System With Two FC*

Switches, Two Dual Controllers and Two Shadow Sets". In addition to the protection offered by *Figure 2.2, "OpenVMS Cluster System With Two FC Switches, Two Dual Controllers and Two Shadow Sets"*, this OpenVMS Cluster configuration provides greater protection from:

- Component failure because there are twice as many components
- Failure of one or two devices in shadow set DSA42 because it is a three-member set

This type of configuration provides continued access to data in spite of the failure of any one or more of these systems or switches.

Figure 2.3. OpenVMS Cluster System With Four Systems, Four FC Switches, Four Dual Controllers, and Two Shadow Sets

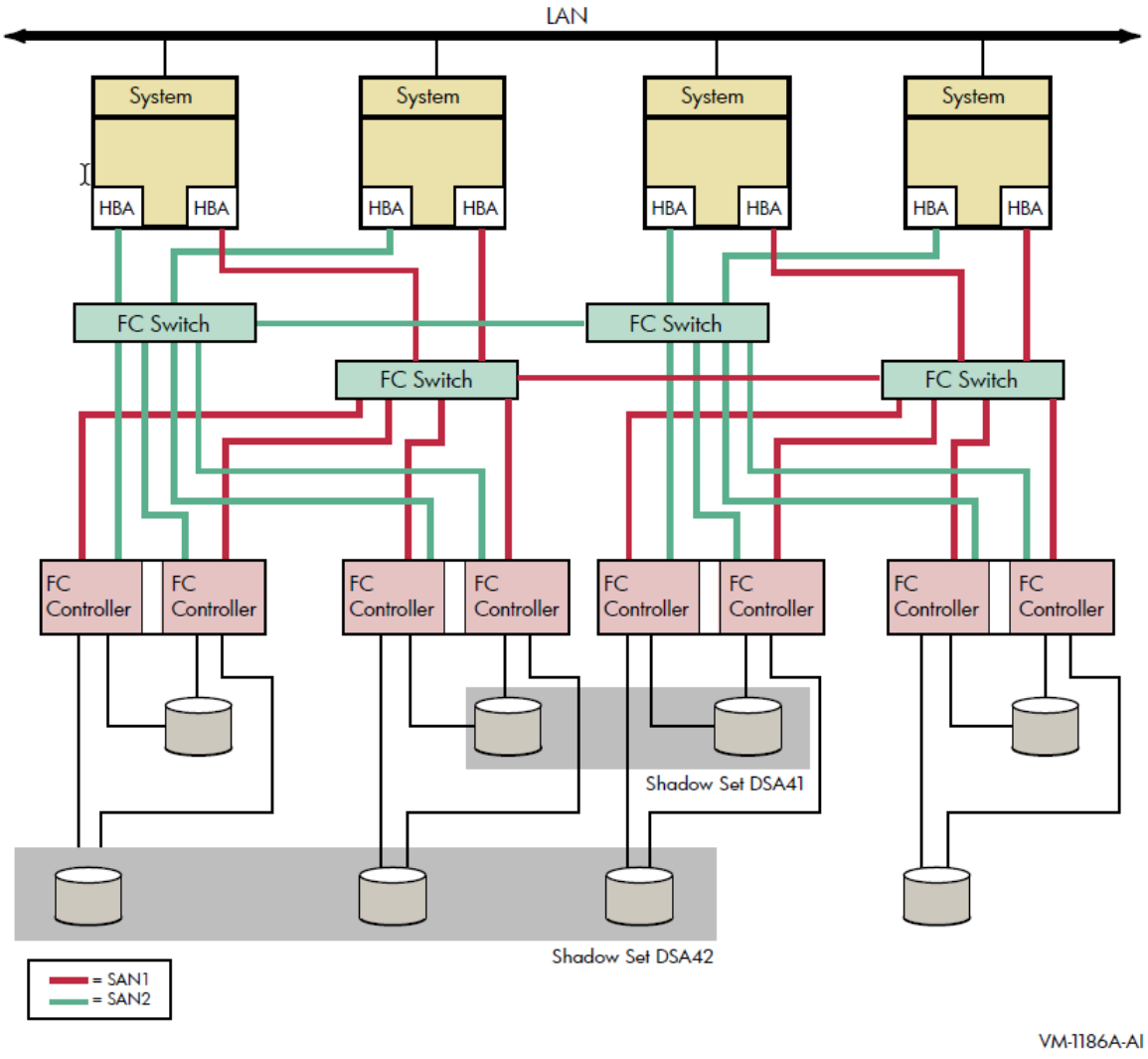
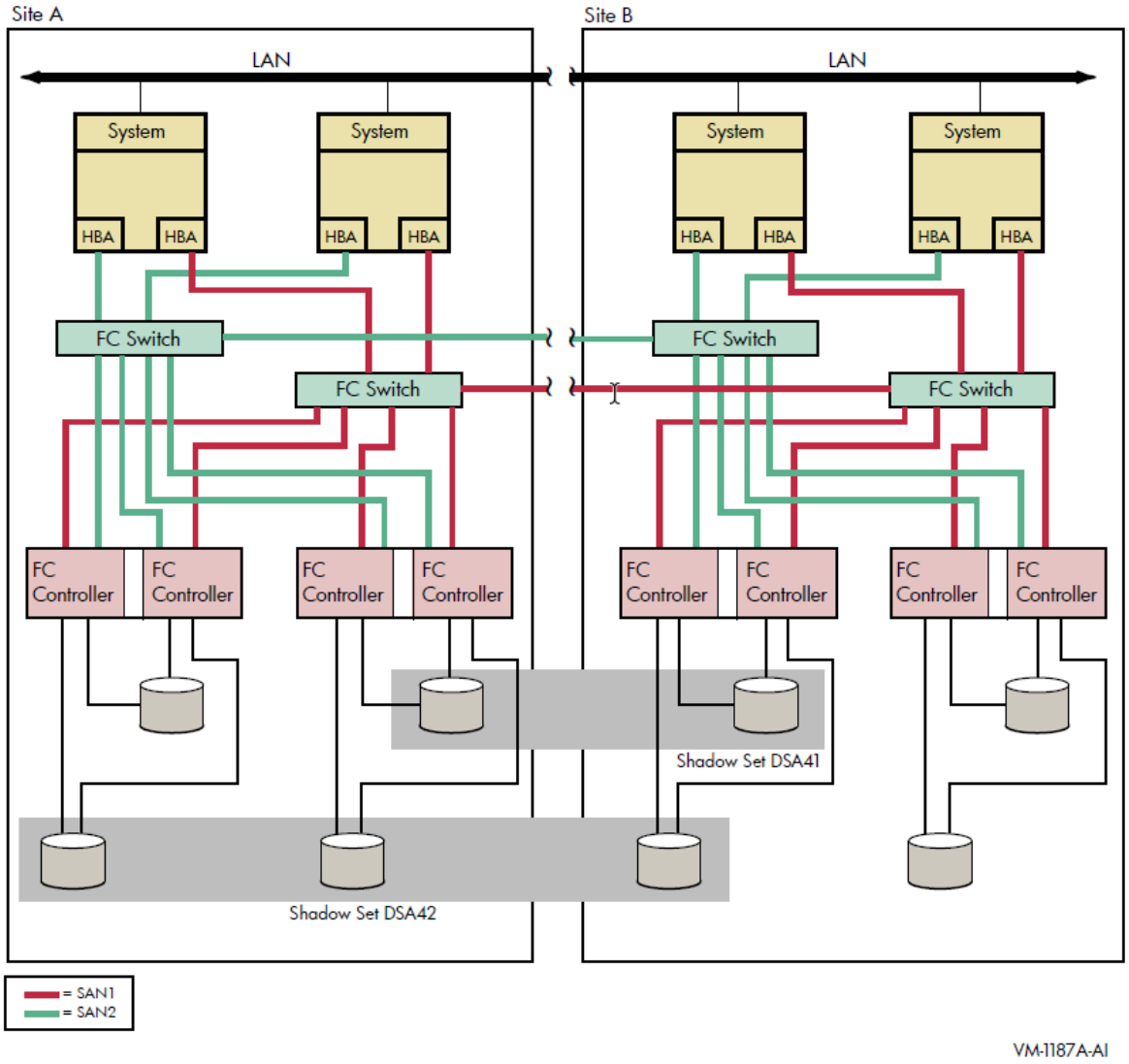


Figure 2.4, "Multiple-Site OpenVMS Cluster System With Four Systems, Four FC Switches, Four Controllers, and Two Shadow Sets" shows an OpenVMS Cluster system identical to *Figure 2.3, "OpenVMS Cluster System With Four Systems, Four FC Switches, Four Dual Controllers, and Two Shadow Sets"* except that the four systems are not in a single location. Instead, two systems are at one site and two at a second site. This figure illustrates how you can shadow data disks over long distances. Members of each shadow set are configured between two distinct and widely separated locations — a multiple-site OpenVMS Cluster system. The OpenVMS systems and shadowed disks in both locations function together as a single OpenVMS Cluster system and shadow set configuration. If a failure occurs at either site, the critical data is still available at the remaining site.

Figure 2.4. Multiple-Site OpenVMS Cluster System With Four Systems, Four FC Switches, Four Controllers, and Two Shadow Sets



Chapter 3. Preparing to Use Volume Shadowing

This chapter describes the configuration tasks that are required before you can use volume shadowing on your system, including setting system parameters and installing licenses (unless volume shadowing is licensed with your OpenVMS Integrity server operating environment). This chapter also documents booting from a system disk and booting satellite nodes.

3.1. Configuration Tasks

Once you have determined how to configure your shadow set, perform the following steps:

1. Select which of your disk drives you want to shadow. Prepare the selected volumes for mounting by physically placing the volumes in the drives (for removable media disks). Ensure the disks are not write locked.

2. Consider whether or not you want to initialize the volumes you have chosen to shadow. Do not initialize volumes that contain useful data.

   If you are creating a *new* shadow set, you can initialize one volume at a time, or multiple volumes with one command, which can streamline the creation of a shadow set (see *Section 4.3, "Using INITIALIZE/SHADOW/ERASE to Form a Shadow Set"*). When you initialize one volume at a time, you can give it a volume label to be used for the shadow set. When you later mount additional volumes into the shadow set, each volume is initialized and is given the same volume label automatically.

3. Install the Volume Shadowing for OpenVMS licenses unless you are running OpenVMS Integrity servers and purchased either the Enterprise Operating Environment or the Mission Critical Operating Environment. These operating environments include the Volume Shadowing for OpenVMS license. See *Section 3.2, "Licensing Volume Shadowing for OpenVMS"* for more information.

4. Set the SHADOWING parameter to enable volume shadowing on each node that will use volume shadowing. See *Section 3.3, "Volume Shadowing Parameters"* for more information.

   Setting the SHADOWING parameter requires that you reboot the system.

5. Set the ALLOCLASS parameter to a nonzero value. This parameter enables the use of allocation classes in device names. You must include a nonzero allocation class in the device name of shadowed disks. For more information, see *Section 4.2, "Creating a Shadow Set"*.

6. Dismount the disk drives you selected for the shadow set and remount them (along with the additional shadow set disk drives) as shadow set members. Note that:

   - You do not need to change the device volume labels and logical names.

   - If you use mount command files, ensure that the commands mount the physical devices using the appropriate naming syntax for virtual units (DSA *n*:).

For more information on the **MOUNT** command, see *Chapter 4, "Creating and Managing Shadow Sets Using DCL Commands"*.

System disks can be shadowed. All nodes booting from that system disk must have shadowing licensed and enabled.

3.2. Licensing Volume Shadowing for OpenVMS

To use the volume shadowing product on OpenVMS Alpha, you must purchase a license for it, even though the volume shadowing software is part of the OpenVMS operating system. On OpenVMS Integrity server systems, the volume shadowing license is included in enterprise, mission critical, and high availability operating environments.

For OpenVMS Integrity server computers, a volume shadowing license is included in the collection of OpenVMS products known as the High Availability Operating Environment (HAOE). It is not included in the Base Operating Environment for OpenVMS license.

After licensing the OpenVMS operating system by registering an OpenVMS Product Authorization Key (PAK), OpenVMS Alpha system managers and managers of OpenVMS Integrity server systems with the FOE or BOE must also license Volume Shadowing for OpenVMS with a separate volume shadowing PAK. The PAK provides information that defines the Volume Shadowing for OpenVMS license contract you have with VSI. Obtain a PAK from your VSI sales representative.

When you enter information from the PAK into the online LICENSE database, the OpenVMS License Management Facility (LMF) authorizes the use of volume shadowing.

You must register and activate a license for Volume Shadowing for OpenVMS on each node that mounts a shadow set, including satellites in an OpenVMS Cluster system. If you do not register and activate licenses on nodes that use volume shadowing, subsequent shadow set mount operations do not succeed and displays error messages similar to the ones shown in *Example 3.1, "Nodes Not Registered to Use Volume Shadowing"*.

Example 3.1. Nodes Not Registered to Use Volume Shadowing

```
%LICENSE-E-NOAUTH, DEC VOLSHAD use is not authorized on this node
-LICENSE-F-NOLICENSE, no license is active for this software product
-LICENSE-I-SYSMGR, please see your system manager
```

After you register the volume shadowing PAK, you must set the shadowing parameters on each node where you want to enable shadowing.

For more information about volume shadowing licensing, see the *VSI Volume Shadowing for OpenVMS Software Product Description* (DO-VIBHAA-031). For more information about the License Management Facility, see the *OpenVMS Operating System Software Product Description* (DO-VIBHAA-005 for Integrity V8.4-1H1; and DO-DVASPQ-001 for Alpha V8.4-2L1). You can also consult the *VSI OpenVMS License Management Utility Guide*.

3.3. Volume Shadowing Parameters

Table 3.1, "Volume Shadowing Parameters" lists the system parameters that are required to specify the use of Volume Shadowing for OpenVMS and the system parameters you can use to tailor the shadowing software on your system.

The term dynamic in *Table 3.1, "Volume Shadowing Parameters"* means that the active value can be changed on a running system. For more information about setting system parameters, see the *VSI OpenVMS System Manager's Manual, Volume 1: Essentials*.

Table 3.4, "Write Bitmap System Parameters" describes four bitmap system parameters. These system parameters support the host-based minicopy operation, described in *Chapter 7, "Using Minicopy for*

Backing Up Data", and the host-based minimerge (HBMM) operation, described in *Chapter 8, "Host-Based Minimerge (HBMM)"*.

Table 3.1. Volume Shadowing Parameters

Parameter	Function	Range	Default	Dynamic
ALLOCLASS	Specifies the device allocation class for the system. When using Volume Shadowing for OpenVMS, a nonzero value is required.	0–255	0	No
SHADOWING	A value of 2 enables volume shadowing. See *Table 3.2, "SHADOWING Parameter Settings "* for a description of parameter values.	0, 2[1]	0	No
SHADOW_MAX_COPY	Limits the number of concurrent merge or copy operations on a given node.	0–200	4	Yes
SHADOW_MBR_TMO	Controls the amount of time the system tries to fail over physical members of a shadow set.	1–65,535 seconds	120	Yes
SHADOW_MAX_UNIT	Specifies the maximum number of shadow sets that can exist on a node. Dismounted shadow sets, unused shadow sets, and shadow sets with no write bitmaps allocated to them are included in this total.	10–10,000	500 on Alpha	No
SHADOW_SYS_DISK	Allows system disk to be a shadow set	0–1	0	0–1
SHADOW_SYS_DISK	Allows system disk to be a shadow set and, optionally, enables a minimerge to occur. If a minimerge is enabled, the system must also be configured for writing to a nonshadowed, nonsystem disk of your choice.	0, 1, 4097 [1]	0	Yes
SHADOW_SYS_TMO	Controls the amount of time members of a system disk shadow set have to return to the set.	1–65,535 seconds	120	Yes
SHADOW_SYS_UNIT	Contains the virtual unit number of the system disk.	0–9999	0	No
SHADOW_SYS_WAIT	This parameter applies only to shadow sets that are currently mounted in the cluster.	1–65,535 seconds	480	Yes

Parameter	Function	Range	Default	Dynamic
	Controls the amount of time a booting system will wait for all members of a mounted system disk shadow set to become available.			

[1]All other values are reserved for use by VSI.

3.3.1. Guidelines for Using Volume Shadowing Parameters

This section provides guidelines for using volume shadowing parameters.

ALLOCLASS

The ALLOCLASS parameter is used to specify an allocation class that forms part of a device name. The purpose of allocation classes is to provide unique and unchanging device names. When using Volume Shadowing for OpenVMS on a single system or on an OpenVMS Cluster system, a nonzero allocation class value is required for each physical device in the shadow set. For more information about using allocation classes, see the *VSI OpenVMS Cluster Systems Manual*.

SHADOWING

The SHADOWING parameter enables or disables volume shadowing on your system, as shown in *Table 3.2, "SHADOWING Parameter Settings "*.

Table 3.2. SHADOWING Parameter Settings

Setting	Effect
0	Shadowing is not enabled. This is the default value.
2	Enables host-based shadowing. This setting provides shadowing of all disks that are located on a standalone system or on an OpenVMS Cluster system. Set SHADOWING to 2 on every node that will mount a shadow set, including satellite nodes.

SHADOW_HBMM_RTC

SHADOW_HBMM_RTC is used to specify, in seconds, how frequently each shadow set on this system has its modified block count compared with its reset threshold. If the modified block count exceeds the reset threshold, the bitmap for that shadow set is zeroed. This comparison is performed for all shadow sets mounted on the system that have HBMM bitmaps. The reset threshold is specified by the RESET_THRESHOLD keyword in the **/POLICY** qualifier of the **SET SHADOW** command. When the comparison is made, the modified block count might exceed the reset threshold by a small increment or by a much larger amount. The difference depends on the write activity to the volume and the setting of this parameter.

The default setting of SHADOW_HBMM_RTC is 150 seconds.

You can view the reset threshold setting and the modified block count, since the last reset, in the **SHOW SHADOW** command display. For guidelines on setting the reset threshold values and a sample **SHOW SHADOW** display, see *Section 8.5.2, "Considerations for Setting a Bitmap RESET_THRESHOLD Value"*. For a **SHOW SHADOW** display that includes a modified block count greater than the reset threshold value, refer to the *VSI OpenVMS DCL Dictionary: N–Z*.

SHADOW_MAX_COPY

The SHADOW_MAX_COPY parameter controls how many parallel copy and merge operations are allowed on a given node. (Copy and merge operations are described in *Chapter 6, "Ensuring Shadow Set Consistency"*.) This parameter provides a way to limit the number of copy and merge operations in progress at any time.

The value of SHADOW_MAX_COPY can range from 0 to 200. The default value is specific to the OpenVMS version. You can determine the default value by looking at the parameter setting. When the value of the SHADOW_MAX_COPY parameter is 4, and you mount five multivolume shadow sets that all need a copy operation, only four copy operations can proceed. The fifth copy operation must wait until one of the first four copies completes.

Consider the following when choosing a value for the SHADOW_MAX_COPY parameter:

- CPU power
- Disk controller bandwidth
- Interconnect controller bandwidth
- Other work loads on the system

For example, the default value of 4 may be too high for a small node. (In particular, satellite nodes should have SHADOW_MAX_COPY set to a value of 0.) Too low a value for SHADOW_MAX_COPY unnecessarily restricts the number of operations your system can effectively handle and extends the amount of time it takes to merge all of the shadow sets.

SHADOW_MAX_COPY is a dynamic parameter. Changes to the parameter affect only future copy and merge operations; current operations (pending or already in progress) are not affected.

SHADOW_MAX_UNIT

The SHADOW_MAX_UNIT specifies the number of shadow sets that can exist on a node and determines the memory reserved for the bitmap for each shadow set. (See *Section 1.3.1, "Memory Requirements"*.) The important thing to note about this value is that any shadow set that has been created, regardless of whether it is in use, is included in this total. Because this is not a dynamic system parameter, you must be very careful when determining the value to use. If you have to change this parameter, you must reboot the system.

The default value for OpenVMS Alpha systems is 500.

Caution

Any **MOUNT** command that attempts to create more shadow sets than the maximum specified for the node fails.

Note that this parameter does not affect the naming of shadow sets. For example, with the default value of 100, a device name such as DSA999 is still valid.

SHADOW_MBR_TMO

The SHADOW_MBR_TMO parameter controls the amount of time the system tries to fail over physical members of a shadow set before removing them from the set. SHADOW_MBR_TMO is a dynamic parameter that you can change on a running system.

With the SHADOW_MBR_TMO parameter, you specify the number of seconds, from 1 to 65,535, during which recovery of a shadow set member is attempted.

Note

The value of SHADOW_MBR_TMO should not exceed the value of the parameter MVTIMEOUT.

If you specify zero, a default delay is used. The default delay is specific to the version of OpenVMS running on your system. For shadow sets in an OpenVMS Cluster configuration, the value of SHADOW_MBR_TMO must be set to the same value on each node.

Determining the correct value for SHADOW_MBR_TMO is a trade-off between rapid recovery and high availability. If rapid recovery is required, set SHADOW_MBR_TMO to a low value. This ensures that failing shadow set members are removed from the shadow set quickly and that user access to the shadow set continues. However, removal of shadow set members reduces data availability and, after the failed member is repaired, a full copy operation is required when it is mounted back into the shadow set.

If high availability is paramount, set SHADOW_MBR_TMO to a high value. This allows the shadowing software additional time to regain access to failed members. However, user access to the shadow set is stalled during the recovery process. If recovery is successful, access to the shadow set continues without the need for a full copy operation, and data availability is not degraded. Setting SHADOW_MBR_TMO to a high value may be appropriate when shadow set members are configured across LANs that require lengthy bridge recovery time.

Shadowing uses a timer to adhere to the number of seconds specified by the SHADOW_MBR_TMO parameter. For directly connected SCSI devices that have been powered down or do not answer to polling, the elapsed time before a device is removed from a shadow set can take several minutes.

The use of default settings for certain system parameters may lead to the occasional removal of shadow set members (systems that are using Volume Shadowing for OpenVMS) that are configured for multi-path support. Therefore, when configuring multi-path shadow sets using Volume Shadowing for OpenVMS, follow the recommendations shown in *Table 3.3, "System Parameter Settings for Multipath Shadow Sets"*.

Table 3.3. System Parameter Settings for Multipath Shadow Sets

System Parameter	Recommended Setting
MSCP_CMD_TMO	60 as a minimum. The value of 60 is appropriate for most configurations. Some configurations may require a higher setting.
SHADOW_MBR_TMO	At least 3 x MSCP_CMD_TMO
SHADOW_SYS_TMO	At least 3 x MSCP_CMD_TMO
MVTIMEOUT	At least 4 x SHADOW_MBR_TMO

Note

The recommended setting for MVTIMEOUT, as shown in *Table 3.3, "System Parameter Settings for Multipath Shadow Sets"*.

To modify SHADOW_MBR_TMO for an existing shadow set member, see the **SET SHADOW/RECOVERY_OPTIONS=DELAY_PER_SERVED_MEMBER=*n*** command, which is described in *Section 4.8, "Managing Copy and Merge Operations"*.

SHADOW_PSM_DLY

SHADOW_PSM_DLY allows the system manager to adjust the delay that Shadowing adds automatically when a copy or merge operation is needed on a shadow set that is mounted on many systems.

The Shadowing facility attempts to perform the operation on a system that has a local connection to all the shadow set members. Shadowing implements the copy or merge operation by adding a time delay based on the number of shadow set members that are MSCP-served to the system. No delay is added for local members. Therefore, a system with all locally accessible shadow set members usually performs the copy or merge before a system on which one or more members is served and is therefore delayed.

When a shadow set is mounted on a system, the value of SHADOW_PSM_DLY is used as the default shadow set member recovery delay for that shadow set. To modify SHADOW_PSM_DLY for an existing shadow set, see the **SET SHADOW/RECOVERY_OPTIONS=DELAY_PER_SERVED_MEMBER=*n*** command, which is described in *Section 4.8, "Managing Copy and Merge Operations"*.

SHADOW_PSM_DLY is a static parameter; its range is 0 to 65535 seconds. The default value is 30 seconds for each MSCP served shadow set member.

SHADOW_REC_DLY

SHADOW_REC_DLY governs the system behavior after a system failure or after a shadow set is aborted. The value of the SHADOW_REC_DLY parameter is added to the value of the RECNXINTERVAL parameter to determine how long a system waits before it attempts to manage a merge or copy operation on any shadow sets that it has mounted.

SHADOW_REC_DLY can be used to predict the systems that can perform recovery operations in an OpenVMS Cluster. This is done by setting lower values of SHADOW_REC_DLY on systems that are preferred to handle recovery operations and higher values of SHADOW_REC_DLY on the remaining systems.

SHADOW_REC_DLY is a dynamic parameter; its range is 0 to 65535 seconds. The default value is 20 seconds.

For more information about controlling which systems perform the merge or copy operations, see *Section 4.9.5, "Controlling Which Systems Manage Merge and Copy Operations"*.

SHADOW_SYS_DISK

A SHADOW_SYS_DISK parameter value of 1 enables shadowing of the system disk. A value of 0 disables shadowing of the system disk. A value of 4097 enables a minimerge. The default value is 0.

If you enable a minimerge of the system disk, you must also configure your system to write a dump to a non-shadowed, non-system disk of your choice. This is known as dump off system disk (DOSD).

For more information on DOSD, see the *VSI OpenVMS System Manager's Manual, Volume 2: Tuning, Monitoring, and Complex Systems*.

In addition, you must specify a system-disk, shadow-set virtual unit number with the SHADOW_SYS_UNIT system parameter, unless the desired system disk virtual unit number is DSA0.

SHADOW_SYS_TMO

You can use the SHADOW_SYS_TMO parameter in two ways: during the booting process and during normal operations. SHADOW_SYS_TMO is a dynamic parameter that you can change on a running system.

During the booting process, you can use this parameter on the first node in the cluster to boot and to create a specific shadow set. If the proposed shadow set is not currently mounted in the cluster, use this parameter to extend the time a booting system waits for all former members of the system disk shadow set to become available.

The second use of this parameter comes into effect once the system successfully mounts the shadow set and begins normal operations. Just as the SHADOW_MBR_TMO parameter controls the time the operating system waits for failing members of an application disk shadow set to rejoin the shadow set, the SHADOW_SYS_TMO parameter controls how long the operating system waits for failing members of a system disk shadow set. All nodes using a particular system disk shadow set must have their SHADOW_SYS_TMO parameter equal to the same value, after normal operations begin. Therefore, after booting, this parameter applies only to members of the system disk shadow set.

The default value is OpenVMS version specific. You can set a range of up to 65,535 seconds if you want the system to wait longer than the default for all members to join the shadow set.

SHADOW_SYS_UNIT

The SHADOW_SYS_UNIT parameter, which must be used when the SHADOW_SYS_DISK parameter is set to 1, contains the virtual unit number of the system disk.

The SHADOW_SYS_UNIT parameter is an integer value that contains the virtual unit number of the system disk. The default value is 0. The maximum value allowed is 9999. This parameter is effective only when the SHADOW_SYS_DISK parameter has a value of 1. This parameter must be set to the same value on all nodes that boot off a particular system disk shadow set. SHADOW_SYS_UNIT is not a dynamic parameter.

SHADOW_SYS_WAIT

Use the SHADOW_SYS_WAIT parameter to extend the time a booting system waits for all current members of a mounted system disk shadow set to become available to *this* node. SHADOW_SYS_WAIT is a dynamic parameter that you can change on a running system (for debugging purposes only). The shadow set must already be mounted by at least one other cluster node for this parameter to take effect. The default value is 256 seconds. Change this parameter to a higher value if you want the system to wait more than the 256-second default for all members to join the shadow set. This parameter has a range of 1 through 65,535 seconds.

3.4. Bitmap System Parameters

The four system parameters for managing minicopy bitmap messages apply equally to managing HBMM bitmap messages. Three parameters are used to manage update traffic between a master bitmap and its corresponding local bitmaps in an OpenVMS Cluster system. The fourth parameter controls whether

bitmap system messages are sent to the operator console and, if they are to be sent, the volume of messages. System parameters are dynamic; they can be changed on a running system. *Table 3.4, "Write Bitmap System Parameters"* lists the bitmap system parameters.

The bitmap system parameters check if the messages are buffered and then packaged in a single System Communications Services (SCS) message to update the master bitmap or whether each message is sent immediately. The system parameters are used to set the upper and lower thresholds of message traffic and a time interval during which the traffic is measured.

The writes issued by each remote node are, by default, sent one at a time in individual SCS messages to the node with the master bitmap. This is known as single-message mode.

If the writes sent by a remote node reach an upper threshold of messages during a specified interval, the single-message mode switches to the buffered-message mode. In the buffered-message mode, messages (up to nine) are collected for a specified interval and then sent in one SCS message. During increased message traffic, grouping multiple messages in one SCS message is more efficient than sending each message separately.

Table 3.4. Write Bitmap System Parameters

Parameter	Meaning	Unit	Min	Max[1]	Default
WBM_MSG_INT	In single-message mode, the time interval msec between assessment of the most suitable bitmap message mode. In buffered-message mode, the maximum time (in milliseconds) that a message waits before it is sent.	msec	10 1	-1 100	10 7
WBM_MSG_UPPER	The upper threshold for the number of messages sent during the test interval (calculated in 100 millisecond windows) that initiates buffered-message mode.	msgs/ interval	0	-1	80
WBM_MSG_LOWER	The lower threshold for the number of messages sent during the test interval (calculated in 100 millisecond windows) that initiates single-message mode.	msgs/ interval	0	-1	20
WBM_OPCOM_LVL	Controls whether bitmap messages are provided to the operator console: 0 means messages are turned off; 1 means messages are provided when bitmaps are started,	n/a	0	2	1

Parameter	Meaning	Unit	Min	Max[1]	Default
	deleted, and renamed, and when the SCS message mode (buffered or single) changes; 2 means that all messages for a setting of 1 are provided along with detailed messages for debugging purposes.				

[1]The maximum value of -1 corresponds to the maximum positive value that can be represented by a longword.

3.4.1. Setting System Parameters

To set or modify volume shadowing parameters, edit the [SYSn.SYSEXE]MODPARAMS.DAT file or the appropriate AUTOGEN include file. After editing the file, execute SYS$UPDATE:AUTOGEN as described in the *VSI OpenVMS System Manager's Manual, Volume 2: Tuning, Monitoring, and Complex Systems*. If you have an OpenVMS Cluster system, ensure that the system parameters are updated on each node. *Example 3.2, "MODPARAMS.DAT File"* illustrates a MODPARAMS.DAT file that includes assignment statements to set shadowing parameters.

Example 3.2. MODPARAMS.DAT File

```
    .
    .
    .
! Volume Shadowing Parameters:
SHADOWING=2             ! Enables phase II shadowing

SHADOW_SYS_DISK=1       ! Enables system disk shadowing

SHADOW_SYS_UNIT=7       ! Specifies 7 as the virtual unit number
                          of the system disk

SHADOW_MAX_COPY=4       ! Specifies that 4 parallel copies can occur at one
 time

SHADOW_MBR_TMO=120      ! Allows 120 seconds for physical members to fail
 over
                        ! before removal from the shadow set

    .
    .
    .
```

See the *VSI OpenVMS System Manager's Manual, Volume 2: Tuning, Monitoring, and Complex Systems* for complete information about invoking AUTOGEN and specifying the appropriate command qualifiers to perform the desired AUTOGEN operations.

3.4.2. Displaying System Parameters

It is sometimes useful to use the SYSGEN command **SHOW** to display the values of system parameters.

You do not need special privileges to invoke the SYSGEN utility. You can use either a qualifier or the name of a system parameter with the **SHOW** command, or you can use the **SHOW/ALL** command to display information about all system parameters. (Enter **HELP SHOW** at the SYSGEN> prompt for

more information about the **SHOW** command.) The following example illustrates how you can check the current default, minimum, and maximum values for the SHADOWING parameter.

```
$ MCR SYSGEN
SYSGEN> SHOW SHADOWING
Parameter Name   Current  Default  Minimum  Maximum  Unit        Dynamic
--------------   -------  -------  -------  -------  ----        -------
SHADOWING              2        0        0        2  Coded-value
SYSGEN>
```

3.5. Dynamic Volume Expansion

The basis of dynamic volume expansion is the one-time allocation of extra bitmap space to the maximum size ever used on this volume. The current limit is 1 TB. The one-time allocation of extra bitmap space can be performed either at disk initialization time with the **INITIALIZE/LIMIT** command or on a mounted volume with the **SET VOLUME/LIMIT** command. By allocating extra bitmap space, you can later expand the logical volume size while the device is mounted by using **SET VOLUME *volume-name*/SIZE=*x*** command. (The logical volume size is the amount of disk space allocated to the file system.) For example, you might prepare a disk for 1 TB of storage (by allocating 1 TB of bitmap space) but use only 18 GB today. Next year, you might increase it to 36 GB, and so on, until you reach the maximum of 1 TB. By allocating the maximum size for storage on the disk, you can later increase the size of the volume without stopping the application or dismounting a disk. To use the **SET VOLUME/LIMIT** command to allocate extra bitmap space, the disk must be mounted privately. However, once allocated, the volume can be expanded while the disk is mounted as shareable (**MOUNT/SHARE**).

You can allocate additional bitmap space regardless of whether the physical volume has room for expansion.

Note

In volume expansion, you must disable and re-enable HBMM so that write bitmaps are recreated, which encompasses the new volume size. Failing to do this might result in longer than expected merge times because the expansion area is subject to a complete merge.

The following command allocates extra bitmap size on a new volume:

```
$ INITIALIZE/LIMIT $1$DGAnnn: ! Allocates 1 TB bitmap
```

The following command allocates extra bitmap size on a mounted volume:

```
$ SET VOLUME/LIMIT $1$DGAnnn
```

The default **/LIMIT** size for both commands is 1 TB, which is also the maximum size currently supported on OpenVMS. In special circumstances, you may want to specify less.

When you use the **/LIMIT** qualifier with the **INITIALIZE** or **SET VOLUME** command, you increase the BITMAP.SYS file by a few hundred blocks, which gives you much greater flexibility in the future.

When additional physical storage is made available (either by adding a larger device to the shadow set and removing the smaller member, or by increasing the size on the storage subsystem), you can then enter the following command to increase the volume size:

```
$ SET VOLUME $1$DGAn/SIZE=x
```

In this command syntax, x represents the number of blocks.

Note

If the volume of a shadow set is expanded to be larger than the physical size of a member, the smaller member can no longer be added back to the shadow set.

3.5.1. Using the /SIZE Qualifier With the INITIALIZE Command

You can use the **INITIALIZE/SIZE** command to create a file system that is smaller than the current physical size of the volume. If you have a 36-GB disk and you anticipate adding an 18-GB disk in the future, then you can initialize the disk with the following command:

```
$ INIT/SIZE=36000000 $1$DGAnlabel
```

In this example, 18GB disk = 36,000,000 blocks of 512 bytes each approximately.

3.5.2. When to Increase the Expansion Limit on Each Volume

If you are adding a new volume to your system, increase the expansion limit on the volume when you initialize the disk with **INITIALIZE/LIMIT**. To increase the expansion limit on volumes already in use, plan to increase the expansion limit during the next convenient maintenance period using the command **SET VOLUME/LIMIT**.

If **INITIALIZE/LIMIT** is used, the default cluster size of the **/CLUSTER_SIZE** qualifier is 8. This value controls how much space the bitmap occupies. You can later expand the volume (using the **SET VOLUME *volume-name*/SIZE=*x*** command) while the device is still mounted if your storage requirements grow unexpectedly.

3.6. Booting from a System Disk Shadow Set

When multiple nodes boot from a common system disk shadow set, ensure that all nodes specify a physical disk that is a source member of the system disk shadow set.

At boot time, the volume shadowing software attempts to construct a complete system disk shadow set based on the shadowing membership information contained in the **storage control block (SCB)** of the boot device. The SCB is an ODS-2 or ODS-5 file system data structure that resides on each storage device and contains information about shadow set membership (described in *Section 6.1, "Shadow Set Consistency"*). Depending on what information is in the SCB at boot time, the following scenarios are possible:

- If the boot device was not formerly a member of a shadow set, the system creates a new shadow set containing only the boot device. You can manually mount additional disks into the shadow set after the system boot procedure completes.
- If the boot device is already a valid member of an existing shadow set (for instance, if it is already an up-to-date member of a shadow set mounted by another node in the cluster), the shadowing software automatically locates all the members of the set.
- When booting the first node in a cluster, information stored in the SCB of the physical boot device is used to locate other members of the shadow set and to create the complete system disk shadow set.

- The shadowing software detects boot attempts from a physical disk that is inconsistent with currently active shadow set members. In this case, the boot attempt detects the existence of the other shadow set members and determines (using the information in the SCB) that the boot device is not a valid member of the shadow set. When this occurs, the boot attempt fails with a SHADBOOTFAIL bugcheck message on the system console, and a dump file is written to the boot device.

  The system bugchecks because it can boot only from a currently valid member of the system disk shadow set. If the boot device fails out of or is otherwise removed from the system disk shadow set, you must either mount the boot device back into the shadow set (and wait for the copy operation to complete) or modify the boot command file to boot from a current shadow set member.

The boot process automatically locates all the members of a system disk shadow set. You should not add system disk shadow set members in startup procedures as formerly recommended when phase I shadowing was supported.

Caution

Do not add members to a system disk shadow set in startup procedures. Doing so can result in loss of data under the following circumstances:

1. A system is operating normally with a multiple member system disk shadow set.
2. The original boot device is removed from the shadow set but remains as a functioning disk.
3. The system continues with the remaining members.
4. The system is shut down or it fails.
5. The system is rebooted using the original boot device (which is now out of date).
6. The boot process determines that the boot device is not consistent with the other shadow set members and, therefore, does not add them into the shadow set. This behavior preserves the up-to-date data on the other members.
7. A **MOUNT** command in the startup procedure adds the other shadow set members to the system disk shadow set.
8. A copy operation from the boot device to the other shadow set members is initiated, thereby overwriting them.

If the boot device fails, the following console warning message displays:

```
virtual-unit: does not contain the member named to VMB.
System may not reboot.
```

After the boot device has been repaired, manually add it back into the system disk shadow set.

3.7. Booting Satellite Nodes from a Served, System Disk Shadow Set

The OpenVMS operating system uses the Maintenance Operations Procedure (MOP) protocol to boot satellite nodes. MOP protocol support is provided by either the LANACP process controlled by the

LANCP utility or by DECnet software controlled by the NCP or NCL utilities. You must specify the name of the satellite's system disk using LANCP, NCP, or NCL commands (depending on which you are using to boot satellites). If the system disk is shadowed, the commands must specify the name of the virtual unit or the virtual unit logical name rather than the name of any physical unit.

The MOP server accesses the system disk shadow set (using the virtual unit defined) to perform downline load operations to the satellite. These operations include downline loading the physical boot device name to the satellite. When downline loading is complete, the satellite is able to connect to an MSCP server and access the physical boot device directly. The satellite's shadowing parameters are then used in the same way as a non-satellite node.

You can use the SYS$MANAGER:CLUSTER_CONFIG_LAN.COM procedure or the SYS$MANAGER:CLUSTER_CONFIG.COM procedure to set MOP server, MSCP server, and satellite parameters automatically. When configuring satellite nodes with the cluster configuration command procedure, you can specify a shadowed system disk virtual unit as the satellite's system disk. The cluster configuration command procedure then automatically sets the satellite's system parameters SHADOW_SYS_DISK and SHADOW_SYS_UNIT for you. The values of these parameters are transferred automatically to the system parameter file ALPHAVMSSYS.PAR for Alpha satellites. (See the *VSI OpenVMS Cluster Systems Manual* for more information about using this command procedure.)

Example 3.3, "LANCP Database Example of a Satellite Node" shows the commands to enter to display the LANCP satellite database entries.

Example 3.3. LANCP Database Example of a Satellite Node

```
$ MCR LANCP
LANCP> LIST DEVICE/MOPDLL


Device Listing, permanent database:
  --- MOP Downline Load Service Characteristics ---
Device    State   Access Mode      Client            Data Size
------    -----   -----------      ------            ---------
ESA0    Disabled NoExlusive  NoKnownClientsOnly     246 bytes
FCA0    Disabled NoExlusive  NoKnownClientsOnly     246 bytes
LANCP> EXIT
```

For DECnet–Plus commands, see the *DECnet–Plus* documentation.

Example 3.4, "DECnet Database Example of a Satellite Node" shows the NCP commands you must enter on a MOP server to display a satellite DECnet database entry. Note that the load assist parameter displays the shadow set virtual unit name that downline loads the satellite node HIWAY1. *Example 3.4, "DECnet Database Example of a Satellite Node"* uses an explicit virtual unit name. However, you might prefer to use a logical name that translates to the virtual unit.

Example 3.4. DECnet Database Example of a Satellite Node

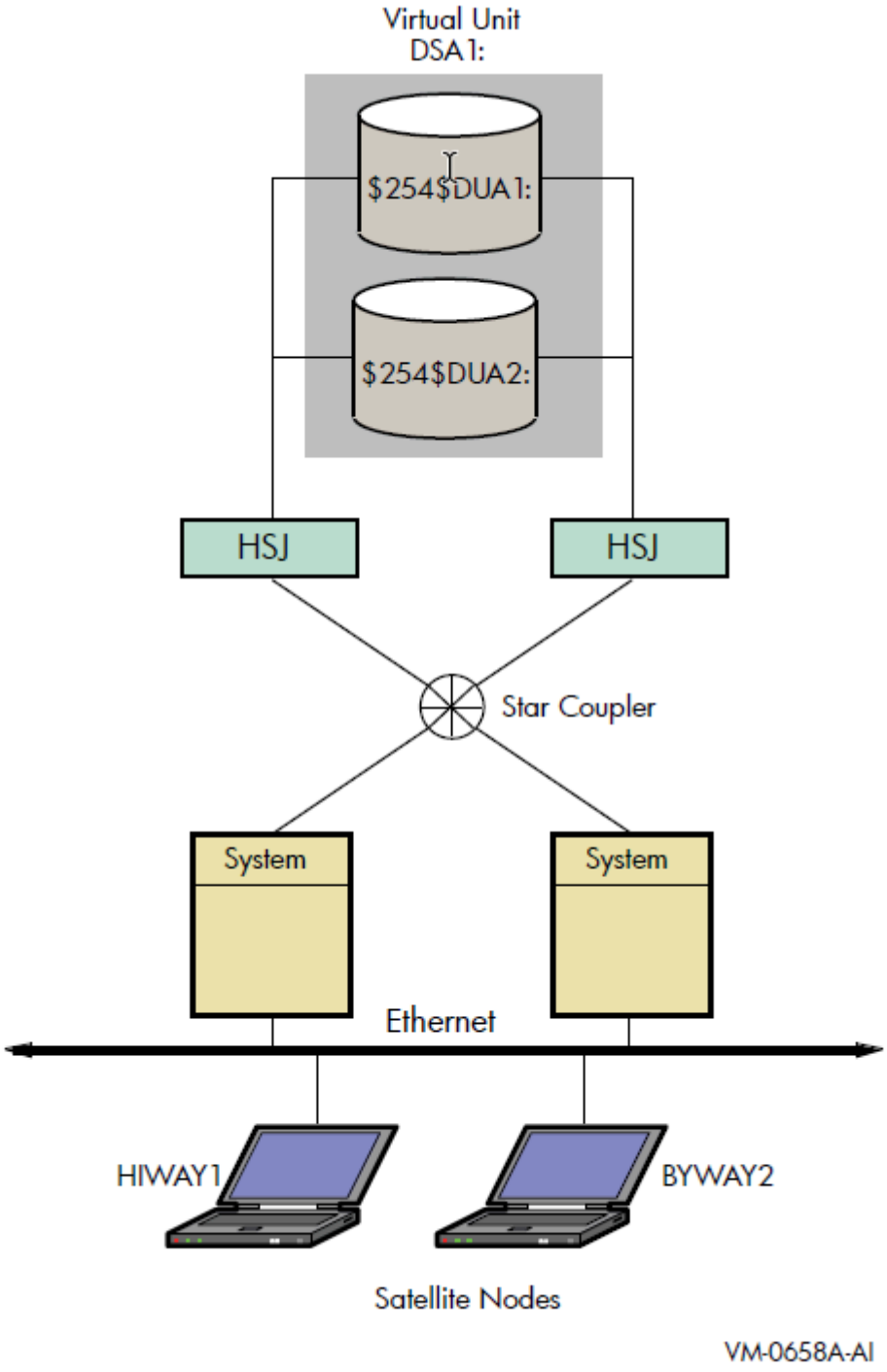
```
$ MCR NCP
NCP> SHOW NODE HIWAY1 CHAR
Node Volatile Characteristics as of 12-MAR-2000 14:53:59
Remote node =   19.891 (HIWAY1)
Hardware address         = 03-03-03-03-03-BC
Tertiary loader          = SYS$SYSTEM:TERTIARY_VMB.EXE
Load Assist Agent        = SYS$SHARE:NISCS_LAA.EXE
Load Assist Parameter    = DSA1:
NCP> EXIT
```

You may need to adjust the settings of the SHADOW_MBR_TMO and SHADOW_MAX_COPY parameters on satellite nodes. These parameters are not automatically set by the cluster configuration command procedure. See *Section 3.3, "Volume Shadowing Parameters"* for more information.

The cluster configuration command procedure automatically enables shadowing on satellite nodes when you want to shadow the system disk. If you do not want to shadow the system disk but need to enable shadowing, you must do so manually after the cluster configuration command procedure completes. Set shadowing parameters in the satellite node's MODPARAMS.DAT file and execute AUTOGEN as described in *Section 3.3, "Volume Shadowing Parameters"* and in *Section 3.4.1, "Setting System Parameters"*.

Figure 3.1, "Booting Satellite Nodes" shows two satellite nodes with shadowed system disk volumes located in an OpenVMS Cluster system configuration. In this configuration, the devices 254DUA1 and 254DUA2 make up a two-member shadow set. The satellites HIWAY1 and BYWAY2 access shadow set members across the Ethernet via the MSCP servers in the two boot nodes.

Figure 3.1. Booting Satellite Nodes



When a satellite node in *Figure 3.1, "Booting Satellite Nodes"* is booted, the boot node (MOP server) downline loads initial bootstrap code from the virtual unit DSA1. The boot node points the satellite to use either 254DUA1 or 254DUA2 as a boot device for the remainder of the boot process. Note that the boot node must have the virtual unit mounted. The satellite then forms the system disk shadow set locally according to the shadow set membership information stored in the SCB on the boot device.

The following **SHOW DEVICES** command displays how the shadow set appears after the satellite node HIWAY1 is booted. In this example, the physical disk devices are accessed through the MSCP server node BTNODE.

```
$ SHOW DEVICES DSA1
Device                  Device           Error    Volume    Free   Trans Mnt
Name                    Status           Count    Label     Blocks Count Cnt
DSA1:                   Mounted           0       MYVOLUME  181779   194  37
$254$DUA1:   (BTNODE)   ShadowSetMember   0       (member of DSA1:)
$254$DUA2:   (BTNODE)   ShadowSetMember   0       (member of DSA1:)
$
```

Chapter 4. Creating and Managing Shadow Sets Using DCL Commands

This chapter describes how to create, mount, dismount, and dissolve shadow sets using interactive DCL commands. It also describes how to use the DCL command **SET SHADOW** to manage merge and copy operations and to specify management attributes for shadow set members located at different sites in a multiple-site OpenVMS Cluster system. In addition, it describes how to use the DCL command **SHOW DEVICE** and the lexical function F$GETDVI to access current information about the state of shadow sets.

Volume Shadowing for OpenVMS improves data availability by ensuring that corresponding logical block numbers (LBNs) on multiple disk volumes contain the same information. Upon receiving a command to mount or dismount disks in a shadow set, the volume shadowing software may need to reconcile data differences and ensure that corresponding LBNs contain the same information.

An understanding of the copy and merge operations used for data reconciliation is essential to the discussions in this chapter. Therefore, you may find it helpful to refer to *Chapter 6, "Ensuring Shadow Set Consistency"* to understand how Volume Shadowing for OpenVMS ensures data availability and consistency during changes in shadow set membership.

4.1. Allocating Devices

To avoid the possibility of another user mounting a particular device before you enter the **MOUNT** command, you can optionally allocate the device before issuing the **MOUNT** command. Use the DCL command **ALLOCATE** to provide your process with exclusive access to a physical device until you either deallocate the device or terminate your process. Optionally, you can associate a logical name with the device. The format for the **ALLOCATE** command is as follows:

```
ALLOCATE device-name[:] logical-name[:]
```

4.2. Creating a Shadow Set

To create a shadow set, you must use the **MOUNT** command with the **/SHADOW** qualifier to mount at least one physical disk into a shadow set and assign a virtual unit name to the set, as shown in *Example 4.1, "Creating a Shadow Set"*.

Example 4.1. Creating a Shadow Set

```
$ MOUNT DSA23:❶ /SHADOW❷ =$4$DUA9:❸ volume-label❹ logical-name❺
```

This example forms a shadow set represented by the virtual unit DSA23, and includes one shadow set member, 4DUA9. To create a shadow set, you must observe the following rules:

❶ Use the DSAn: format to name the shadow set virtual unit, where n represents a unique number from 0 through 9999. If you do not include a number after the DSA prefix, **MOUNT** automatically assigns the highest unit number available. Numbering starts at 9999 and decrements to 0; the first virtual unit mounted is numbered 9999, the second 9998, and so on.

Each virtual unit number must be unique across the system, regardless of whether or not the unit is mounted for public (mounted with the **/SYSTEM** qualifier) or private access. Virtual units are named independently of the controllers involved.

❷ The **/SHADOW** qualifier is required when specifying a physical device. You must name at least one physical device as a parameter to the **/SHADOW** qualifier. Although one-member shadow sets are valid, you must mount one or two additional disks in order for the shadowing software to maintain duplicate data. Adding disks to an existing shadow set is discussed in *Section 4.5, "Adding Shadow Set Members"*.

❸ Use a non-zero allocation class for each physical device in the shadow set. Use the allocation class naming format `$allocation-class$ddcu`, where:

- `allocation-class` is a numeric value from 1 to 255.
- `dd` describes the device type of the physical device (for example, DU, DK, or DG).
- `c` is a letter from A to Z that represents the controller designation. Note that you cannot use more than 3 characters for the `ddc` portion of the name. Failure to observe this requirement results in failure to mount the shadow set.
- `u` is the unit number of the device.

Note that you cannot use more than 3 letters for the ddc portion of the name. See *VSI OpenVMS Cluster Systems Manual* for more information about allocation classes.

❹ Specify a 1- to 12-character volume label for the virtual unit.

❺ Optionally, specify a 1- to 255-alphanumeric-character logical name string for the shadow set.

In addition, you can specify **/SYSTEM**, **/GROUP**, or **/CLUSTER** to make the shadow set available to all users of a system, all members of a group, or all nodes in a cluster on which shadowing is enabled.

To create a three-member shadow set, you can add two members in a single **MOUNT** command to an existing one-member shadow set. This method optimizes the I/O operation because both members are copied at the same time. (See the example in *Section 4.4.4, "Creating a Shadow Set With /SYSTEM and With /CLUSTER"*.)

You can also streamline the process of creating a shadow set by initialized multiple devices in one command, using **INITIALIZE/SHADOW/ERASE**, as described in *Section 4.3, "Using INITIALIZE/SHADOW/ERASE to Form a Shadow Set"*.

Upon receiving a command to create a shadow set, the volume shadowing software may perform a copy or a merge operation to reconcile data differences. If you are not sure which disks might be targets of copy operations, you can specify the **/CONFIRM** or **/NOCOPY** qualifiers as a precaution against overwriting important data when you mount a disk. These and other **MOUNT** command qualifiers are discussed in *Section 4.4, "MOUNT Command Qualifiers for Shadowing"*.

4.3. Using INITIALIZE/SHADOW/ERASE to Form a Shadow Set

You can use the DCL command **INITIALIZE** with the **/SHADOW** and **/ERASE** command qualifiers to initialize multiple members of a future shadow set. Initializing multiple members in this way eliminates the requirement of a full copy when you later create a shadow set.

The **INITIALIZE** command with the **/SHADOW** and **/ERASE** qualifiers performs the following operations:

- Formats up to six devices with one command, so that any three can be subsequently mounted together as members of a new host-based shadow set.
- Writes a label on each volume.
- Deletes all information from the devices except for the system files and leaves each device with identical file structure information.

All former contents of the disks are lost. You can then mount up to three of the devices that you have initialized in this way as members of a new host-based shadow set.

4.3.1. Benefits and Side Effects of Using /ERASE

VSI strongly recommends that you use the **/ERASE** qualifier. By using the **/ERASE** qualifier, a subsequent merge operation will be substantially reduced.

If you omit the **/ERASE** qualifier, then the portions of the volume that do not contain file system data structures contain indeterminate data. This data can differ from one shadow set member to another. Make sure to take this into account when using utilities that compare all of the LBNs between shadow set members.

The next time a full merge operation occurs, the presence of this indeterminate data causes the merge to take much longer than it takes without the use of the **INITIALIZE/SHADOW/ERASE** command. When this full merge completes, the LBNs contain identical data, and the storage control block (SCB) no longer indicates that the **/ERASE** qualifier was omitted from the **INITIALIZE/SHADOW** command.

Note, however, that a side effect of using **/ERASE** is that the ERASE volume attribute is set. In effect, each file on the volume is erased when it is deleted. Another side effect is that an **INITIALIZE/ERASE** operation is always slower than an **INITIALIZE/NOERASE** operation. The disks are erased sequentially, which effectively doubles or triples the time it takes for the command to complete. If the disks are large, consider performing multiple, simultaneous **INITIALIZE/ERASE** commands (with the **/SHADOW** qualifier) to erase the disks. After all the commands have completed, then perform an **INITIALIZE/SHADOW** command with the **/ERASE** qualifier.

You can remove the ERASE volume attribute by issuing the **SET VOLUME/NOERASE_ON_DELETE** command.

For more information about these DCL commands and qualifiers, see the *VSI OpenVMS DCL Dictionary: N–Z*.

4.3.2. Requirements for Using INITIALIZE/SHADOW

Shadow set members can differ in size, that is, they can have different nonzero values for Total Blocks. If devices of different sizes are specified in the **INITIALIZE** command, and **/SIZE** or **/LIMIT** or both are omitted, the default values for these qualifiers take effect. The default value for **/SIZE** (for the logical volume size for the device) is the smallest member's MAXBLOCK value. The default value for **/LIMIT** (for future expansion) is the largest member's MAXBLOCK value, which is used to compute the expansion limit.

You can view the Total Blocks value by entering the **SHOW DEVICE/FULL** command. If a device has never been mounted or initialized on this system, the **SHOW DEVICE/FULL** command for the device does not display a value for Total Blocks. To correct this condition, either mount and then dismount the device, or initialize the device. The Total Blocks value is then displayed by **SHOW DEVICE/FULL**.

The use of **INITIALIZE/SHADOW** requires the VOLPRO privilege.

Note that the **INITIALIZE/SHADOW** command must not be used to initialize a disk to be added to an existing shadow set, since there is no benefit to be gained.

The format of this command follows:

```
INITIALIZE/SHADOW=(device_name1, device_name2, device_name3) label
```

4.3.3. INITIALIZE/SHADOW Examples

The following example shows the *correct* use of this command. Note that the command specifies multiple devices on the same line.

```
$ INITIALIZE /ERASE /SHADOW=($4$DKA1300, $4$DKA1301) NONVOLATILE

$ MOUN/SYS DSA42 /SHAD=( $4$DKA1300 , $4$DKA1301 ) NONVOLATILE
%MOUNT-I-MOUNTED, NONVOLATILE MOUNTED ON _DSA42:
%MOUNT-I-SHDWMEMSUCC, _$4$DKA1300: (WILD3) IS NOW A VALID MEMBER OF THE
 SHADOW SET
%MOUNT-I-SHDWMEMSUCC, _$4$DKA1301: (WILD4) IS NOW A VALID MEMBER OF THE
 SHADOW SET
$ SHO DEV DSA42:

DEVICE               DEVICE           ERROR   VOLUME       FREE  TRANS MNT
 NAME                STATUS           COUNT    LABEL      BLOCKS COUNT CNT
DSA42:               MOUNTED              0  NONVOLATILE  5799600     1   1
$4$DKA1300: (WILD3)  SHADOWSETMEMBER      0  (MEMBER OF DSA42:)
$4$DKA1301: (WILD4)  SHADOWSETMEMBER      0  (MEMBER OF DSA42:)
```

The following example shows an *incorrect* use of this command. Do not use a separate command to initialize each device.

```
$ INITIALIZE /ERASE /SHADOW=  $4$DKA1300 NONVOLATILE
$ INITIALIZE /ERASE /SHADOW=  $4$DKA1301 NONVOLATILE

$ MOUN/SYS DSA42 /SHAD=( $4$DKA1300 , $4$DKA1301 ) NONVOLATILE
%MOUNT-I-MOUNTED, NONVOLATILE MOUNTED ON _DSA42:
%MOUNT-I-SHDWMEMSUCC, _$4$DKA1300: (WILD3) IS NOW A VALID MEMBER OF THE
 SHADOW SET
%MOUNT-I-SHDWMEMSUCC, _$4$DKA1301: (WILD4) IS NOW A VALID MEMBER OF THE
 SHADOW SET
$ SHO DEV DSA42:
DEVICE               DEVICE           ERROR   VOLUME       FREE  TRANS MNT
 NAME                STATUS           COUNT    LABEL      BLOCKS COUNT CNT
DSA42:              MOUNTED              0  NONVOLATILE  5799600     1   1
$4$DKA1300:    (WILD3)  ShadowSetMember      0  (member of DSA42:)
$4$DKA1301:    (WILD4)  ShadowCopying        0  (copy trgt DSA42:   0%
 copied)
```

4.4. MOUNT Command Qualifiers for Shadowing

This section briefly describes the **MOUNT** command qualifiers that are useful for shadow set management. See also the *VSI OpenVMS System Management Utilities Reference Manual, Volume 2: M-Z* for complete information about these and other DCL commands.

You must use the **/SHADOW** qualifier when you create a new shadow set or when you add a member to an existing shadow set. You can also use the optional qualifiers described in *Table 4.1, "MOUNT Command Qualifiers (Shadowing Specific)"* and in *Table 4.2, "Additional MOUNT Command Qualifiers (Not Shadowing Specific)"*. These qualifiers require the VOLPRO and OPER privileges, or your user identification code (UIC) must match the owner UIC of the volume being mounted. To mount a shadow set throughout the system, you must also have the SYSNAM privilege. In addition, the **MOUNT/POLICY=[NO]MINICOPY[=OPTIONAL]** command requires the LOG_IO privilege.

Detailed examples and descriptions of how to use these qualifiers are included in *Section 4.5, "Adding Shadow Set Members"*. In addition to the shadowing-specific qualifiers described in *Table 4.1, "MOUNT Command Qualifiers (Shadowing Specific)"*, the **/NOASSIST**, **/SYSTEM**, **/GROUP**, and **/CLUSTER** qualifiers are also frequently used when mounting shadow sets, as described in *Table 4.2, "Additional MOUNT Command Qualifiers (Not Shadowing Specific)"* and in *Section 4.4.2, "Additional MOUNT Command Qualifiers Used for Shadowing"*.

4.4.1. MOUNT Command Qualifiers Specific to Shadowing

The **MOUNT** command qualifiers described in *Table 4.1, "MOUNT Command Qualifiers (Shadowing Specific)"* are specific to shadowing.

Table 4.1. MOUNT Command Qualifiers (Shadowing Specific)

Qualifier	Function
/[NO]CONFIRM	Controls whether the Mount utility issues a request to confirm a copy operation when mounting a shadow set. The default is **/NOCONFIRM**.
/[NO]COPY	Enables or disables copy operations on physical devices named when mounting or adding to a shadow set. The default is **/COPY**.
/[NO]INCLUDE	Automatically mounts and reinstates a shadow set to the way it was before the shadow set was dissolved. The default is **/NOINCLUDE**.
/OVERRIDE=NO_FORCED_ERROR	Directs the Mount utility to proceed with shadowing, even though the device or controller does not support forced error handling. Using unsupported SCSI disks can cause members to be removed from a shadow set if certain error conditions arise that cannot be corrected, because some SCSI disks do not implement **READL** and **WRITEL** commands that support disk bad-block repair. If the SCSI device does not support **READL** and **WRITEL** commands, the SCSI disk class driver sets a NOFE (no forced error) bit in a System Dump Analyzer display. See *Section 4.11.5.1, "Using SDA to Obtain Information About Third-Party SCSI Devices"* for more information.
/OVERRIDE=SHADOW_MEMBERSHIP	Mounts a former shadow set member and zeroes the disk's shadow set generation number so that the disk is no longer marked as having been a member of the shadow set.

Qualifier	Function
/POLICY=[NO]MINICOPY [=OPTIONAL]	Controls the setup and use of the shadowing minicopy function. This qualifier requires LOG_IO privilege. The meaning of [NO]MINICOPY[=OPTIONAL] depends on the status of the shadow set. If the shadow set is not mounted, either on a standalone system or on any cluster member, and MINICOPY=OPTIONAL is specified, the shadow set is mounted and a write bitmap is created. (A write bitmap enables a shadowing minicopy operation.) **MOUNT/POLICY=MINICOPY[=OPTIONAL]** must be specified on the initial mount of a shadow set, either on a standalone system or in a cluster, to enable the shadowing minicopy operation. The OPTIONAL keyword allows the mount to continue, even if the system was unable to start the write bitmap. A bitmap could fail to start properly because of an improperly dismounted shadow set, a shadow set that requires a merge operation, or various resource problems. If the OPTIONAL keyword is omitted and the system is unable to start the write bitmap, the shadow set will not be mounted. If you specify **/POLICY=MINICOPY=OPTIONAL** and the shadow set was already mounted on another node in the cluster without this qualifier and keyword, the **MOUNT** command will succeed but a write bitmap will not be created. If NOMINICOPY is specified, the shadow set will be mounted but a write bitmap will not be created. If a former member of the shadow set is returned to the shadow set, which has minicopy enabled, then a minicopy is started instead of a full copy. This is the default behavior and will occur even if you omit **/POLICY=MINICOPY[=OPTIONAL]**. If a minicopy successfully starts and then fails for some reason, a full copy will be performed. If a minicopy cannot be started and the keyword OPTIONAL was omitted, the mount will fail. If NOMINICOPY is specified, then a minicopy will not be performed, even if one is possible.
/POLICY=REQUIRE_MEMBERS	Controls whether every physical device specified with the **/SHADOW** qualifier must be accessible when the **MOUNT** command is issued in order for the **MOUNT** command to take effect. The proposed members are either specified in the command line or found on the disk by means of the **/INCLUDE** qualifier. The

Qualifier	Function
	behavior, without this qualifier, is that if one or more members is not accessible for any reason (such as a connectivity failure), then the virtual unit will be created with the members that are accessible. This option is especially useful in the recovery of disaster-tolerant clusters because it ensures that the correct membership is selected after an event.
/POLICY=VERIFY_LABEL	Requires that any member to be added to the shadow set have a volume label of SCRATCH_DISK. This helps ensure that the wrong disk is not added to a shadow set by mistake. If you plan to use VERIFY_LABEL, then before using this qualifier you must either initialize the disk to be added to the set with the label SCRATCH_DISK, or specify a label for the disk with the command **SET VOLUME/LABEL**. The default behavior is NOVERIFY_LABEL, which means that the volume label of the copy targets will not be checked. This is the same behavior that occurred before the introduction of this qualifier. The volume label of the copy targets will not be checked.
/SHADOW=(*physical-device-name*[:][, …])	Directs the Mount utility to bind the specified physical devices into a shadow set represented by the virtual unit named in the command.

Caution

Do not use the **/OVERRIDE=IDENTIFICATION** or **/NOMOUNT_VERIFICATION** qualifiers when mounting shadow sets. Using either of these qualifiers can result in loss of data.

If you mount a shadow set with the **/OVERRIDE=IDENTIFICATION** qualifier, individual shadow set members start with different volume labels, which can cause a volume to lose data.

If you specify the **/NOMOUNT_VERIFICATION** qualifier, the shadow set becomes unusable at the first state change of the shadow set.

4.4.2. Additional MOUNT Command Qualifiers Used for Shadowing

The **MOUNT** command qualifiers described in this section are not specific to shadowing but can be very useful when creating shadow sets. These additional qualifiers are described in *Table 4.2, "Additional MOUNT Command Qualifiers (Not Shadowing Specific)"* and in the examples that follow.

Table 4.2. Additional MOUNT Command Qualifiers (Not Shadowing Specific)

Qualifier	Function
/NOASSIST	Successfully mounts a shadow set if at least one of the devices included in the **MOUNT** command is available for mounting. In the absence of this

Qualifier	Function
	qualifier, if one of the devices specified to be mounted is not available for mounting, the shadow set will *not* be mounted.
/SYSTEM	Makes the volume available to all users on the system. Use this qualifier when you add a disk to an existing shadow set. If the **/CLUSTER** qualifier was used when the shadow set was created, the use of **/SYSTEM** will make the new member of the shadow set available to all nodes in the cluster that already have the shadow set mounted.
/GROUP	Makes the volume available to all users with the same group number in their UICs as the user entering the **MOUNT** command. You must have GRPNAM and SYSNAM user privileges to mount group and system volumes.
/CLUSTER	Creates the virtual unit automatically on every node in the cluster on which shadowing is enabled. Use this qualifier if the shadow set is to be accessed across the cluster. You must have the SYSNAM privilege to use this qualifier. Using **/CLUSTER** automatically includes the **/SYSTEM** qualifier, making the shadow set available to all users on the system.

4.4.3. Creating a Shadow Set With /NOASSIST

You may occasionally find it useful to specify the **/NOASSIST** qualifier on the **MOUNT** command. For example, you can use the **MOUNT/NOASSIST** command in startup files to avoid failure of a **MOUNT** command when a device you specify in the command is not available. The **/NOASSIST** qualifier can be used in startup files because operator intervention is impossible during startup.

The **MOUNT/NOASSIST** command can successfully mount the shadow set as long as at least one of the devices included in the **MOUNT** command is available for mounting. *Example 4.2, "Using the /NOASSIST Qualifier"* shows an example of the **/NOASSIST** qualifier and the resulting messages when one of the members included in the command is not available for mounting.

Example 4.2. Using the /NOASSIST Qualifier

```
$ MOUNT/SYS DSA65:/SHADOW=($4$DIA6,$4$DIA5) GALEXY/NOASSIST
%MOUNT-I-MOUNTED, GALEXY mounted on _DSA65:
%MOUNT-I-SHDWMEMSUCC, _$4$DIA6: (READY) is now a valid member of the
 shadowset
%MOUNT-I-SHDWMEMFAIL, $4$DIA5 failed as a member of the shadow set
-SYSTEM-F-VOLINV, volume is not software enabled
```

Even though device 4DIA5 is not available for mounting, the **MOUNT** command continues to create the shadow set with 4DIA6 as its only member. If the command did not include the **/NOASSIST** qualifier, the **MOUNT** command would not mount the shadow set.

4.4.4. Creating a Shadow Set With /SYSTEM and With /CLUSTER

When you create a shadow set, you must specify either the **/SYSTEM** qualifier or the **/CLUSTER** qualifier, or both (see *Table 4.2, "Additional MOUNT Command Qualifiers (Not Shadowing Specific)"*) to provide access for all users on a single system or on a cluster.

In *Example 4.3, "Using the /CLUSTER Qualifier"*, if the shadow set (identified by its virtual unit name DSA2) is not currently mounted, the first command creates a shadow set with one shadow set member;

the second command adds two more members to the *same* shadow set. An automatic copy operation causes any data on the second and third volumes to be overwritten as the shadow set members are added.

In the second **MOUNT** command, you have to specify only **/SYSTEM** when you add the 6DIA5 and 6DIA6 devices to the shadow set. Do not use **/CLUSTER**. These disks are added with the same status that the shadow set currently has, which in this case is clusterwide access.

Example 4.3. Using the /CLUSTER Qualifier

```
$ MOUNT DSA2: /CLUSTER /SHADOW=$6$DIA4: PEAKSISLAND DISK$PEAKSISLAND
$ MOUNT DSA2: /SYSTEM/SHADOW=($6$DIA5:,$6$DIA6:) PEAKSISLAND DISK
$PEAKSISLAND
```

4.5. Adding Shadow Set Members

Once a shadow set is created, you can add and remove individual members by mounting or dismounting physical disk devices. The shadowing software allows you to add and remove shadow set members at any time, transparently to user processes or applications running on the system.

4.5.1. Adding a Disk to an Existing Shadow Set

The following command shows how to add the disk 4DUA3 to the DSA23 shadow set:

```
$  MOUNT/CONFIRM/SYSTEM DSA23: /SHADOW=($4$DUA9,$4$DUA3) volume-label
```

The command specifies both the currently active shadow set member (4DUA9) and the new member (4DUA3). Although it is not necessary to include them when mounting additional physical devices, you can specify current shadow set members without affecting their membership state.

Note that when you add volumes to an existing shadow set mounted across an OpenVMS Cluster system, the shadowing software automatically adds the new members on each OpenVMS Cluster node.

4.5.2. Creating a Two-Member Shadow Set and Adding a Third Member

Example 4.4, "Creating a Shadow Set and Adding Third Member" shows how to create a two-member shadow set with the first command and how to add another member to the shadow set with the second command.

Example 4.4. Creating a Shadow Set and Adding Third Member

```
$ MOUNT/SYSTEM DSA4: /SHADOW = ($3$DIA7:, $3$DIA8:)
FORMERSELF
%MOUNT-I-MOUNTED, FORMERSELF   mounted on DSA4:
%MOUNT-I-SHDWMEMSUCC, _$3$DIA7: (DISK300) is now a valid member of
                      the shadow set
%MOUNT-I-SHDWMEMSUCC, _$3$DIA8: (DISK301) is now a valid member of
                      the shadow set

$ MOUNT/SYSTEM DSA4: /SHADOW = $3$DIA6:  FORMERSELF

%MOUNT-I-SHDWMEMCOPY, _$3$DIA6: (DISK302) added to the shadow set
                      with a copy operation
```

In this example, the first command creates a shadow set whose virtual unit name is DSA4. The member disks are 3DIA7 and 3DIA8. The second command mounts the disk 3DIA6 and adds it to shadow set DSA4. The shadow set now includes three members: 3DIA6, 3DIA7, and 3DIA8. In this example, when you add 3DIA6 after the shadow set already exists, the added volume becomes the target of a copy operation.

4.5.3. Checking Status of Potential Shadow Set Members With /CONFIRM

When you add a disk to an existing shadow set, a copy operation is necessary. Volume shadowing automatically performs the copy operation, unless you use the **/CONFIRM** qualifier or the **/NOCOPY** qualifier. When you specify the **/CONFIRM** qualifier, as shown in *Example 4.5, "Using the /CONFIRM Qualifier"*, the **MOUNT** command displays the targets of copy operations and prompts for permission before the operations are performed. This precaution can prevent the erasure of important data. For more information about copy operations, see *Chapter 6, "Ensuring Shadow Set Consistency"*.

Example 4.5. Using the /CONFIRM Qualifier

```
$ MOUNT/CONFIRM DSA23: /SHADOW=($1$DUA4:,$1$DUA6:) SHADOWVOL ❶
%MOUNT-F-SHDWCOPYREQ, shadow copy required
Virtual Unit - DSA23 Volume Label - SHADOWVOL ❷
     Member                    Volume Label Owner UIC ❸
     $1$DUA6: (LOVE)           SCRATCH      [100,100]
Allow FULL shadow copy on the above member(s)? [N]: NO ❹
$
```

❶ This command instructs **MOUNT** to build a shadow set with the specified devices and to prompt for permission to perform any copy operations.

❷ Because a copy operation is necessary, the virtual unit name and the volume label are displayed.

❸ The display also includes the physical device name, the volume label, and the volume owner of the potential shadow set member that requires the copy operation.

❹ A response of No causes **MOUNT** to quit without mounting or copying.

4.5.4. Checking Status of Potential Shadow Set Members With /NOCOPY

When you specify more than one disk, the shadowing software automatically determines the correct copy operation to perform in order to make shadow set members consistent with each other (see *Section 6.2, "Copy Operations"* for details). The Mount utility interprets information recorded on each member to determine whether a member requires a copy operation, a merge operation, or no copy operation. If you are not sure which disks might be targets of copy operations, you can specify the **/CONFIRM** qualifier or the **/NOCOPY** qualifier as a precaution against overwriting important data when you mount a disk. With the **/NOCOPY** qualifier, you disable the copy operation.

Example 4.6, "Using the /NOCOPY Qualifier" shows how to use the **/NOCOPY** qualifier to check the status of potential shadow set members before any data is erased.

Example 4.6. Using the /NOCOPY Qualifier

```
$ MOUNT/NOCOPY DSA2: /SHADOW=($1$DUA4:,$1$DUA6:,$1$DUA7:) -
_$ SHADOWVOL DISK$SHADOWVOL ❶
%MOUNT-F-SHDWCOPYREQ, shadow copy required
```

```
%MOUNT-I-SHDWMEMFAIL, DUA7: failed as a member of the shadow set
%MOUNT-F-SHDWCOPYREQ, shadow copy required ❷
$ MOUNT/COPY❸ DSA2: /SHADOW=($1$DUA4:,$1$DUA6:,$1$DUA7:) -
_$ SHADOWVOL DISK$SHADOWVOL
%MOUNT-I-MOUNTED, SHADOWVOL    mounted on _DSA2:
%MOUNT-I-SHDWMEMSUCC, _$1$DUA4: (VOLUME001) is now a valid member of
                      the shadow set
%MOUNT-I-SHDWMEMSUCC, _$1$DUA6: (VOLUME002) is now a valid member of
                      the shadow set
%MOUNT-I-SHDWMEMCOPY, _$1$DUA7: (VOLUME003) added to the shadow set
                      with a copy operation ❹
```

❶ This command instructs **MOUNT** to build a shadow set, with the specified devices, but only if a copy or merge operation is not required.

❷ **MOUNT** did not build the shadow set because the specified disk, loaded on device 1DUA7, required a copy operation. At this point you can verify that the volume in device 1DUA7 does not contain any useful data.

❸ If the device does not contain valuable data, you can reenter the **MOUNT** command and include the **/COPY** qualifier. This command instructs **MOUNT** to mount a shadow set and to proceed with the necessary copy or merge operation.

❹ The shadow set is successfully mounted. The 1DUA7 device is currently the target of a copy operation; it attains full shadow set membership when the copy operation completes.

4.6. Mounting a Shadow Set on Other Nodes in the Cluster

If a shadow set is already mounted on one or more nodes in an OpenVMS Cluster system, the **/SHADOW** qualifier is not required when you mount the same shadow set on other nodes in the cluster. For example, if DSA42 is already mounted in the cluster when a new node is brought into the cluster, you can use the following command to mount DSA42 on the new node:

```
$ MOUNT/SYS DSA42: volume-label logical-name
```

Upon receiving this command, the volume shadowing software creates the virtual unit on the new node with the same members that currently exist on other nodes in the cluster.

4.6.1. Reconstructing a Shadow Set With /INCLUDE

Example 4.7, "Reconstructing Shadow Sets With /INCLUDE" shows how to reconstruct a shadow set. The volume shadowing software determines which disk volumes are former members of the shadow set.

Example 4.7. Reconstructing Shadow Sets With /INCLUDE

```
$ MOUNT /SYSTEM DSA4/SHAD=($4$DIA1,$4$DIA2,$4$DIA3) NEWDISK❶
%MOUNT-I-MOUNTED, NEWDISK   mounted on _DSA4:
%MOUNT-I-SHDWMEMSUCC, _$4$DIA1: (DISK01) is now a valid member
                          of the shadow set
%MOUNT-I-SHDWMEMCOPY, _$4$DIA2: (DISK02) added to the shadow set
                          with a copy operation
%MOUNT-I-SHDWMEMCOPY, _$4$DIA3: (DISK03) added to the shadow set
                          with a copy operation
$ DISMOUNT DSA4❷
$
```

```
$ MOUNT DSA4:/SYSTEM/SHAD=$4$DIA1 NEWDISK/INCLUDE❸
%MOUNT-I-MOUNTED, NEWDISK   mounted on _DSA4:
%MOUNT-I-SHDWMEMSUCC, _$4$DIA1: (DISK01) is now a valid member ❹
                           of the shadow set
%MOUNT-I-AUTOMEMCOPY, _$4$DIA2: (DISK02) automatically added ❹
                           to the shadow set
%MOUNT-I-AUTOMEMCOPY, _$4$DIA3: (DISK03) automatically added ❹
                           to the shadow set
```

❶ This is the original **MOUNT** command that created the shadow set represented by DSA4. The shadow set consists of three shadow set members: 4DIA1, 4DIA2, and 4DIA3.

❷ After all copy operations have completed, the **DISMOUNT** command dissolves the shadow set.

❸ The **/INCLUDE** qualifier triggers the **MOUNT** command to reconstruct the shadow set back to the way it was before the shadow set was dissolved. The **MOUNT** command must specify the original virtual unit name (DSA4) and at least one of the original shadow set members (4DIA1). The MOUNT utility reads the membership list on 4DIA1 (specified in the **MOUNT** command) to determine that 4DIA2 and 4DIA3 are also members of the shadow set.

❹ Because the shadow set was properly dismounted, the shadow set members are in a consistent state. The **MOUNT** status messages indicate that the shadow set devices are added back into the shadow set without the need for copy operations.

4.6.2. Mounting a Former Shadow Set Member as a Non-shadowed Disk

Occasionally, you have to mount a physical shadow set member as a nonshadowed disk. By default, when a shadow set member is mounted outside a shadow set, the Mount utility automatically write-locks the disk. This provides a safeguard against accidental modification, thereby allowing the disk to be remounted into a shadow set at a later time.

To override this default behavior, include the **/OVERRIDE=SHADOW_MEMBERSHIP** qualifier on the **MOUNT** command as shown in the following example:

```
$ MOUNT/OVERRIDE=SHADOW_MEMBERSHIP $4$DUA20: WORKDISK
```

This command ignores shadow set membership status and mounts a former shadow set member on 4DUA20 as a nonshadowed disk with write access.

4.7. Managing Shadow Sets With SET SHADOW

Many of the **SET SHADOW** qualifiers, described in *Table 4.3, "SET SHADOW Command Qualifiers"*, can be applied to individual shadow set members or to the entire shadow set.

By using these qualifiers, system managers can override the default volume shadowing actions that can occur when the systems at one site of a multiple-site OpenVMS Cluster configuration fail or when a merge operation is required. Designed primarily for use in a configuration that uses Fibre Channel for a storage interconnect, either locally or site-to-site, these command qualifiers can be used in other configurations as well.

Similarly, the DCL command **DISMOUNT** was enhanced by the addition of the qualifier **/FORCE_REMOVAL *ddcu*:**. This qualifier was added to give system managers greater control of

shadow set members located at different sites. For more information about this qualifier, see *Section 4.10.1, "Removing Members from Shadow Sets"*.

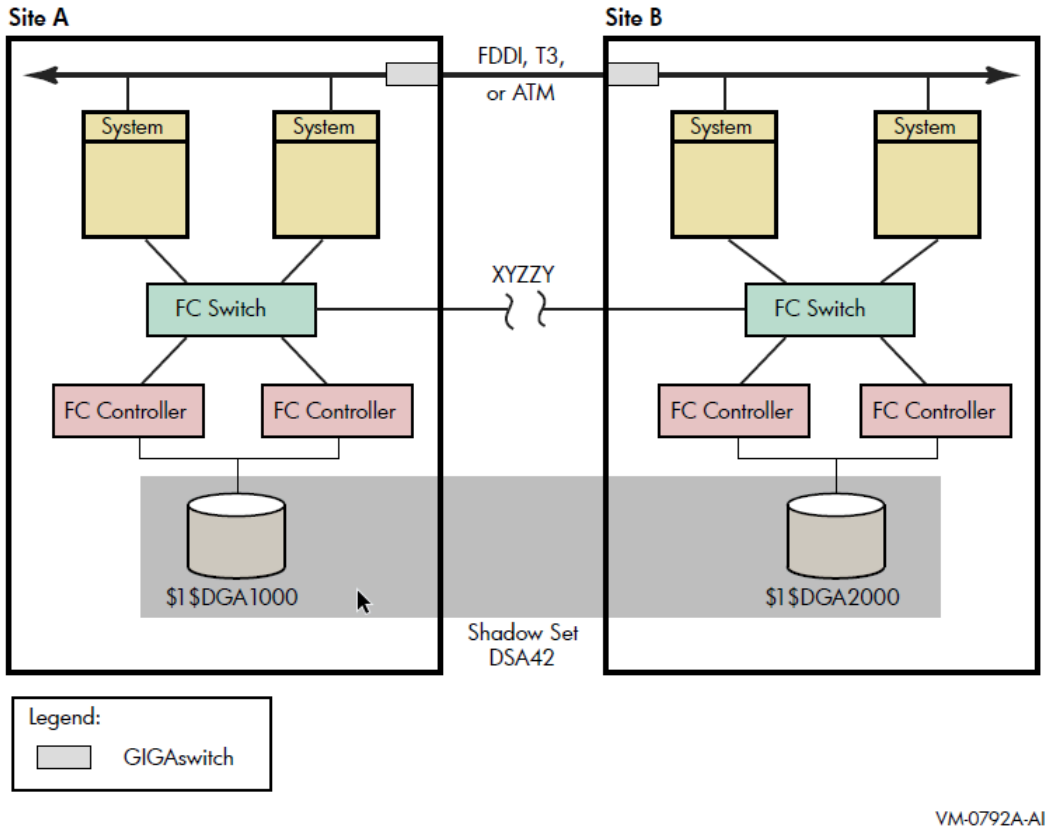
4.7.1. How to Use the Multiple-Site SET SHADOW and DISMOUNT Command Qualifiers

Figure 4.1, "Multiple-Site OpenVMS Cluster System With FC and LAN Interconnects" depicts a typical multiple-site cluster using Fibre Channel. The figure illustrates the steps required to recover one site manually when the site-to-site storage interconnect fails. These steps must be taken for multiple-site OpenVMS Cluster systems that are running:

- Earlier versions of OpenVMS that do not support MSCP failover to a served path.
- Versions of OpenVMS Alpha that support MSCP failover to a served path but serve only a subset of their disks.

  If you have chosen to serve only a subset of the disks in your configuration, you must use this configuration method for site recovery for the disks that are not served. One reason to serve only a subset of your disks is that failover of the served disks, from a Fibre Channel interconnect to the LAN interconnects and the inter-site link, can put a very heavy load on these interconnects, which can seriously degrade performance.

Figure 4.1. Multiple-Site OpenVMS Cluster System With FC and LAN Interconnects



To prevent the shadowing driver from automatically recovering shadow sets from connection-related failures, you must perform the following three configuration tasks prior to any failure:

1. Every device that is a member of a multiple-site shadow set must have its MEMBER_TIMEOUT setting raised to a high value, using the following command:

```
$ SET SHADOW /MEMBER_TIMEOUT=x  ddcu:
```

This command overrides the SHADOW_MBR_TMO value, is normally used for a shadow set member. A value for *x* of 259200 would be a 72-hour wait time.

2. Every shadow set that spans multiple sites must have its mount verification timeout setting raised to a very high value, higher than the MEMBER_TIMEOUT settings for each member of the shadow set.

   Use the following command to increase the mount verification timeout setting for the shadow set:

   ```
   $ SET DEVICE /MVTIMEOUT=y  DSAn
   ```

   The *y* value of this command must always be greater than the *x* value of the **SET DEVICE /MEMBER_TIMEOUT=*x ddcu*:** command.

   The **SET DEVICE /MVTIMEOUT=*y*** command overrides the MVTIMEOUT value, which is normally used for the shadow set. A value for y of 262800 would be a 73-hour wait.

3. Every shadow set and every shadow set member must have a site qualifier. As already noted, a site qualifier ensures that the read cost is correctly set. The other critical factor is three-member shadow sets. When they are being used, the site qualifier will ensure that the master member of the shadow set is properly maintained.

Figure 4.1, "Multiple-Site OpenVMS Cluster System With FC and LAN Interconnects" shows a shadow set DSA42, whose members are devices 1DGA1000 and 1DGA2000. Systems at Site A or Site B have direct access to all devices at both sites via Fibre Channel connections. XYZZY is a theoretical point between the two sites. If the Fibre Channel connection were to break at this point, each site could access different “local” members of DSA42 without error.

For the purpose of this example, Site A will be the sole site chosen to retain access to the shadow set.

The following steps must be taken to recover the shadow set at Site A.

1. On Site A, issue the following command:

   ```
   $ DISMOUNT /FORCE_REMOVAL= $1$DGA2000:
   ```

   Once the command has completed, the shadow set is available for use only at site A.

2. On Site B, issue the following command:

   ```
   $ SET DEVICE /ABORT_VIRTUAL_UNIT DSA42:
   ```

   Once the command has completed, the shadow set status will be `MntVerifyTimeout`.

3. Next, issue the following command to free up the shadow set:

   ```
   $ DISMOUNT/ABORT DSA42:
   ```

   These steps must be taken for all affected multiple-site shadow sets.

4.8. Managing Copy and Merge Operations

Copies and merges performed by the volume shadowing software are regulated automatically by the locking software and by the setting of SHADOW_MAX_COPIES. The **SET SHADOW** command provides better control over the order of copies and merges and allows you to specify the systems on which the copy operations must take place.

All **SET SHADOW** qualifiers pertain to shadow sets (DSAn:), and some can also be applied to individual shadow set members (ddcu:), as described in *Table 4.3, "SET SHADOW Command Qualifiers"*. For most qualifiers that take a shadow set as a parameter, the **/ALL** qualifier can be used in place of the shadow set name to indicate that the requested action applies to all shadow sets on the system.

The qualifiers remain in effect until the device (shadow set or shadow set member) is dismounted. If the device is remounted (in the case of a shadow set member, returned to the shadow set from which it was dismounted), the qualifier must be specified again. The **SET SHADOW** command requires the SYSPRV privilege.

Note

The qualifiers **/DELETE**, **/DISABLE**, **/ENABLE**, **/NAME**, and **/POLICY** are used only to manage host-based minimerge (HBMM) operations and do not apply to other operations. If you specify any other (non-HBMM) qualifiers in a command that includes HBMM qualifiers, the command fails. For more information about HBMM, see *Chapter 8, "Host-Based Minimerge (HBMM)"*.

The following example shows how to specify qualifiers for a shadow set:

```
$ SET SHADOW DSAn:/qualifier/qualifier
```

Table 4.3. SET SHADOW Command Qualifiers

Qualifier	Function
/ABORT_VIRTUAL_UNIT {DSA*n*:|/ALL}	Aborts mount verification on the specified shadow set or on all shadow sets in mount verification on the system. Use this qualifier when you know that the unit cannot be recovered. When you use this qualifier, the shadow set must be in mount verification. The shadow set aborts mount verification immediately on the system from which the command is issued. If the shadow set is not in mount verification, this command returns the error %SYSTEM-E-UNSUPPORTED, unsupported operation or function. After this command completes, the shadow set must still be dismounted. Use the following command to dismount the shadow set: `$ DISMOUNT/ABORT/OVERRIDE=CHECKS DSAn`
/ALL	Causes the command to operate on all shadow sets that are mounted on the system from which the command is issued. **/ALL** can be used instead of DSAn: in most commands that take a shadow set device specification as a parameter, except with the **/DEMAND_MERGE**, **/DELETE**, **/EVALUATE=RESOURCES**, and **/POLICY** qualifiers or with any qualifier that operates only on individual shadow set members (for example, **/MEMBER_TIMEOUT** and **/FORCE_REMOVAL**.

Qualifier	Function
/CONFIRM **/NOCONFIRM** (default)	Specifies whether a query is made before each merge operation to confirm that the operation must be performed on the designated shadow set. This qualifier can be used only in conjunction with the **/DEMAND_MERGE** qualifier. The following responses are valid in response to the query: ● Affirmative: YES, TRUE, or 1. ● Negative: NO, FALSE, 0 (zero), or pressing the Return key. ● End the process: QUIT or Ctrl/Z. ● When you enter ALL, the command continues to process, but no further prompts are given. You can enter word responses in uppercase or lowercase letters, and words can be abbreviated to one or more letters. If you enter an illegal response, DCL redisplays the prompt. For examples, see the **SET SHADOW** examples in the *VSI OpenVMS DCL Dictionary: N–Z*.
/COPY_SOURCE **{*ddcu*:|DSA*n*:|/ALL}**	Specifies which source member of a shadow set to use as the source for read data during full copy operations when a third member is added to a shadow set that contains two full members. This qualifier affects only those copy operations that do not use disk copy data (DCD) commands. The source specified by this qualifier persists until the shadow set is dismounted. Some storage controllers, such as the HSG80, have a read-ahead cache, which significantly improves a device's read performance. Copy operations normally alternate reads between the two source members, which effectively nullifies the benefits of the read-ahead cache. This qualifier lets you force all reads from a single, specified source member for the duration of a copy operation. In addition to improving copy performance, **/COPY_SOURCE** can be used to prevent read operations from a specific shadow set member that is considered unreliable. By specifying only the reliable shadow set member, the copy operations can continue to completion. The unreliable shadow set member can be removed once the copy operation completes successfully. If a shadow set (DSAn) is specified, all reads for full copy operations are performed from the device that is the current "master" member, regardless of physical location of the disk. If a shadow set member (ddcu:) is specified, that member is used

Qualifier	Function
	as the read source for all copy operations. This setting allows you to choose any source member. For example, you can choose a source member that is at the same site as the member being added, rather than using a master member that is not at the same site. If **/ALL** is specified, all reads for full copy operations on all currently mounted virtual units are performed from the master member.

/DELETE {DSA*n*:|*/NAME*}	Used only in conjunction with **/POLICY=HBMM**, **/DELETE** removes a host-based minimerge (HBMM) policy from a specified shadow set, or deletes an HBMM named policy from the entire cluster. For example, the following command removes the policy that is currently associated with shadow set DSA1:
	
	`$ SET SHADOW /DELETE DSA1 / POLICY=HBMM`
	
	In contrast, the following command removes COMPANY_POLICY from the cluster:
	
	`$ SET SHADOW /DELETE / NAME=COMPANY_POLICY /POLICY=HBMM`
	
	You cannot delete the NODEFAULT policy, nor can you specify **/ALL** with **/DELETE**.

/DEMAND_MERGE	Initiates a merge operation on the specified shadow set. This qualifier is useful if the shadow set was created with the **INITIALIZE/SHADOW** command without the use of the **/ERASE** qualifier. For more information about using **/DEMAND_MERGE**, see *Section 4.8.1, "Using /DEMAND_MERGE to Start a Merge Operation"*. You cannot specify **/ALL** with **/DEMAND_MERGE**. An OPCOM message is displayed for each shadow set indicating that a demand merge has been invoked and recording the process ID (PID) of the process that executed the command. For example: `%%%%%%%%%%% OPCOM 9-MAR-2004 10:35:23.24 %%%%%%%%%%% Message from user SYSTEM on NODE1 Demand Merge requested for _DSA721:, PID: 2760009A`
/DISABLE=HBMM {DSA*n*:| /ALL}	Disables host-based minimerge (HBMM) on the specified shadow set or clusterwide on all shadow sets.

Qualifier	Function
	HBMM is the only supported value for **/DISABLE**, and it must be included.
/DISABLE=SPLIT_READ_LBNS	Disables the split behavior of LBNs and as a result the reads are alternated between the source shadow set members having the same read_cost and device queue length.
/ENABLE=HBMM	Enables host-based minimerge (HBMM) on the specified shadow set or across the entire cluster if an applicable HBMM policy exists. HBMM is the only supported value for **/DISABLE**, and it must be included.
/ENABLE=SPLIT_READ_LBNS	Logically divides the shadow set members having the same read cost into equal groups of LBNs. When a virtual unit performs a read, it does so by reading from the corresponding LBN group. This results in the maximum usage of the controller read-ahead cache.
/EVALUATE=RESOURCES	Forces the system to evaluate whether it must act on most shadow copy and merge operations currently being managed on the system. It cancels most operations and then, based on the value of system parameter SHADOW_MAX_COPY and the copy/merge priority of each shadow set, it evaluates the order in which the pending copies and merges should be restarted. RESOURCES is the only supported value for **/EVALUATE**, and it must be included. EVALUATE does not apply to MSCP-based minimerge operations. MSCP-based minimerge operations are not subject to cancellation and restart by **/EVALUATE**. This command is intended to be used after changing the value of the dynamic system parameter SHADOW_MAX_COPY or after issuing a **SET SHADOW /PRIORITY=*n*** command for a shadow set. After a suitable delay, all available SHADOW_MAX_COPY slots on the system are allocated using the priority list.
/FORCE_REMOVAL*ddcu*	Expels the specified shadow set member from the shadow set. The specified device must be a member of a shadow set that is mounted on the system where the command is issued. You cannot specify **/ALL** with **/FORCE_REMOVAL**. If connectivity to a device has been lost and the shadow set is in mount verification, this qualifier

Qualifier	Function
	causes the member to be expelled from the shadow set immediately. If the shadow set is not currently in mount verification, no immediate action is taken. If connectivity to a device has been lost but the shadow set is not in mount verification, this qualifier lets you flag the member to be expelled from the shadow set as soon the shadow set enters mount verification. If no action has been taken on the specified member and you wish to clear the flag, use **/NOFORCE_REMOVAL**. If the shadow set is dismounted before the member is expelled, the FORCE_REMOVAL request expires.
/LOG	Instructs the volume shadowing software to display a brief message confirming that the **SET SHADOW** command completed. If **/OUTPUT** is also specified, this information is written to the output file.
/MEMBER_TIMEOUT =*nddcu*:	Specifies the timeout value to be used for a shadow set member. The specified device must be a member of a shadow set that is mounted on the system where the command is issued. The value supplied by this qualifier overrides the system parameter SHADOW_MBR_TMO for this specific device. Each member of a shadow set can be assigned a different MEMBER_TIMEOUT value. The valid range for n is 1 to 16777215 seconds. The timeout value set by **/MEMBER_TIMEOUT** does not persist after the shadow set is dismounted.
/MVTIMEOUT {= *n* DSA*n*:|=*n* /ALL}	Specifies the mount verification timeout value to be used for all shadow sets on the cluster or for the shadow set, specified by its virtual unit name (DSA*n*:). The specified shadow set must be mounted on the system where the command is issued. The value supplied by this qualifier overrides the value specified by the system parameter MVTIMEOUT for this specific shadow set. **Note** You cannot change the value of MVTIMEOUT for a system disk. Any attempt to do so results in an error.

Qualifier	Function
	The valid range for n is 1 to 16777215 seconds. The timeout value set by **/MVTIMEOUT** does not persist after the shadow set is dismounted.
/NAME=*policy-name*	Used with **/POLICY=HBMM** to define a named host-based minimerge (HBMM) policy or used with **/DELETE** to delete a policy. The policy is defined clusterwide. See detailed descriptions under **/DELETE** and **/POLICY**. Policy names are case insensitive and must consist of 1 to 64 characters. Only letters, numbers, the dollar sign ($), and the underscore (_) are allowed. If you create a default policy, you must assign it the name DEFAULT. For details about creating and using policy names, see *Chapter 8, "Host-Based Minimerge (HBMM)"*.
/OUTPUT=*file-name*	Outputs any messages to the specified file.
/POLICY=HBMM{=*policy-name*| =*policy-specification*}	Creates or deletes a policy for host-based minimerge (HBMM). HBMM is the only supported value for the **/POLICY** qualifier, and it must be included. You can optionally specify a named policy, including DEFAULT, or you can specify NODEFAULT to indicate that the shadow set to which it is applied is not to use HBMM, including any DEFAULT policy. For information about specifying policies and using the DEFAULT and NODEFAULT names, see *Chapter 8, "Host-Based Minimerge (HBMM)"*. When **/POLICY** is specified with **/DELETE**, it removes either a specified HBMM named policy or the HBMM policy for a specific shadow set. You cannot delete the NODEFAULT policy. When **/POLICY** is specified with **/NAME**, it defines a clusterwide named policy. When no qualifiers others than **/NAME** and **/DELETE** are specified, **/POLICY** defines a policy for a specific shadow set. Deleting bitmaps with the **DELETE/BITMAP** command causes a bitmap to be deleted. However, the shadowing software recognizes this condition and starts a new bitmap immediately. To disable HBMM bitmaps, you must use the command **SET SHADOW/DISABLE=HBMM**.

Qualifier	Function

	When defining a policy, you use five keywords (MASTER_LIST, COUNT, RESET_THRESHOLD, MULTIUSE, and DISMOUNT) to control the placement and management of HBMM bitmaps. An HBMM policy specification consists of a list of these keywords enclosed within parentheses. Only the MASTER_LIST keyword is required. If the COUNT and RESET_THRESHOLD keywords are omitted, default values are applied.
	
	The MULTIUSE and DISMOUNT keywords specify the number of bitmaps to be converted to multiuse bitmaps during the automatic and manual removal of members respectively. If MULTIUSE is omitted, the automatic minicopy on volume processing is not enabled. As a result, none of the HBMM bitmaps are converted to multiuse bitmaps. If DISMOUNT is omitted, a maximum of six HBMM bitmaps can be used as multiuse bitmaps.
	
	● `MASTER_LIST=list`
	
	The MASTER_LIST keyword is used to identify a set of systems as candidates for a master bitmap. The list value can be a single system name; a parenthesized, comma-separated list of system names; or the wildcard character, as shown in the following examples:
	
	`MASTER_LIST=Node1`
	`MASTER_LIST=(NODE1,NODE2,NODE3)`
	`MASTER_LIST=*`
	
	When the system list consists of a single system name or the wildcard character, parentheses are optional.
	
	An HBMM policy must include at least one MASTER_LIST. Multiple master lists are optional. If a policy has multiple master lists, the entire policy must be enclosed with parentheses, and each constituent master list must be separated by a comma as shown in the following example:
	
	`(MASTER_LIST=(NODE1,NODE2),`
	`MASTER_LIST=(NODE3,NODE4))`
	
	There is no significance to the position of a system name in a master list.
	
	● `COUNT=n`

Qualifier	Function

	The COUNT keyword specifies the number of systems in the master list that can have master bitmaps. Therefore, the COUNT keyword and its associated MASTER_LIST must be enclosed within a single parenthetical statement.
	
	The COUNT value specifies the number of systems on which you want master bitmaps. It does not necessarily mean that the first n systems in the list are chosen.
	
	When the COUNT keyword is omitted, the default value is six or the number of systems in the master list, whichever is smaller.
	
	You cannot specify more than one COUNT keyword per master list. Examples:
	
	`(MASTER_LIST=(NODE1,NODE2,NODE3), COUNT=2`
	`(MASTER_LIST=(NODE1,NODE2,NODE3), COUNT=2),`
	`(COUNT=2, MASTER_LIST=(NODE4,NODE5,NODE6))`
	
	● `RESET_THRESHOLD=n`
	
	The RESET_THRESHOLD keyword specifies the number of blocks that can be set before the bitmap can be cleared. Each set bit in a master bitmap corresponds to a set of blocks to be merged, so this value can affect the merge time.
	
	Bitmaps are eligible to be cleared when the RESET_THRESHOLD is exceeded. However, the reset does not occur immediately when the threshold is crossed. For more information about selecting a value for this attribute, see the OpenVMS Support for Host-based Minimerge (HBMM) document.
	
	The reset threshold is associated with a specific HBMM policy. Therefore, the RESET_THRESHOLD keyword can be defined only once in a policy specification. Because its scope is the entire policy, the RESET_THRESHOLD keyword cannot be specified inside a constituent master list when the policy uses multiple master lists.

Qualifier	Function

	When the RESET_THRESHOLD keyword is omitted, the value of 1,000,000 is used by default.
	
	Example:
	
	`(MASTER_LIST=*, COUNT=4,`
	`RESET_THRESHOLD=100000)`
	
	In a policy with multiple master lists, a given system name can appear in only one master list. A shadow set need not be mounted to have an HBMM policy defined for it. For more **/POLICY** examples, see the **SET SHADOW** Examples section in the *VSI OpenVMS DCL Dictionary: N–Z*.
	
	● `MULTIUSE=n`
	
	The MULTIUSE keyword enables automatic minicopy on volume processing. n specifies the number of existing HBMM master bitmaps to be converted to MULTIUSE bitmaps in the event that a shadow set member is removed from the shadow set by the shadowing driver.
	
	During loss of connectivity to a site or controller, shadowing may remove a member from the shadow set. When the member is added back to the shadow set, a full shadow copy occurs.
	
	By converting a few of the HBMM bitmaps to multiuse bitmaps, all the writes that are performed to the shadow set are recorded. Thus, when the member is added back to the shadow set, the multiuse bitmap can be used for a minicopy operation. This is much faster than a full copy operation.
	
	The value of n cannot exceed the implied or explicit value of COUNT. If MULTIUSE is not specified, bitmaps are not converted to multiuse and a full copy operation is required. Fatal drive errors that remove a shadow set member do not cause a multiuse conversion because the drive must be replaced, and therefore requires a full copy operation. For more information, see *Section 8.10, "Multiuse Property for Host-Based Minicopies"*.
	
	● `DISMOUNT=n`

Qualifier	Function
	The DISMOUNT keyword allows all the 12 write bitmaps to be used by Shadowing as multiuse bitmaps, thereby reducing the single point of failure of single minicopy master bitmaps. n specifies the number of HBMM bitmaps to be converted to multiuse bitmaps every time a member is dismounted from a shadow set using the following command: `DISMOUNT/POLICY=MINICOPY`
/PRIORITY=*n* DSA*n*:	Overrides the current default priority setting. Priorities range from 0 (lowest) to 10000 (highest). The default priority is 5000. A shadow set with a priority of 0 is never considered for a merge or a copy on the system. When a recovery operation (that is, either a merge or a copy) is needed on multiple shadow sets, the shadow sets are recovered in priority order from highest to lowest. The priority setting is system specific; any change in priority made on a single system does not propagate to the entire cluster and does not persist across a system reboot. Once this qualifier has been applied to a shadow set that is mounted, the setting persists across any subsequent **DISMOUNT** and **MOUNT** commands. For more information about using this qualifier, see *Section 4.9, "Prioritizing Merge and Copy Operations"*.
/READ_COST =*n* {*ddcu*:|DSA*n*:}	Enables you to modify the default “cost” assigned to each shadow set member (ddcu:). By modifying the assignments, you can bias the reads in favor of one member of a two-member shadow set, or, in the case of three-member shadow sets, in favor of one or two members of the set over the remaining members. The device specified must be a member of a shadow set that is mounted on the node where the command is issued. The valid range for the specified cost (n) is 1 to 65,535 units. You cannot specify **/ALL** with **/READ_COST**. The shadowing driver assigns default READ_COST values to shadow set members when each member is initially mounted. The default value depends on the device type and its configuration relative to the system mounting it. The following list of device types is ordered by the

Qualifier	Function
	default READ_COST assignments, from the lowest cost to the highest cost: • DECram device • Directly connected device in the same physical location • Directly connected device in a remote location • DECram served device • Default value for other served devices The value supplied by the **/READ_COST** qualifier overrides the default assignment. The shadowing driver adds the value of the current queue depth of the shadow set member to the READ_COST value and then reads from the member with the lowest value. Different systems in the cluster can assign different costs to each shadow set member. When you specify a shadow set (DSAn) instead of a shadow set member, the read cost setting for all shadow set members reverts to the default read cost settings established automatically by the shadowing software. The specified shadow set must be mounted on the system where the command is issued. You an specify any value for the cost; the value is ignored, and the setting reverts to the default settings. After you have applied this qualifier to a member, the setting remains in effect as long as the member is part of the shadow set. If the member is removed from the shadow set and later returned, this qualifier must be specified again. If the **/SITE** command qualifier has been specified, the shadowing driver takes site values into account when it assigns default READ_COST values. In order for the shadowing software to determine whether a device is in the category of "directly connected device in a remote location," the **/SITE** command qualifier must have been applied to both the shadow set and the shadow set member. Reads requested for a shadow set from a system at site 1 are performed from a shadow set member that is also at site 1. Reads requested for the same

Qualifier	Function
	shadow set from site 2 can read from the member located at site 2. **Note** DECram can shadow a DECram disk to a physical disk. However, be aware that in the current implementation of Volume Shadowing for OpenVMS, if the physical disk goes away, you are writing to a volatile disk.
/RESET_COUNTERS	Resets the shadowing-specific counters that are maintained for each shadow set. Counters that are reset to zero (0) are: ● HBMM Reset Count ● Copy Hotblocks ● Copy Collisions ● SCP Merge Repair Count ● APP Merge Repair Count You can display the current settings of the counters using the **SHOW SHADOW** command. The HBMM Reset Count refers to the number of times the RESET_THRESHOLD value is met. The RESET_THRESHOLD is the setting that determines how frequently a bitmap is cleared. Using the HBMM Reset counter, you can gauge the rate of threshold resets.
/RECOVERY_OPTIONS= DELAY_PER_SERVED_MEMBER=*n*	Allows the system manager to adjust the rating assigned to a system based on a delay assessed for each MSCP served shadow set member on that system. The value specified by this qualifier overrides the value established by the SHADOW_PSM_RDLY system parameter. The default delay for each MSCP served member is 30 seconds and the valid range for the specified delay is 0 through 65,535 seconds. When a copy or merge operation is needed on a shadow set that is mounted on multiple systems, OpenVMS Volume Shadowing attempts to perform this work on a system that has a local connection to all of the shadow set members. Systems are rated with a penalty (delay time) assessed for each shadow set member that is MSCP served to the system. No delay is added for local members, so a system with all locally accessible shadow set members is likely to perform the work before a system

Qualifier	Function
	where one or more members is served. If **/ALL** is also specified, the specified delay is applied to all currently mounted shadow sets.
/SITE = *n* {*ddcu*:| DSA*n*:}	Indicates to the shadowing driver the site location of the specified shadow set (DSAn:) or shadow set member (ddcu:). The SHADOW_SITE_ID system parameter defines the default site location of the shadow set. You can override the default location of the shadow set with this qualifier. The valid range for the site location, represented by n, is 1 through 255. If **/ALL** is specified, all shadow sets are assigned the new value. The shadow set's member site values remain unchanged. After you apply this qualifier, the setting remains in effect until you change it using a **SET SHADOW/SITE** command. This qualifier can improve read performance because the member that is physically local to the system is the preferred disk from which to read, provided that you specify the **/SITE** qualifier for each shadow set member and for the shadow set. (In a Fibre Channel configuration, shadow set members at different sites are directly attached to the system. For the Volume Shadowing and OpenVMS Cluster software, there is no distinction between local and remote in multiple-site Fibre Channel configurations.)

/STALL=WRITES[=*nnn*]	Pauses the write operations for nnn seconds. The default time is SHADOW_MBR_TMO. If a value is not specified for nnn, the lock on write operations is released after SHADOW_MBR_TMO seconds. For example:
	
	`SET SHADOW DSA42 /STALL=WRITES`
	
	In this example, the writes are stalled to the shadow set for a period of SHADOW_MBR_TMO seconds.
	
	`SET SHADOW DSA42 /STALL=WRITES=60`
	
	In this example, the writes are stalled to the shadow set for a period of 60 seconds.

/NOSTALL=WRITES[=*nnn*]	Releases the lock on write operations after the specified period (nnn seconds). After the specified

Qualifier	Function

	period is over, writes are allowed to the shadow set members. See the following example:
	
	`SET SHADOW DSA42 /STALL=WRITES=60`
	`SET SHADOW DSA42 /NOSTALL=WRITES=30`
	
	In this example, initially the write operations are locked for a period of 60 seconds. On providing the **/NOSTALL** qualifier, the writes are allowed to the shadow set after a period of 30 seconds.

4.8.1. Using /DEMAND_MERGE to Start a Merge Operation

The **/DEMAND_MERGE** qualifier was created to force a merge operation on shadow sets that were created with the **INITIALIZE/SHADOW** command without specifying the **/ERASE** qualifier. The **/DEMAND_MERGE** qualifier ensures that all blocks not in use by active files are the same. The system manager can enter this command at a convenient time. If the **/ERASE** qualifier was not used when the shadow set was created with **/INITIALIZE/SHADOW**, and the **SET SHADOW/DEMAND_MERGE** command has not been executed, then the higher overhead of a full merge operation on this shadow set is encountered after a system failure.

System managers can also use the **SET SHADOW/DEMAND_ MERGE** command if the **ANALYZE/DISK/SHADOW** command found differences between the members of the shadow set (see *Section 4.11.4, "Using ANALYZE/DISK/SHADOW to Examine a Shadow Set"*).

4.8.2. SHOW SHADOW Management Functions

The **SHOW SHADOW** command reports on the status of the specified shadow set and indicates whether a merge or copy operation is required, depending on the qualifier that you specify. If a merge or copy operation is required, this command reports whether it is pending or in progress. The qualifiers are described in this section. To use this command, specify the shadow set's virtual unit name, followed by the qualifiers you want to use, as shown in the following example:

```
$ SHOW SHADOW DSAnnnn:/qualifier/qualifier/
```

/ACTIVE

This qualifier returns one of three possible states:

- Merge or copy is not required
- Copy is in progress on node nnnnx at LBN xxxx
- Merge is in progress on node nnnnx

/COPY

This qualifier returns one of three possible states:

- Copy is not required
- Copy is pending

- Copy is in progress on node nnnnx at LBN xxxx

/MERGE

This qualifier returns one of three possible states:

- Merge is not required
- Merge is pending
- Merge is in progress on node nnnnx at LBN xxxx

/OUTPUT=file-name

This qualifier outputs any messages to the specified file.

Example 4.8, "SHOW SHADOW Sample Output" shows sample output from the **SHOW SHADOW** command:

Example 4.8. SHOW SHADOW Sample Output

```
$SHOW SHADOW DSA716:
_DSA716: TST716
  Virtual Unit SCB Status: 0001 - normal
  Local Virtual Unit Status: 00000010 - Local Read

  Total Devices          2    VU_UCB          810419C0
  Source Members         2    SCB LBN         000009C8
  Act Copy Target        0    Generation      00A15F90
  Act Merge Target       0    Number          EDA9D786
  Last Read Index        0    VU Site Value          5
  Master Mbr Index       0    VU Timeout Value    3600
  Copy Hotblocks         0    Copy Collisions        0
  SCP Merge Repair Cnt   0    APP Merge Repair Cnt   0


  Device  $252$DUA716            Master Member
  Index   0   Status   000000A0   src,valid
  Ext.   Member Status       00
  Read Cost                  42   Site  5
  Member Timeout             120  UCB   8116FF80

  Device $252$DUA1010
  Index   1   Status   000000A0   src,valid
  Ext. Member Status         00
  Read Cost                 500   Site  3
  Member Timeout            120   UCB   811DD500
```

4.9. Prioritizing Merge and Copy Operations

The **SET SHADOW** command provides control to system administrators for managing merge and copy operations with the qualifiers **/PRIORITY=*n*** and **/EVALUATE=RESOURCES**, and a system parameter SHADOW_REC_DLY. Using these parameters, system managers can:

- Prioritize shadow sets for merge and copy operations on a per-system basis.
- Control which system performs a merge or copy operation of a particular shadow set.

- Modify the SHADOW_MAX_COPY system parameter, which take effect immediately.

4.9.1. Default Management of Merge and Copy Operations

If a system fails or if it aborts a shadow set, most commonly through mount verification, it is termed as a significant event. When one of these significant events occurs, all systems in the cluster are notified automatically. This notification causes all shadow server processes to stop any full merge or full copy operations and release all the resources performing these operations. Thus, every system can reallocate its resources to newer, higher-priority work.

After a predetermined delay, each system with a non-zero SHADOW_MAX_COPY setting begins to process the shadow sets that are in a transient state, according to their priority. The predetermined delay is governed by the new system parameter SHADOW_REC_DLY. (For more information about SHADOW_REC_DLY, see *Table 3.1, "Volume Shadowing Parameters"* and *Section 4.9.5, "Controlling Which Systems Manage Merge and Copy Operations"*.) Every system allocates the available SHADOW_MAX_COPY resources based on a shadow set's priority.

A shadow set is in a steady state when it is known that all members contain identical data. If a shadow set has one or more of the following operations pending, or one operation active, it is said to be in a transient state:

- Minimerge
- Minicopy
- Full copy
- Full merge

While a combination of these transient states is valid, only one operation at a time can be performed. For example, consider that HBMM is not enabled. After a device is added to a shadow set, it is marked as being in a full copy transient state. If the system on which this shadow set is mounted fails, the shadow set is further marked as being in a full merge state. In this example, the full copy operation is performed before the full merge is started.

Note

The priority assigned to a shadow set does not affect the hierarchy of transient state operations.

4.9.2. Hierarchy of Transient State Operations

Shadow set operations for a specific shadow set are performed in the following order:

1. Minimerge
2. Copy (either minicopy or full copy)
3. Full merge

4.9.3. Assigning Priorities to Shadow Sets

When first mounted on a system, every shadow set is assigned a default priority of 5000. You can assign a unique priority to every mounted shadow set on a per-system basis using the

SET SHADOW/PRIORITY=*n* DSA*n* command. Every shadow set can have a unique priority per system, or shadow sets can be assigned the same priority. Shadow sets with the same priority are managed in a consistent way for each release. However, the order in which shadow sets with the same priority are managed may change from release to release because of changes to the algorithm. Therefore, if the order is important, assign them different priorities.

The valid range for priority values is 0 through 10,000. The higher the assigned value, the higher the priority. To ensure that high-priority volumes are merged (or copied) before less important volumes, use **SET SHADOW/PRIORITY=*n* DSA*n*** command to override the default priority assignment on a system.

A priority level of 0 has a unique meaning. It means that the shadow set is not considered for merge or copy operations on this system.

Note

After the notification of a significant event and the allocation of a system's resources, it is not possible to directly affect any of the current merge or copy operations on the system by assigning a different priority level to one or more shadow sets. If you have to re-prioritize one or more shadow sets, you must use another technique, as described in *Section 4.9.8, "Managing Transient States in Progress"*.

4.9.4. Displaying Shadow Set Priority Values

You can display the priority of a shadow set on a specific system by issuing the following command:

```
$ SHOW SHADOW/BY_PRIORITY DSAn:
```

This command displays the current priority and status of the specified shadow set. If any copy or merge operations are in progress, the node on which the operation is progressing is displayed, along with its progress. For example:

```
$ SHOW SHADOW DSA1104/BY_PRIORITY
Device     Mbr                                          Active
 Name      Cnt   Priority   Virtual   Unit   State   on Node
_DSA1104:   2      5000     Merge    Active  (29%)     MAX
```

You can use the **SHOW SHADOW/BY_PRIORITY** command to display the priority level and the status for all of the shadow sets that exist on the system. The status indicates whether the shadow set is currently undergoing a copy or merge operation or whether one is required. If either or both operations are underway, the systems on which they occur are identified in the display, as shown in the following example:

```
$ SHOW SHADOW/BY_PRIORITY

Device     Mbr                                                    Active
 Name      Cnt   Priority   Virtual   Unit   State                on Node
_DSA106:    2      10000    Steady    State
_DSA108:    3       8000    Steady    State
_DSA110:    3       8000    Steady    State
_DSA112:    3       8000    Steady    State
_DSA114:    1       7000    Steady    State
_DSA116:    1       7000    Steady    State
_DSA150:    2       7000    Steady    State
_DSA152:            7000    Not Mounted on this node
_DSA154:    3       6000    Steady    State
_DSA156:    1       6000    Steady    State
```

```
_DSA159:    2       5000    Steady    State
_DSA74:     3       5000    Merge    Active (47%)                    CASSID
_DSA304:   2+1      5000    Merge    Active (30%), Copy Active (3%) MAX
_DSA1104:   2       5000    Merge    Active (29%)                    MAX
_DSA300:   2+1      5000    Merge    Active (59%), Copy Active (0%) MAX
_DSA0:     1+2      5000    Copy     Active (83%)                    CASSID
_DSA3:      2       3000    Steady    State
_DSA100:    2       3000    Steady    State
_DSA102:    1       3000    Steady    State
_DSA104:    3       3000    Steady    State
Total of 19 Operational shadow sets; 0 in Mount Verification; 1 not mounted
$
```

In this example, the 20 shadow sets on this system are displayed in their priority order. In the event of a failure of another system in the cluster that has these shadow sets mounted, the shadow sets are merged in this order on the system.

The `Mbr Cnt` field shows the number of source members in each shadow set. If members are being added via a copy operation, this is indicated by `+1` or `+2`. Therefore, `2+1` indicates two source members and one member being added. The notation `1+2` indicates one source member and two members being copied into the set.

The summary line provides the total number of shadow sets that were found to be in the various conditions. `Operational shadow sets` are shadow sets that are mounted with one or more members and may or may not have copy or merge operations occurring. These shadow sets are available to applications for reads and writes. `Mount Verification` indicates the number of shadow sets that are in some mount verification state. Shadow sets that have exceeded their mount verification timeout times are also included in this total.

For additional examples, see the **`SHOW SHADOW`** examples in the *VSI OpenVMS DCL Dictionary: N–Z*.

4.9.5. Controlling Which Systems Manage Merge and Copy Operations

When a system fails or aborts a shadow set, this significant event causes every shadow set to be reassessed by all other systems with that shadow set mounted. All active minimerge, full merge, or copy operations cease at this time, returning their resources to those systems. (However, if a system is performing a minicopy operation, that operation continues to completion.)

These systems wait a predetermined amount of time, measured in seconds, before each attempts to manage any shadow set in a transient state. This pause is called a significant-event recovery delay. It is the total of the values specified for two system parameters, SHADOW_REC_DLY and RECNXINTERVAL. (The default value for each is 20 seconds.)

If the value of the significant-event recovery delay is the same on all systems, it is not possible to predict which systems manage which shadow set. However, by making the value of the significant-event recovery delay different on all systems, you can predict when a specific system begins to manage transient-state operations.

4.9.6. Managing Merge Operations

A merge transient state is an event that cannot be predicted. The management of merge activity, on a specific system for multiple shadow sets, can be predicted if the priority level settings for the shadow sets differ.

The following example illustrates how the priority level is used to select shadow sets when only merge operations are involved. In this example:

- There are four shadow sets
- The SHADOW_MAX_COPY parameter on this system is equal to 1. (The value of 1 means that only one merge or copy operation can occur at the same time.)
- Two shadow sets are assigned a priority level and two have the default priority level of 5000.
- The four shadow sets DSA1, DSA20, DSA22, and DSA42 are mounted on two systems.
- DSA20 and DSA42 are minimerge enabled.

```
$ SET SHADOW/PRIORITY=7000 DSA1:
$ SET SHADOW/PRIORITY=3000 DSA42:
! DSA20: and DSA22: are at the default priority level of 5000
```

When one of the systems in this example fails, all shadow sets are put into a merge-required state. After the significant-event recovery delay time elapses, this system evaluates the shadow sets, and the operations are performed in the following order:

1. A minimerge operation starts first on DSA20, even though its priority of 5000 is lower than DSA1's priority of 7000. A minimerge operation always takes precedence over other operations. DSA20 and DSA42 are both minimerge enabled, but DSA20's higher priority causes its minimerge operation to start first.
2. A minimerge operation starts on DSA42. Its priority of 3000 is the lowest of all the shadow sets, but a minimerge operation takes precedence over other operations.
3. Because there are no other minimerge capable units, DSA1, with a priority level of 7000, is selected to start a merge operation, and it runs to completion.
4. A merge operation starts on DSA22, the one remaining shadow set whose priority is the default value of 5000, and runs to completion.

4.9.7. Managing Copy Operations

A copy transient state can be predicted by the user because it is the result of direct user action. Therefore, a full copy operation caused by adding a device to a shadow set is not considered a significant event in the cluster. The copy operation is managed by the first system that has an available resource.

In the following example, assume that there are four shadow sets, and the SHADOW_MAX COPY parameter on this system is equal to 1. Note that the for shadow sets that are not assigned a specific level, a default priority level is assigned.

For the following example, assume that:

- DSA1, DSA20, DSA22, and DSA42 are mounted on multiple systems.
- Only DSA42 is minimerge enabled.
- DSA22 is already in a full copy state being managed on this system.
- DSA1 has a priority level of 7000.
- DSA42 has a priority level of 3000.
- DSA20 has a priority level of 3000.

- DSA22 has a default priority level of 5000.

The user adds a device to DSA1. This is not a significant event, and this system does not interrupt the full copy operation of the DSA22 in favor of performing the DSA1 full copy operation.

To expand on this example, assume that a system fails (a significant event) before the copy operations have completed. All shadow sets are put into a merge required state. Specifically, DSA1, DSA20, and DSA22 are put into a full merge state, and DSA42 is put into a minimerge state.

After the significant event recovery delay expires, this system begins to evaluate all the shadow sets in a transient state. The operations take place in the following order:

1. A minimerge operation starts on DSA42 and continues until completion. This operation takes priority over other operations, regardless of its priority level.
2. A copy operation starts on DSA1. The full merge operation is not started because a copy operation takes precedence over a full merge operation.
3. A merge operation is started and completed on DSA1.
4. A copy operation is started and completed on DSA22.
5. A merge operation is started and completed on DSA22.
6. A merge operation is started and completed on DSA20.

Thus, in this example, the priority level is used to direct the priority of merge and copy operations on this system.

4.9.8. Managing Transient States in Progress

SHADOW_MAX_COPY is a dynamic system parameter that governs the use of system resources by shadowing. Shadowing can be directed to immediately respond to changes in this parameter setting using the following DCL command:

```
$ SET SHADOW/EVALUATE=RESOURCES
```

This command stops all the current merge and copy operations on the system on which it is issued. It then restarts the work using the new value of SHADOW_MAX_COPY.

This command is also useful in other circumstances. For example, if a shadow set has a priority level 0 or another low value, the **SET SHADOW /PRIORITY=*n*** command can be used to increase the value. Then, using the **/EVALUATE=RESOURCES** qualifier, the priority of shadow sets in a transient state is reevaluated.

The **/PRIORITY** and **/EVALUATE=RESOURCES** qualifiers can be used on the same command line.

When a significant event occurs, all of the SHADOW_MAX_COPY resources are applied. If the value of SHADOW_MAX_COPY is modified using the **SYSGEN SET** and **WRITE ACTIVE** commands, and then a **SET SHADOW/EVALUATE=RESOURCES** is issued, the new value of SHADOW_MAX_COPY has a direct and immediate effect.

To determine which system is controlling a transient operation, enter the following command:

```
$ SHOW SHADOW/ACTIVE DSAn:
```

To determine the priority values assigned to each shadow set, enter the following command:

```
$ SHOW SHADOW/BY_PRIORITY DSAn:
```

4.10. Removing Members and Dissolving Shadow Sets

You can remove shadow set members and dissolve shadow sets with the DCL command **DISMOUNT**. You must have GRPNAM and SYSNAM user privileges to dismount group and system volumes. You must also have the LOG_IO user privilege to use the **/POLICY=[NO]MINICOPY [=OPTIONAL]** qualifier.

The **DISMOUNT** command has the following format:

```
DISMOUNT {device-name[:] virtual-unit-name}
```

The action taken differs depending on whether you specify an individual shadow set member or the shadow set (by its virtual unit name) on the **DISMOUNT** command:

- If you specify the device name of a shadow set member, only that member is dismounted, and the remaining shadow set members continue servicing I/O requests.
- If you specify a shadow set virtual unit, all shadow set members are dismounted and the shadow set is dissolved.

To dismount a shadow set that is mounted across an OpenVMS Cluster system, include the **/CLUSTER** qualifier with the **DISMOUNT** command. If you dismount a shadow set without including the **/CLUSTER** qualifier, only the node from which you issued the command dismounts the shadow set. The shadow set remains operational on the other OpenVMS Cluster nodes that have the shadow set mounted.

If the disks on your system are neither SCSI nor Fibre Channel disks, you can use the **/NOUNLOAD** qualifier on the **DISMOUNT** command to prevent the disk volume or volumes from spinning down. The devices remain in a ready state. If you specify the **/UNLOAD** qualifier when dismounting a virtual unit, the disk volumes are physically spun down after the shadow set is dissolved. See the *VSI OpenVMS DCL Dictionary: A–M* for more information about using the **DISMOUNT** command and its qualifiers.

4.10.1. Removing Members from Shadow Sets

To remove an individual member from a shadow set, specify the name of the physical device with the **DISMOUNT** command. For example:

```
$DISMOUNT $5$DUA7:
```

When you dismount an individual shadow set member, all outstanding I/O operations are completed and the member is removed from the set.

The **/FORCE_REMOVAL *ddcu*:** qualifier is available. If connectivity to a device has been lost and the shadow set is in mount verification, **/FORCE_REMOVAL *ddcu*:** can be used to immediately expel a named shadow set member (ddcu:) from the shadow set. If you omit this qualifier, the device is not dismounted until mount verification completes. Note that this qualifier cannot be used in conjunction with the **/POLICY=[NO]MINICOPY [=OPTIONAL]** qualifier.

The device specified must be a member of a shadow set that is mounted on the node where the command is issued.

The **/FORCE_REMOVAL** qualifier gives system managers greater control of shadow sets whose members are located at different sites in an OpenVMS Cluster configuration. **SET SHADOW** command

qualifiers are also available for specifying management attributes for shadow set members located at the same or different sites, as described in *Section 4.7, "Managing Shadow Sets With SET SHADOW "* and in *Section 4.8, "Managing Copy and Merge Operations"*.

Note

You cannot dismount a device if it is the only source member in a shadow set. All shadow sets must have at least one valid source member. If you try to dismount the only source member device, the **DISMOUNT** command fails and returns the message:

```
%DISM-F-SRCMEM, Only source member of shadow set cannot be dismounted
```

The only way to dismount the last source member of a shadow set is to dissolve the shadow set by specifying the virtual unit name on the **DISMOUNT** command.

4.10.2. Dissolving Shadow Sets

The way you dissolve a shadow set depends on whether it is mounted on a single system or on two or more systems in an OpenVMS Cluster system. In both cases, you use the **DISMOUNT** command. If the shadow set is mounted on a single system, you can dissolve the shadow set by specifying its virtual unit name with the **DISMOUNT** command. If the shadow set is mounted in a cluster, you must include the **/CLUSTER** qualifier to dissolve the DSA36 shadow set across the cluster. For example:

```
$ DISMOUNT /CLUSTER DSA36:
```

Dismounting the shadow set can be done only after all files are closed, thereby ensuring that the dismounted disks are fully consistent from a file system perspective. The dismount operation marks the shadow set members as being properly dismounted so that a rebuild is not required the next time the disks are mounted. However, if a merge operation was either pending or in progress, then the dismount operation marks the shadow set members as being improperly dismounted and requires a merge operation.

Note

If you dismount a virtual unit while a copy operation is in progress for the shadow set, the copy operation aborts and the shadow set is dissolved. You receive OPCOM messages similar to those in the following example:

```
$DISMOUNT DSA9999:

%%%%%%%%%%% OPCOM 24-MAR-1990 20:29:57.52 %%%%%%%%%%%
$7$DUA6: (WRKDSK) has been removed from shadow set.
%%%%%%%%%%% OPCOM 24-MAR-1990 20:29:57.68 %%%%%%%%%%%
$7$DUA56: (PLADSK) has been removed from shadow set.
%%%%%%%%%%% OPCOM 24-MAR-1990 20:29:57.88 %%%%%%%%%%%
Message from user SYSTEM on SYSTMX
```

4.10.3. Dismounting Shadow Sets in Site-Specific Shutdown Procedures

Site-specific shutdown command procedures can be created for each system in your cluster, as described in the OpenVMS System Manager's Manual. The default SHUTDOWN.COM procedure that ships

with the operating system performs a **DISMOUNT/ABORT/OVERRIDE=CHECKS** operation on all mounted volumes. If files are left open on any mounted shadow sets, a merge operation is required for these shadow sets when the system is rebooted.

To prevent such unnecessary merge operations, VSI recommends that you modify each site-specific SYSHUTDWN.COM command procedure to dismount the shadow sets without using the **DISMOUNT/ABORT/OVERRIDE=CHECKS** qualifiers. If open files are found, they should be closed.

4.10.4. Dismounting and Remounting With One Less Member for Backup

As discussed in *Section 4.10.2, "Dissolving Shadow Sets"*, the virtual unit can be dismounted on the system or across an OpenVMS Cluster system. To ensure that the virtual unit has been dismounted correctly, the following steps are recommended:

1. Issue the **MOUNT/NOWRITE** command, followed by the **SHOW DEVICE** command, for example:

   ```
   $ MOUNT/NOWRITE DSA42: /SHADOW=($4$DUA3,$4$DUA4,$4$DUA5) volume-label
   $ SHOW DEVICE DSA42:
   ```

2. Observe that the virtual unit is in a steady state; that is, all members are consistent and no copy or merge operation is in progress. If a copy or merge operation is in progress, you must wait for the operation to complete.

3. When the virtual unit is in a steady state, remove a member from the shadow set with the **DISMOUNT** command, as shown in the following example:

   ```
   $ DISMOUNT $4$DUA5
   ```

4. Dismount the virtual unit and then remount it with one less member, as shown by the following command:

   ```
   $ DISMOUNT DSA42:
   $ MOUNT/SYS DSA42: /SHADOW=($4$DUA3,$4$DUA4) volume-label
   ```

   The shadow set member that was removed can now be used for a backup operation of the virtual unit.

Note

If your application must run continuously (that is, you cannot dismount the virtual unit without disrupting your business), you can still remove a shadow set member that you plan to return later to the shadow set. Your application and recovery procedures must be designed to ensure data consistency, as described in *Section 7.11, "Guidelines for Using a Shadow Set Member for Backup"*.

4.11. Displaying Information About Shadow Sets

You can use the DCL command **SHOW DEVICE** or the F$GETDVI lexical function to get information about a shadow set virtual unit and the physical volumes that make up the members. You can also use the System Dump Analyzer (SDA) to get more information about shadow sets.

The following sections describe how to use these tools to examine volume shadowing virtual units and shadow set members. See also the *VSI OpenVMS DCL Dictionary: N–Z* for a full description of how to use the SHOW DEVICE command and the F$GETDVI lexical function. See the *VSI OpenVMS System Analysis Tools Manual* for more information about how to use SDA.

You can use any of the **SHOW DEVICE** qualifiers when you examine shadow sets (by specifying a shadow set's virtual unit name) or shadow set members.

Note

Because shadow sets are created and maintained individually on each node in the OpenVMS Cluster, the **SHOW DEVICE** display does not list shadow sets that have been created on only remote nodes.

4.11.1. Listing Shadow Sets

Use **SHOW DEVICE** in the following format to display information about shadow sets:

```
SHOW DEVICE [virtual-unit-name[:]]
```

The variable virtual-unit-name replaces device-name as the **SHOW DEVICE** command parameter for shadow sets. Use the virtual unit naming format DSAn:.

As with any **SHOW DEVICE** command, the colon is optional. Note also that you can specify a complete virtual unit name (or a portion of a virtual unit name) just as you can with device names. If you omit the virtual unit number, **SHOW DEVICE** lists all the shadow set virtual units that represent shadow set member disks of the type specified. If you truncate a device name (for example, if you specify D), **SHOW DEVICE** lists all the devices and all the virtual units that begin with the letters you entered (in this case, D).

When you specify the virtual unit number, **SHOW DEVICE** displays the names of the shadow set members it represents. If you use the **/FULL** qualifier, **SHOW DEVICE** displays full information about the shadow set and all the associated shadow set members.

Because individual shadow set members that are mounted for systemwide or clusterwide access are not allocated or mounted in the traditional sense, a **SHOW DEVICE** command with the **/ALLOCATED** or **/MOUNTED** qualifiers displays only virtual units.

4.11.2. Listing Shadow Set Members

Use the same format for the **SHOW DEVICE** command with shadow set members as you use with other physical devices. The command lists all shadow set members of the device name you specify.

Because shadow set members are not mounted in a traditional sense and they all have the same device characteristics, **SHOW DEVICE** displays most of the relevant data with the associated virtual unit. Listings of shadow set members include information about current membership status.

If a shadow set is undergoing a copy or a merge operation, the display resulting from the **SHOW DEVICE** command includes the percentage of the disk that has been copied or merged. The **SHOW DEVICE** information is available on all nodes that have the shadow set mounted.

The **SHOW DEVICE** display indicates the exact percentage of the disk that has been copied. The node that is managing the copy operation knows precisely how far the copy or merge operation

has progressed, and periodically notifies the other nodes in the OpenVMS Cluster of the progress. Thus, the other nodes in the cluster know approximately the percentage copied. When you enter the **SHOW DEVICE** command from a node other than the one where the copy or merge operation is taking place, the number indicating the percentage copied in the **SHOW DEVICE** output lags (by a small percentage) the actual percentage copied.

Note that if a copy and a merge operation are occurring at the same time in the same shadow set, the number indicating the percentage merged remains static until the copy completes. Then the merge operation proceeds to completion.

4.11.3. SHOW DEVICE Examples for Shadow Set Information

The following examples of output from the **SHOW DEVICE** command illustrate the types of shadow set information you can obtain, such as shadow set membership and the status of each shadow set member during copy and merge operations. For examples of output for write bitmaps used with the minicopy operation, see *Section 7.9, "Managing Bitmaps With DCL Commands"*.

Examples

```
$ SHOW DEVICE D
Device                Device         Error    Volume          Free  Trans Mnt
 Name                 Status         Count     Label         Blocks Count Cnt
DSA0:                 Mounted            0  SHADOWDISK         8694   151   1
DSA9999:              Mounted            0  APPARITION       292971     1   1
$4$DUA0:    (SYSTMX)  Online             0
$4$DUA8:    (HSJ001)  ShadowSetMember    0  (member of DSA0:)
$4$DUA10:   (SYSTMX)  ShadowSetMember    0  (member of DSA9999:)
$4$DUA11:   (SYSTMX)  ShadowSetMember    0  (member of DSA9999:)
$4$DUA12:   (SYSTMX)  ShadowSetMember    0  (member of DSA9999:)
$4$DUA89:   (HSJ002)  ShadowSetMember    0  (member of DSA0:)
```

By truncating the device name, you cause the **SHOW DEVICE** command to list all the devices and all the virtual units on the local node that begin with the letters you entered (in this case, D). This example shows that two virtual units, DSA0 and DSA9999, are active. Both shadow sets are in a steady state. The device status ShadowSetMember indicates that the shadow set is in a steady state—the shadow set members are consistent with each other.

```
$ SHOW DEVICE DSA8
Device                Device         Error    Volume          Free  Trans Mnt
 Name                 Status         Count     Label         Blocks Count Cnt
DSA8:                 Mounted            0  APPARITION       890937     1   1
$11$DUA8:   (SYSTMX)   ShadowSetMember    0  (member of DSA8:)
$11$DUA89:  (SYSTMY)   ShadowSetMember    0  (member of DSA8:)
```

This example shows the membership and status of the shadow set represented by the DSA8 virtual unit. The **SHOW DEVICE** display provides information not only about the virtual unit DSA8, but also about the physical devices 11DUA8 and 11DUA89 that are members of the shadow set. The device status ShadowSetMember indicates that the shadow set is in a steady state—the shadow set members are consistent with each other. The shadow set members are being served by OpenVMS Cluster nodes SYSTMX and SYSTMY.

```
$ SHOW DEVICE DSA
Device                Device         Error    Volume          Free  Trans Mnt
```

```
 Name                 Status        Count     Label         Blocks Count Cnt
DSA7:                 Mounted           0  PHANTOM          27060    35   7
DSA8:                 Mounted           0  APPARITION      890937     4   6
```

You might specify DSA on the **SHOW DEVICE** command to request information about all the shadow sets on the local node. Entering a generic virtual unit name, such as DSA, as a parameter produces a display of all virtual units representing shadow sets mounted on the local system. This example shows that two shadow sets are mounted on the local node, represented by the virtual units DSA7 and DSA8.

```
$ SHOW DEVICE $11$DUA8:
Device                Device        Error    Volume         Free  Trans Mnt
 Name                 Status        Count     Label        Blocks Count Cnt
DSA8:                 Mounted           0  APPARITION      890937     1   1
$11$DUA8:   (HSJ001) ShadowSetMember   0  (member of DSA8:)
$11$DUA89:  (HSJ002) ShadowSetMember   0  (member of DSA8:)
```

Although the **SHOW DEVICE** command specifies the name of a single device, the resulting display includes information about the membership and status of the shadow set represented by the DSA8 virtual unit to which the 11DUA8 device belongs. The device status ShadowSetMember indicates that the shadow set is in a steady state—the shadow set members are consistent with each other. The shadow set members are accessed through the node named HSJ001.

```
$ SHOW DEVICE $11$DUA8:
Device                Device        Error    Volume         Free  Trans Mnt
 Name                 Status        Count     Label        Blocks Count Cnt
DSA8:                 Mounted           0  APPARITION      890937     1   1
$11$DUA8:   (HSJ001)  ShadowSetMember   0  (member of DSA8:)

$11$DUA89: (HSJ002)  ShadowCopying     0  (copy trgt DSA8:  48% copied)
```

The output from this **SHOW DEVICE** command shows a shadow set that is in a transient state. The device status ShadowCopying indicates that the physical device 11DUA89 is the target of a copy operation, and 48% of the disk has been copied. The device 11DUA8 is the source member for the copy operation.

```
$ SHOW DEVICE DSA8
Device                Device        Error    Volume         Free  Trans Mnt
 Name                 Status        Count     Label        Blocks Count Cnt
DSA8:                 Mounted           0  APPARITION      890937     1  12

$11$DUA8:   (HSJ001)  ShadowCopying     0  (copy trgt DSA8: 5% copied)
$11$DUA89:  (HSJ002)  ShadowMergeMbr    0  (merging DSA8:   0% merged)
```

This example shows how the **SHOW DEVICE** command displays a shadow set during a copy operation after a node in an OpenVMS Cluster system fails. In this example, the shadow set members are located on different nodes in the cluster, and one node on which the shadow set is mounted fails. At the time of the failure, the shadow set was in a transient state, with the 11DUA8 device undergoing a copy operation. The **SHOW DEVICE** command shows the state of the shadow set during the copy operation, before the merge operation occurs.

At the same time the 11DUA89 shadow set member is acting as the source member for the copy operation, 11DUA89 also accepts and performs I/O requests from applications running on the OpenVMS Cluster system. Once the copy operation completes, a merge operation automatically starts. See Chapter 6 for more information about merge operations.

The next example shows how the **SHOW DEVICE** command display looks during the merge operation.

```
$ SHOW DEVICE DSA8
Device                Device         Error    Volume         Free  Trans Mnt
 Name                 Status         Count     Label        Blocks Count Cnt
DSA8:                 Mounted            0  APPARITION      890937     1   1

$11$DUA8:    (HSJ001) ShadowMergeMbr     0  (merging DSA8: 78% merged)
$11$DUA89:   (HSJ002) ShadowMergeMbr     0  (merging DSA8: 78% merged)
```

The **SHOW DEVICE** command produces a display similar to this example when a shadow set is in a transient state because of a merge operation. The merge operation is 78% complete.

```
$ SHOW DEV D
Device                Device         Error    Volume         Free  Trans Mnt
 Name                 Status         Count     Label        Blocks Count Cnt
DSA456:       (FUSS)  Mounted            0  AUDITINGDISK    123189   225  17
$11$DIA1:   (LISBEN)  Online             0
$11$DJA16:  (GALEXI)  Online             0
$11$DJA128:(GALEXI)   Mounted wrtlck     0  CORPORATEVOL    164367     1  18
$11$DJA134:(GALEXI)   Mounted            0  WORKVOLUME      250344     1  16
$11$DUA1:     (FUSS)  Mounted            0  MAR24DISKVOL    676890     1  18
$11$DUA2:     (FUSS)  ShadowSetMember    0  (member of DSA456:)
$11$DUA7:    (BLISS)  Online             0  (remote shadow member)
$11$DUA11:  (LISBEN)  Mounted            0  RMSFILES        621183     1  18
$11$DUA13:   (BLISS)  Mounted            0  RESIDENTVOL     525375     1  18
```

This example shows how the **SHOW DEVICE** command displays remote shadow set members. In this display, the device 11DUA7, whose description is `remote shadow member`, is a member of a shadow set that is not mounted on this system.

```
$ SHOW DEVICE/FULL DSA80
Disk DSA80:, device type MSCP served SCSI disk, is online, mounted, file-
oriented device, shareable, available to cluster, error logging is enabled.

Error count                    0    Operations completed              138
Owner process                 ""    Owner UIC                      [SHADOW]
Owner process ID        00000000    Dev Prot    S:RWED,O:RWED,G:RWED,W:RWED
Reference count                1    Default buffer size               512
Total blocks              891072    Sectors per track                  51
Total cylinders             1248    Tracks per cylinder                14
Volume label          "SHADTEST1"   Relative volume number              0
Cluster size                   3    Transaction count                   1
Free blocks               890937    Maximum files allowed          111384
Extend quantity                5    Mount count                         4
Mount status              System    Cache name         "_DSA2010:XQPCACHE"
Extent cache size             64    Maximum blocks in extent cache   89093
File ID cache size            64    Blocks currently in extent cache     0
Quota cache size               0    Maximum buffers in FCP cache       216
Volume status:  subject to mount verification, file high-water
 marking,write-
  through caching enabled.
Volume is also mounted on BLASTA, CNASTA, SHASTA.
Disk $255$DUA56:, device type MSCP served SCSI disk, is online, member of
shadow set DSA80:, error logging is enabled.
Error count                    0    Shadow member operation count      301
Host name                "SHASTA"   Host type, avail                   yes
Allocation class             255
  Volume status:  volume is a merge member of the shadow set.
Disk $255$DUA58:, device type MSCP served SCSI disk, is online, member of
```

```
shadow set DSA80:, error logging is enabled.
Error count                    0    Shadow member operation count      107
Host name               "SHASTA"    Host type, avail                   yes
Allocation class             255
Volume status:  volume is a merge member of the shadow set.
```

This example shows how the **SHOW DEVICE/FULL** command displays detailed information about the shadow set and its members. Notice that both members, 255DUA56 and 255DUA58, are merge members. *Section 4.11.5, "Displaying Shadow Set Information With SDA"* shows what this shadow set looks like when it is examined using the System Dump Analyzer.

4.11.4. Using ANALYZE/DISK/SHADOW to Examine a Shadow Set

The **/SHADOW** qualifier for the ANALYZE/DISK utility can be used to compare either a specified range of blocks in a shadow set or the entire contents of a shadow set. The **ANALYZE/DISK/SHADOW** command is useful if the **INITIALIZE/SHADOW** command was used without the **/ERASE** qualifier to initialize a shadow set. Another use of **ANALYZE/DISK/SHADOW** is to exercise the I/O subsystem.

In the unlikely event a discrepancy is found, the shadowset's clusterwide write lock is taken on the shadow set, and the blocks are reread. If a discrepancy is still present, the file name is displayed and the data block containing the discrepancy is dumped to the screen or to a file if **/OUTPUT** was specified. If no discrepancy is found on the second read, then the error is considered transient (a write was in flight to that disk block). Although the transient error is logged in the summary, verification that all members contained the same information is considered a success.

Differences outside the file system are expected if **INITIALIZE/SHADOW** was used without the **/ERASE** qualifier to initialize a shadow set. This is not disk corruption. The blocks that are reported as different have not been written to, but they may contain stale data. The blocks reported as inconsistent may even be allocated to a file, because there may be unwritten space between the file's end-of-data location and the end of the allocated space.

To eliminate such inconsistencies, perform a full merge. To initiate a full merge, execute the DCL command **SET SHADOW/DEMAND_MERGE DSAxxx**. If the devices are served by controllers that support controller-based minimerge (for example, HSJ50s), this command should be issued while the shadow set is mounted on only one node within the cluster. Otherwise, a minimerge occurs, and the discrepancy may not be resolved. When you are adding members to a single member shadow set, a full copy operation also ensures that the disk is consistent both within and outside of the file system. If errors are reported on an **ANALYZE/DISK/SHADOW** command after a full merge has been executed, they should be investigated.

Differences are also expected in the following system files:

- SWAPFILE*.*
- PAGEFILE*.*
- SYSDUMP.DMP
- SYS$ERRLOG.DMP

Table 4.4, "ANALYZE/DISK/SHADOW Command Qualifiers" describes the qualifiers for the **ANALYZE/DISK/SHADOW** command.

Table 4.4. ANALYZE/DISK/SHADOW Command Qualifiers

Command	Description
/BLOCKS={(START:*n*,COUNT:*x*, END:*y*), FILE_SYSTEM, ALL}	Compare only the range specified. The options are: • START: n = Number of the first block to be analyzed; the default is the first block. • COUNT:x = Number of blocks to be analyzed. This option is an alternative to the END option; you can specify both. • END:y = Number of the last block to be analyzed; the default is the last block of the volume. • FILE_SYSTEM = Blocks currently in use by valid files on the disk. This is the default. • ALL = All blocks on the disk. You can specify START/END/COUNT and either ALL or FILE_SYSTEM. For example, if you specify **/BLOCKS=(START, END, COUNT:100, ALL)**, the software checks the first 100 blocks on the disk, regardless of whether they are in use by the file system. If you specify **/BLOCKS=(START, END, COUNT:100, FILE_SYSTEM)**, the software checks only those blocks in the first 100 blocks that are in use by valid files on the disk.
/BRIEF	Displays only the logical block number (LBN) if a difference is found. Without this qualifier, if differences exist for an LBN, the hexadecimal data of that block is displayed for each member.
/[NO]IGNORE	Ignore "special" files, which are likely to have some blocks with different data. These differences are not unusual and can be ignored. These special files are SWAPFILE*.*, PAGEFILE*.*, SYSDUMP.DMP, and SYS$ERRLOG.
/OUTPUT=*file-name*	Outputs the information to the specified file.
/STATISTICS	Display only the header and footer. The best use of this is with **/OUTPUT**.

Example 4.9, "ANALYZE/DISK/SHADOW Sample Output" shows the use of the **ANALYZE/DISK/SHADOW** command with the **/BRIEF** and **/BLOCK** qualifiers.

Example 4.9. ANALYZE/DISK/SHADOW Sample Output

```
$ ANALYZE/DISK/SHADOW/BRIEF/BLOCK=COUNT=1000 DSA716:
Starting to check _DSA716: at 14-MAY-2003 13:42:52.43
Members of shadow set _DSA716: are _$252$MDA0: _$252$DUA716:
```

```
and the number of blocks to be compared is 1000.
Checking LBN #0 (approx 0%)
Checking LBN #127 (approx 12%)
Checking LBN #254 (approx 25%)
Checking LBN #381 (approx 38%)
Checking LBN #508 (approx 50%)
Checking LBN #635 (approx 63%)
Checking LBN #762 (approx 76%)
Checking LBN #889 (approx 88%)
Run statistics for _DSA716: are as follows:
         Finish Time = 14-MAY-2003 13:42:52.73
         ELAPSED TIME = 0 00:00:00.29
         CPU TIME = 0:00:00.02
         BUFFERED I/O COUNT = 10
         DIRECT I/O COUNT = 16
         Failed LBNs = 0
         Transient LBN compare errors = 0
```

4.11.4.1. ANALYZE/DISK/SHADOW Command Behavior With a Connectivity Problem

If a member of the shadow set experiences connectivity problems for any reason after you have issued the **ANALYZE/DISK/SHADOW** command, an error is displayed, and the DCL prompt is displayed. To correct the connectivity problem and run the utility again on the same shadow set, you might need to create a temporary file on the virtual unit before reissuing the **ANALYZE/DISK/SHADOW** command.

4.11.4.2. ANALYZE/DISK/SHADOW Command Behavior with Dissimilar Device Shadow Sets

An **ANALYZE/DISK/SHADOW** command may also report explainable discrepancies if a full merge has not occurred since the shadow set was logically expanded after a new member was added. The following example illustrates this problem:

- Shadow set DSA1: consists of two members, 1DGA20: (18 GB) and $1DGA21 (36 GB).
- A second 36 GB member, 1DGA22:, is added to the shadow set with a full copy operation.
- After the copy completes, 1DGA20: is removed from the shadow set.

At this point, if the **SET VOLUME/SIZE DSA1:** command is executed, the shadow set virtual unit DSA1: increases to 36 GB. Then, **ANALYZE/DISK/SHADOW** reports discrepancies because only the first 18 GB of the shadow set contents were copied to 1DGA22:. The discrepancies reported by **ANALYZE/DISK/SHADOW** are harmless because the space in question has not yet been written to by applications.

4.11.5. Displaying Shadow Set Information With SDA

The System Dump Analyzer (SDA) is a utility provided with the OpenVMS operating system. Although the main function of SDA is for crash dump analysis, it is also a useful tool for examining a running system, including the shadow sets. You can also use SDA to determine whether or not a third-party SCSI device supports the shadowing data repair (disk bad block errors) capability.An example is included in *Section 4.11.5.1, "Using SDA to Obtain Information About Third-Party SCSI Devices"*.

The SDA command **SHOW DEVICE** displays information from the system data structures that describe the devices in the system configuration. To examine a shadow set, first enter **ANALYZE/SYSTEM**

at the DCL prompt to invoke the System Dump Analyzer. Then, at the SDA> prompt, enter the **SHOW DEVICE** command followed by the virtual unit name.

The following example shows how to obtain information about the shadow set represented by the virtual unit DSA80. Compare the SDA output in the following example with the **DCL SHOW DEVICE** output shown in the last example in *Section 4.11.3, "SHOW DEVICE Examples for Shadow Set Information"*.

```
$ ANALYZE/SYSTEM
VMS System analyzer
SDA> SHOW DEVICE DSA80
I/O data structures
-------------------
DSA80                                   HSJ00              UCB address:
 810B7F50
Device status:   00021810 online,valid,unload,lcl_valid
Characteristics: 1C4D4008 dir,fod,shr,avl,mnt,elg,idv,odv,rnd
                 00082021 clu,mscp,loc,vrt
Owner UIC [004000,000015]   Operation count        138   ORB address
 810B8080
      PID        00000000   Error count              0   DDB address
 813F49F0
Alloc. lock ID   009C2595   Reference count          1   DDT address
 810BEBB8
Alloc. class            0   Online count             1   VCB address
 810BE3F0
Class/Type          01/15   BOFF                  0000   CRB address
 8129EB10
Def. buf. size        512   Byte count            0200   PDT address
 810121A0
DEVDEPEND        04E00E33   SVAPTE            81FDE55C   CDDB address
 813F4360
DEVDEPND2        00000000   DEVSTS                0004   SHAD address
 8111D460
FLCK index             34   RWAITCNT              0000   I/O wait queue
 empty
DLCK address     00000000
Shadow Device status:   0004 nocnvrt
  ----- Shadow Descriptor Block (SHAD) 8111D460 -----
Virtual Unit status:              0041 normal,merging
Members                2    Act user IRPs          0    VU UCB
 810B7F50
Devices                2    SCB LBN         0006CC63    Write log addr
 00000000
Fcpy Targets           0    Generation Num  28D47C20    Master FL
 empty
Mcpy Targets           2                    00935BC7    Restart FL
 empty
Last Read Index        1    Virtual Unit Id 00000000
Master Index           0                    12610050
     ----- SHAD Device summary for Virtual Unit  DSA80  -----
Device $255$DUA56
 Index 0 Device Status    A6 merge,cip,src,valid
 UCB 810510D0     VCB 81400A00      Unit Id. 12A10038 000000FF
 Merge LBN 0004B94D
Device $255$DUA58
 Index 1 Device Status    A6 merge,cip,src,valid
 UCB 81051260     VCB 81439800      Unit Id. 12A1003A 000000FF
 Merge LBN 0004B94D
```

```
SDA> exit
```

The SDA utility's **SHOW DEVICE** command first displays device characteristics of the DSA80 virtual unit and the addresses of data structures. SDA then displays the DSA80 virtual unit status and the status of the individual shadow set members. Notice how the device status for each member reflects that the unit is in a merge state. For example, 255DUA56 is shown with the following device status:

```
Device $255$DUA56
 Index 0 Device Status    A6 merge (1), cip (2), src (3), valid (4)
 UCB 810510D0     VCB 81400A00      Unit Id. 12A10038 000000FF
 Merge LBN 0004B94D
```

This information translates to the following:

- merge — 255DUA56 is marked for a merge operation.
- cip — Copy in progress. In this example, a merge operation is in progress.
- src — 255DUA56 is considered a source member for the read operations.
- valid — The SCB information on 255DUA56 is considered valid.

Notice also how both devices 255DUA56 and 255DUA58 show that, at the time the SDA took this “snapshot” of the shadow set, the merge operation is merging at LBN 0004B94D.

The following example shows an SDA display of the same shadow set when 255DUA56 is a merge member and 255DUA58 is the recipient of a copy operation. A shadow set can be in this merge/copy state when a node that has the shadow set mounted crashes while a member in the shadow set is undergoing a copy operation. Volume shadowing automatically marks the member undergoing the copy operation so that it receives a merge operation after the copy operation completes. This ensures consistency across the shadow set.

The example first shows output for one shadow set member, using the DCL command **SHOW DEVICE 255DUA58**; then the example shows the output for the entire shadow set, using the SDA command **SHOW DEVICE DSA80**. (SDA is invoked by the **ANALYZE/SYSTEM** command.)

```
$ SHOW DEVICE $255$DUA58
Device                  Device           Error    Volume         Free
 Trans Mnt
 Name                   Status           Count     Label        Blocks
 Count Cnt
DSA80:                  Mounted              0  SHADTEST1       890937
 1   3

$255$DUA56:   (SHASTA)  ShadowMergeMbr       0  (merging DSA80:   0%
 merged)
$255$DUA58:   (SHASTA)  ShadowCopying        0  (copy trgt DSA80: 9%
 copied )

$ ANALYZE/SYSTEM
VMS System analyzer
SDA> SHOW DEVICE DSA80
I/O data structures
-------------------
DSA80                                   RA81             UCB address:
 810B7F50
Device status:   00021810 online,valid,unload,lcl_valid
Characteristics: 1C4D4008 dir,fod,shr,avl,mnt,elg,idv,odv,rnd
```

```
                00082021 clu,mscp,loc,vrt
Owner UIC [004000,000015]   Operation count        130   ORB address
 810B8080
     PID        00000000   Error count              0   DDB address
 813F49F0
Alloc. lock ID   009C2595   Reference count          1   DDT address
 810BEBB8
Alloc. class            0   Online count            1   VCB address
 810BE3F0
Class/Type          01/15   BOFF                 0000   CRB address
 8129EB10
Def. buf. size        512   Byte count           0000   PDT address
 810121A0
DEVDEPEND        04E00E33   SVAPTE           00000000   CDDB address
 813F4360
DEVDEPND2        00000000   DEVSTS               0004   SHAD address
 8111D460
FLCK index             34   RWAITCNT             0000   I/O wait queue
 empty
DLCK address     00000000
Shadow Device status:   0004 nocnvrt
  ----- Shadow Descriptor Block (SHAD) 8111D460 -----
Virtual Unit status:             0061 normal,copying,merging
Members                1    Act user IRPs          0    VU UCB
 810B7F50
Devices                2    SCB LBN         0006CC63    Master FL
 empty
Fcpy Targets           1    Generation Num  7B7BE060    Restart FL
 empty
Mcpy Targets           0                    00935BC4
Last Read Index        0    Virtual Unit Id 00000000
Master Index           0                    12610050
     ----- SHAD Device summary for Virtual Unit  DSA80  -----
Device $255$DUA56
 Index 0 Device Status    A2 merge,src,valid
 UCB 810510D0     VCB 81400A00      Unit Id. 12A10038 000000FF
 Merge LBN FFFFFFFF
Device $255$DUA58
 Index 1 Device Status    87 fcpy,merge,cip,valid
 UCB 81051260     VCB 81439800      Unit Id. 12A1003A 000000FF
 Copy LBN 00033671
```

In this example, in the SHAD Device summary for Virtual Unit DSA80 display, the device status (`fcpy`) for `$255$DUA58` shows that it is the target of a full copy operation. The source of the operation is `$255$DUA56`; notice that the `Merge LBN` line for `$255$DUA56` shows a series of Fs (`FFFFFFFF`). This notation indicates that a merge operation must be done after the copy operation completes. The `Copy LBN` line for the target disk `$255$DUA58` shows that the copy operation is currently copying at `LBN 00033671`.

4.11.5.1. Using SDA to Obtain Information About Third-Party SCSI Devices

When you mount a SCSI disk, the SCSI disk class driver, DKDRIVER, checks the device-specific parameters to see whether the disk supports READL/WRITEL commands.

If a SCSI disk does not support READL and WRITEL commands, DKDRIVER sets a NOFE (no forced error) bit to indicate that the disk cannot support the shadowing data repair (disk bad block

errors) capability. You can use the SDA command **SHOW DEVICE** to check for the NOFE flag in the Characteristics field of the SDA display.

For SCSI devices that support READL and WRITEL operations, SDA displays a Characteristics field that does not contain the NOFE flag, similar to the following example:

Example 4.10. SDA Display of Third-Party SCSI Device

```
SDA> SHOW DEVICE DKA200:
I/O data structures
-------------------
COLOR$DKA200             Generic_DK        UCB address:  806EEAF0

Device status:   00021810 online,valid,unload,lcl_valid
Characteristics: 1C4D4008 dir,fod,shr,avl,mnt,elg,idv,odv,rnd
                 01010281 clu,srv,nnm,scsi
```

The Characteristics field does not show a NOFE bit set; therefore, device DKA200 can support shadowing data repair.

4.11.6. Obtaining Shadow Set Information With F$GETDVI

The F$GETDVI lexical function provides another method for obtaining information about devices mounted in shadow sets. Using F$GETDVI, you can obtain general device and volume information and specific information about the shadow set status of the device or volume. For example, you can determine the following types of information:

- Whether a device is a shadow set virtual unit or a shadow set member
- Whether a copy operation is in progress on a device
- What type of copy operation is in progress on a device
- The name of the virtual unit that represents the shadow set of which the particular device is a member
- The entire membership of a shadow set, including the virtual unit and all of the members

You can use the F$GETDVI lexical function interactively at the DCL command level or in a DCL command procedure. You can also use the $GETDVI system service with volume shadowing (see *Section 5.6, "Using* $GETDVI *to Obtain Information About Shadow Sets"*).

The format for the F$GETDVI lexical function is as follows:

```
F$GETDVI (device-name,item)
```

You supply two arguments to the F$GETDVI lexical function: a physical device name and the name of an item that specifies the type of information you want to obtain.

Note

If you use the file-system-related item codes with the $GETDVI system service to obtain meaningful system information (such as FREEBLOCK information) for a shadow set, you should specify the virtual

unit name with the $GETDVI service. If you specify the device name of one of the shadow set members, the $GETDVI service returns a value of 0.

*Table 4.5, "*F$GETDVI *Item Codes for Volume Shadowing"* lists the items specific to volume shadowing that you can supply as arguments to the F$GETDVI lexical function. It shows the type of information returned by each item and the data types of the return values. (The *VSI OpenVMS DCL Dictionary: A–M* lists all the item codes that you can supply as an argument to F$GETDVI.)

Table 4.5. F$GETDVI Item Codes for Volume Shadowing

Item	ReturnType	Information Returned
SHDW_CATCHUP_COPYING	String	Returns TRUE or FALSE to indicate whether the device is a member that is the target of a copy operation.
SHDW_MASTER	String	Returns TRUE or FALSE to indicate whether the device is a virtual unit.
SHDW_MASTER_NAME	String	Returns the name of the virtual unit that represents the shadow set of which the specified device is a member. F$GETDVI returns a null string if the specified device is not a member or is, itself, a virtual unit.
SHDW_MEMBER	String	Returns TRUE or FALSE to indicate whether the device is a shadow set member.
SHDW_MERGE_COPYING	String	Returns TRUE or FALSE to indicate whether the device is a member that is a merge member of the shadow set.
SHDW_NEXT_MBR_NAME	String	Returns the device name of the next member in the shadow set. If you specify a virtual unit, F$GETDVI returns the device name of a member of the shadow set. If you specify the name of a shadow set member with the device name and item arguments, F$GETDVI returns the name of the "next" member or a null string if there are no more members. To determine all the members of a shadow set, first specify the virtual unit to F$GETDVI; on subsequent calls, specify the member name returned by the previous F$GETDVI call until it has finished, when it returns a null member name.

Example

To check a device for possible shadow set membership, you could include the following DCL command in a command procedure:

```
$  IF F$GETDVI("WRKD$:","SHDW_MEMBER") THEN GOTO SHADOW_MEMBER
```

If WRKD$ (a logical name for a disk) is a shadow set member, then F$GETDVI returns the string TRUE and directs the procedure to the volume labeled SHADOW_MEMBER.

See the *VSI OpenVMS DCL Dictionary: A–M* for additional information about the F$GETDVI lexical function.

Chapter 5. Creating and Managing Shadow Sets with System Services

This chapter describes how to create, mount, dismount, and dissolve shadow sets using the $MOUNT and $DISMOU system services. It also describes how to use the $GETDVI system service to access current information about the state of shadow sets. For complete information about these OpenVMS system services, see the *VSI OpenVMS System Services Reference Manual: A–GETUAI*.

5.1. Using $MOUNT to Create and Mount Shadow Sets

You can create and mount shadow sets using the $MOUNT system service in a user-written program. Program calls to $MOUNT that create, mount, or add devices to shadow sets use the same syntax. To direct the system to perform any mount operation, you construct a $MOUNT item list. The item list specifies the virtual unit that represents the shadow set and the members (physical devices) that the shadow set contains.

The call to the $MOUNT system service has the following format:

```
SYS$MOUNT itmlst
```

Example 5.1, "Item List to Create and Mount a Shadow Set" illustrates MACRO-32 statements that produce a $MOUNT system service item list to create and mount a shadow set.

Example 5.1. Item List to Create and Mount a Shadow Set

```
DSA23:  .ASCID /DSA23:/
MEMBER001:   .ASCID /$4$DUA9:/
MEMBER002:   .ASCID /$4$DUA5:/

VOLUME_LABEL:  .ASCID /MYVOLUME/
VOLUME_LOGNM:  .ASCID /DISK$MYVOLUME/

        .MACRO   .ITEM, SIZE, CODE, BUFFER, RETURN=0
        .WORD    SIZE, CODE
        .ADDRESS BUFFER, RETURN
        .ENDM    .ITEM

ITMLST: .ITEM   6,  MNT$_SHANAM, DSA23  ❶
        .ITEM   8,  MNT$_SHAMEM, MEMBER001   ❷
        .ITEM   8,  MNT$_SHAMEM, MEMBER002

        .ITEM   8,  MNT$_VOLNAM, VOLUME_LABEL  ❸
        .ITEM   13, MNT$_LOGNAM, VOLUME_LOGNM  ❹
        .LONG   0
         .ITEM   8,  MNT$_SHAMEM, MEMBER001
         .ITEM   8,  MNT$_SHAMEM, MEMBER002
         .LONG   0
```

The following list describes the elements in *Example 5.1, "Item List to Create and Mount a Shadow Set"*:

❶ Notice that the virtual unit item descriptor occurs first. This item descriptor specifies DSA23 as the name of the virtual unit. See *Section 4.2, "Creating a Shadow Set"* for the proper naming syntax for the virtual unit and shadow set members.

❷ The virtual unit item descriptor is followed by two member-unit item descriptors. Because Volume Shadowing for OpenVMS automatically determines the type of operation (copy or merge) necessary before disks can join a shadow set, all of the devices are mounted with MNT $_SHAMEM item descriptors. These item descriptors specify that the physical devices, 4DUA9 and 4DUA5, are to join the shadow set represented by DSA23.

❸ The member item descriptors are followed by an item descriptor that specifies MYVOLUME as the volume label for the shadow set.

❹ The last item descriptor specifies DISK$MYVOLUME as the logical name for the shadow set.

Later, if you want to add another device to the shadow set, you make another call to $MOUNT that specifies an item list that contains the name of the virtual unit and the name of the device you want to add to the shadow set. *Example 5.2, "Item List to Add a Member to a Shadow Set"* shows how to add the physical device 4DUA10: to the shadow set created in *Example 5.1, "Item List to Create and Mount a Shadow Set"*.

Example 5.2. Item List to Add a Member to a Shadow Set

```
DSA23:  .ASCID /DSA23:/

MEMBER003:  .ASCID /$4$DUA10:/
VOLUME_LABEL:  .ASCID /MYVOLUME/
VOLUME_LOGNM:  .ASCID /DISK$MYVOLUME/

        .MACRO   .ITEM, SIZE, CODE, BUFFER, RETURN=0
        .WORD    SIZE, CODE
        .ADDRESS BUFFER, RETURN
        .ENDM    .ITEM

ITMLST: .ITEM   6,  MNT$_SHANAM, DSA23

        .ITEM   9,  MNT$_SHAMEM, MEMBER003
        .ITEM   8,  MNT$_VOLNAM, VOLUME_LABEL
        .ITEM   13, MNT$_LOGNAM, VOLUME_LOGNM
        .LONG   0
```

Section 5.2, "$MOUNT *Shadow Set Item Codes"* briefly describes the $MOUNT shadow set item codes and discusses how to construct a valid $MOUNT item list. For a complete description of the $MOUNT service and all its item codes, refer to the *VSI OpenVMS System Services Reference Manual: GETUTC–Z*.

5.2. $MOUNT Shadow Set Item Codes

This section briefly describes the SYS$MOUNT item codes that are useful for shadow set management. Refer to the *VSI OpenVMS System Services Reference Manual: GETUTC–Z* for complete information about SYS$MOUNT, item codes, and other system services.

MNT$_FLAGS Item Code

Specifies a longword bit vector in which each bit specifies an option for the mount operation. The buffer must contain a longword, which is the bit vector.

The $MNTDEF macro defines symbolic names for each option (bit) in the bit vector. You construct the bit vector by specifying the symbolic names for the desired options in a logical OR operation. The following list describes the symbolic names for each shadow set option:

- MNT$M_INCLUDE automatically reconstructs a shadow set to the state it was in before the shadow set was dissolved (because of dismounting or system failure). Use this option when mounting a complete shadow set.
- MNT$M_NOCOPY disables automatic copy operations on all physical devices being mounted or added to a shadow set. This option prevents accidental loss of data that could occur if an unintended device is added to the shadow set.
- MNT$M_MINICOPY_REQUIRED means that $MOUNT fails if minicopy has not been enabled on the disk.
- MNT$M_MINICOPY_OPTIONAL means that $MOUNT continues even if minicopy has not been enabled on the disk.
- MNT$M_OVR_SHAMEM allows you to mount former shadow set members outside of the shadow set. If you do not specify this option, $MOUNT automatically mounts the volume write-locked to prevent accidental deletion of data. To specify this option, you must either own the volume or have the VOLPRO privilege.

  When you use this option, the shadow set generation number is erased from the volume. If you then remount the volume in the former shadow set, $MOUNT considers it an unrelated volume and marks it for a copy operation.
- MNT$M_REQUIRE_MEMBERS controls whether every physical device specified with the **/SHADOW** qualifier must be accessible when the **MOUNT** command is issued in order for the $MOUNT system service to take effect.
- MNT$M_VERIFY_LABELS requires that any member to be added to the shadow set have a volume label of SCRATCH_DISK. This helps ensure that the wrong disk is not added to a shadow set. If you plan to use VERIFY_LABELS, you must assign the disk a label first. You can do this either by initializing the disk to be added to the set with the label SCRATCH_DISK or by specifying a label for the disk with the **SET VOLUME/LABEL** command. The default is NOVERIFY_LABEL, which means that the volume label of the copy targets is not checked. This default behavior is the same that occurred prior to the introduction of this option.

MNT$_SHANAM Item Code

Specifies the name of the virtual unit to be mounted. The buffer is a 1- to 64-character string containing the virtual unit name in the format DSA `n:`. This string can also be a logical name; if it is a logical name, it must translate to a virtual unit name. An item list must include at least one MNT$_SHANAM item descriptor.

If you are mounting a volume set containing more than one shadow set, you must include one MNT $_SHANAM item descriptor for each virtual unit included in the volume set.

MNT$_SHAMEM Item Code

Specifies the name of a physical device to be mounted into a shadow set. The shadowing software adds the device to the shadow set represented by the virtual unit specified in the MNT$_SHANAM item descriptor. The MNT$_SHAMEM descriptor is a 1- to 64-character string containing the device name.

The string can be a physical device name or a logical name; if it is a logical name, it must translate to a physical device name.

An item list must contain at least one item descriptor specifying a member; this item descriptor must appear after the MNT$_SHANAM item descriptor.

Points to Remember When Constructing a $MOUNT Item List

Here are some important things to remember when you construct a $MOUNT item list:

- Every item list that mounts a shadow set must contain at least one item descriptor that specifies the virtual unit and at least one item descriptor that specifies a member.
- The item descriptor that specifies the virtual unit must come before the item descriptors that specify the members contained in the shadow set. Then, you can specify any number of members that are to be represented by that virtual unit by using the MNT$_SHAMEM item code.
- When mounting a volume set, your item list must contain an item descriptor for each virtual unit. The virtual unit item descriptor must be followed by item descriptors specifying the members to be represented by that virtual unit.
- When you mount a shadow set, the system determines whether a device requires a copy or merge operation before it can join the shadow set. Therefore, you can use the MNT$_SHAMEM item code to specify any member, regardless of the operation the device requires.

5.3. Using $MOUNT to Mount Volume Sets

When mounting volume sets, always list the volume with the largest storage capacity first. You should name the largest volume first because the volume set and directory information goes on the first volume listed in a **MOUNT** command line. A small-capacity disk may not have adequate storage for the volume and directory information.

Example 5.3, "Item List to Create and Mount a Volume Set" shows the MACRO-32 statements required to produce a $MOUNT system service item to mount a volume set that contains two shadow sets.

Example 5.3. Item List to Create and Mount a Volume Set

```
DSA23:  .ASCID /DSA23:/
DSA51:  .ASCID /DSA51:/
MEMBER009:   .ASCID /$4$DUA9:/
MEMBER005:   .ASCID /$4$DUA5:/
MEMBER010:  .ASCID /$4$DUA10:/
MEMBER012:  .ASCID /$4$DUA12:/
MEMBER003:   .ASCID /$4$DUA3:/
MEMBER034:  .ASCID /$4$DUA34:/
VOLUME_WORK1:  .ASCID /WORK1/
VOLUME_WORK2:  .ASCID /WORK2/
VOLUME_LOGNM:  .ASCID /WRKD$/

        .MACRO   .ITEM, SIZE, CODE, BUFFER, RETURN=0
        .WORD    SIZE, CODE
        .ADDRESS BUFFER, RETURN
        .ENDM    .ITEM
```

```
ITMLST: .ITEM   6, MNT$_SHANAM, DSA23  ❶
        .ITEM   8, MNT$_SHAMEM, MEMBER009   ❷
        .ITEM   8, MNT$_SHAMEM, MEMBER005
        .ITEM   9, MNT$_SHAMEM, MEMBER010
        .ITEM   5, MNT$_VOLNAM, VOLUME_WORK1  ❸
        .ITEM   6, MNT$_SHANAM, DSA51  ❹
        .ITEM   9, MNT$_SHAMEM, MEMBER012  ❹
        .ITEM   8, MNT$_SHAMEM, MEMBER003
        .ITEM   9, MNT$_SHAMEM, MEMBER034
        .ITEM   5, MNT$_VOLNAM, VOLUME_WORK2   ❹
        .ITEM   5, MNT$_LOGNAM, VOLUME_LOGNM   ❺
        .LONG   0
```

The following list describes the elements in *Example 5.3, "Item List to Create and Mount a Volume Set"*:

❶ Notice that the virtual unit item descriptor for the first volume in the volume set occurs first. This item descriptor specifies `DSA23` as the name of the first virtual unit in the volume set.

❷ The virtual unit item descriptor is followed by item descriptors for each of the devices or members that are to be represented by the first virtual unit: `$4$DUA9`, `$4$DUA5`, and `$4$DUA10`.

❸ The member item descriptors are followed by an item descriptor that specifies the volume label for the first shadow set in the volume set as `WORK1`.

❹ Following the descriptors for the first shadow set in the volume set are similar item descriptors for the second shadow set in the volume set. These item descriptors specify the second virtual unit as `DSA51`; the devices as `$4$DUA12`, `$4$DUA3`, and `$4$DUA34`; and the volume label as `WORK2`.

❺ The last item descriptor specifies the logical name for the entire volume set as `WRKD$`.

5.4. Using $DISMOU to Dismount Shadow Sets

You can use the $DISMOU system service to perform the following four shadow set operations:

- Remove a member from a shadow set;
- Remove a member from a shadow set for a minicopy operation (as described in *Section 7.11, "Guidelines for Using a Shadow Set Member for Backup"*);
- Dismount a shadow set across a cluster from a single node;
- Dismount and dissolve a shadow set.

The call to the $DISMOU system service has the following format:

```
SYS$DISMOU devnam, flags
```

The action that $DISMOU takes depends in part on whether you specify a shadow set virtual unit or a shadow set member in the *devnam* argument.

For a complete description of the $DISMOU service and its arguments, see the *VSI OpenVMS System Services Reference Manual: A–GETUAI*.

5.4.1. Removing Members from Shadow Sets

If you want to remove a single member from a shadow set, you must make a call to $DISMOU. In the *devnam* argument, you should specify the name of the shadow set member you want to remove. The specified member is spun down unless you specify the DMT$M_NOUNLOAD option in the *flags* argument.

The MACRO-32 code in *Example 5.4, "Removing a Member from a Shadow Set"* demonstrates a call to $DISMOU that removes the member 2DUA9 from a shadow set.

Example 5.4. Removing a Member from a Shadow Set

```
$DMTDEF
FLAGS:  .LONG DMT$M_NOUNLOAD
MEMBER001: .ASCID /$2$DUA9:/
 .
 .
 .

$DISMOU_S -
 devnam = MEMBER001, -
 flags = FLAGS
 .
 .
 .
.END
```

5.4.2. Dismounting and Dissolving Shadow Sets

If you want to dismount a shadow set on a single node, you must make a call to $DISMOU. In the *devnam* argument, you should specify the name of the virtual unit that represents the shadow set you want to dismount. If you want to dismount the shadow set clusterwide, specify the DMT$M_CLUSTER option in the *flags* argument of the call.

When you dismount a shadow set on a single node in an OpenVMS Cluster system, and other nodes in the OpenVMS Cluster still have the shadow set mounted, none of the shadow set members contained in the shadow set are spun down, even if you have not specified the DMT$M_NOUNLOAD flag. After this call completes, the shadow set is unavailable on the node from which the call was made. The shadow set is still available to other nodes in the cluster that have the shadow set mounted.

If the node on which the shadow set is being dismounted is the only node that has the shadow set mounted, the shadow set dissolves. The shadow set member devices are spun down unless you specify the DMT$M_NOUNLOAD flag.

The MACRO-32 code in *Example 5.5, "Dismounting and Dissolving a Shadow Set Locally"* demonstrates how to use the $DISMOU system service to dismount the shadow set represented by the virtual unit DSA23.

Example 5.5. Dismounting and Dissolving a Shadow Set Locally

```
$DMTDEF
FLAGS:    .LONG 0
DSA23:  .ASCID /DSA23:/
 .
 .
 .
```

```
$DISMOU_S -
 devnam = DSA23, -
 flags = FLAGS
 .
 .
 .
.END
```

When a shadow set is dissolved:

- Each of the former shadow set members can be mounted as a single disk for other purposes.

  Each volume, however, continues to be marked as having been part of a shadow set. After you dissolve a shadow set, each volume retains the volume shadowing generation number that identifies it as being a former shadow set member (unless you remount the volume outside of the shadow set). Volumes marked as having been part of a shadow set are automatically software write-locked to prevent accidental deletion of data. You cannot mount these volumes for writing outside of a shadow set unless you use the MNT$M_OVR_SHAMEM option with the system service MNT$_FLAGS item code.

- The virtual unit changes to an offline state.

The MACRO-32 code in *Example 5.6, "Dismounting and Dissolving a Shadow Set Across the Cluster"* demonstrates a call to the $DISMOU system service to perform a dismount across the cluster. When the shadow set is dismounted from the last node, the shadow set is dissolved.

Example 5.6. Dismounting and Dissolving a Shadow Set Across the Cluster

```
$DMTDEF
FLAGS:   .LONG  DMT$M_CLUSTER
DSA23:  .ASCID /DSA23:/
 .
 .
 .

$DISMOU_S -
 devnam = DSA23, -
 flags = FLAGS
 .
 .
 .
.END
```

You must specify the DMT$M_CLUSTER option with the *flags* argument if you want the shadow set dismounted from every node in the cluster. When each node in the cluster has dismounted the shadow set (the number of hosts having the shadow set mounted reaches zero), the volume shadowing software dissolves the shadow set.

5.4.3. Setting $DISMOU Flags for Shadow Set Operations

Table 5.1, "$DISMOU Flag Options" lists the options for the $DISMOU *flags* argument and describes the shadow set operations that use these options. For a full description of each of these flag options, see the description of the $DISMOU service in the *VSI OpenVMS System Services Reference Manual: A–GETUAI*.

Table 5.1. $DISMOU Flag Options

Option	Description
DMT$M_MINICOPY_REQUIRED	$DISMOU fails if minicopy has not been enabled on the disk.
DMT$M_MINICOPY_OPTIONAL	$DISMOU takes place, regardless of whether minicopy is enabled on the disk.
DMT$M_FORCE	If connectivity to a device has been lost and the shadow set is in mount verification, this flag causes a named shadow set member to be immediately expelled from the shadow set.
DMT$M_UNLOAD	Valid for all shadowing-related requests.
DMT$M_CLUSTER	Valid for all shadowing-related requests.
DMT$M_ABORT	Honored for virtual units, ignored for members.
DMT$M_UNIT	Ignored for virtual units and their members.

5.5. Evaluating Condition Values Returned by $DISMOU and $MOUNT

This section discusses the condition values returned by the $DISMOU and $MOUNT system services that pertain to mounting and using shadow sets. For a complete list of the condition values returned by these services, see the *VSI OpenVMS System Services Reference Manual: GETUTC–Z*.

If $MOUNT returns the condition value SS$_BADPARAM, your item list probably contains one of the following errors:

- The virtual unit specified in one of your MNT$_SHANAM item descriptors contains a name other than DSA `n`:.
- A MNT$_SHAMEM item descriptor appears in the item list before any MNT$_SHANAM item descriptor.
- Your item list contains a MNT$_SHANAM item descriptor, but it is not followed by the item descriptor MNT$_SHAMEM.
- A MNT$_DEVNAM item descriptor appears in the item list in the middle of a series of item descriptors that specify a single shadow set. You can construct a volume set that contains one or more nonshadowed disks, as well as one or more shadow sets. However, when you use the MNT $_DEVNAM item descriptor to specify the nonshadowed disk, it must not appear between the MNT $_SHANAM item descriptor that specifies a virtual unit and the item descriptors that specify the members of the shadow set that the virtual unit represents.
- The following list contains possible status messages that $MOUNT can return when mounting and using shadow sets:
  - SS$_VOLINV (label mismatched)
  - SS$_SHACHASTA (shadow state change occurred during a mount operation)
  - SS$_MEDOFL (physical unit not accessible)
  - SS$_INCSHAMEM (physical disk incompatible for shadow set)

See also *Appendix A, "Messages"* for shadowing-related status messages.

5.6. Using $GETDVI to Obtain Information About Shadow Sets

The $GETDVI system service is useful for obtaining information about the shadow set devices on your system. Through the use of the shadow set item codes, you can determine the following types of information:

- Whether a device is a shadow set virtual unit or a shadow set member
- Whether a device is the target of a copy or merge operation
- The name of the virtual unit that represents the shadow set of which the particular device is a member
- The entire membership of a shadow set, including the virtual unit and all of the members
- Whether or not a member has been removed from the shadow set

The call to $GETDVI has the following format:

```
SYS$GETDVI [efn],[chan],[devnam],itmlst,[iosb],[astadr],[astprm],[nullarg]
```

For a complete description of the $GETDVI and $GETDVIW services and their arguments, see the *VSI OpenVMS System Services Reference Manual: A–GETUAI*.

Note

If you use the file-system-related item codes with the $GETDVI system service to obtain meaningful system information (such as FREEBLOCK information) for a shadow set, you should specify the virtual unit name with the $GETDVI service. If you specify the device name of one of the shadow set members, the $GETDVI service returns a value of 0.

5.6.1. $GETDVI Shadow Set Item Codes

Table 5.2, "SYS$GETDVI Item Codes" lists the information returned by the $GETDVI shadow set item codes.

Table 5.2. SYS$GETDVI Item Codes

Item Code	Function
DVI$_SHDW_CATCHUP_COPYING	Returns a Boolean longword. The value 1 indicates that the device is the target of a copy operation.
DVI$_SHDW_COPIER_NODE	Returns the name of the node that is actively performing either the copy or the merge operation, as a string
DVI$_SHDW_DEVICE_COUNT	Returns the total number of devices in the virtual unit, including devices being added as copy targets, as a longword
DVI$_SHDW_GENERATION	Returns the current, internal revision number of the virtual unit, as a quadword.

Item Code	Function
DVI$_SHDW_MASTER	Returns a Boolean longword. The value 1 indicates that the device is a virtual unit.
DVI$_SHDW_MASTER_MBR	Returns the name of the master member unit that is used for merge and copy repair operations and for shadow set recovery operations, as a string.
DVI$_SHDW_MASTER_NAME	When the specified device is a shadow set member, $GETDVI returns the virtual unit name for the shadow set of which it is a member. Because shadow set device names can include up to 64 characters, the buffer length field of this item descriptor should specify 64 (bytes). If you specify a virtual unit or a device that is not a shadow set member, $GETDVI returns a null string.
DVI$_SHDW_MBR_COPY_DONE	Returns the percentage of the copy operation that is complete on the current member unit, as a longword.
DVI$_SHDW_MBR_COUNT	Returns the number of full source members in the virtual unit, as a longword. Devices added as copy targets are not full source members.
DVI$_SHDW_MBR_MERGE_DONE	Returns the percentage of the merge operation that has been completed on the member, as a longword.
DVI$_SHDW_MBR_READ_COST	Returns the current value set for the member unit, as a longword. This value can be modified to use a customer-specified value.
DVI$_SHDW_MEMBER	Returns a Boolean longword. The value 1 indicates that the device is a shadow set member.
DVI$_SHDW_MERGE_COPYING	Returns a Boolean longword. The value 1 indicates that the device is a merge member of the shadow set.
DVI$_SHDW_MINIMERGE_ENABLE	Returns a longword interpreted as a Boolean. A value of TRUE indicates that the virtual unit undergoes a minimerge, not a full merge, if a system in the cluster fails.
DVI$_SHDW_NEXT_MBR_NAME	Returns the device name of the next member in the shadow set. If you specify a virtual unit, $GETDVI returns the member device names in the shadow set. If you specify the name of a device that is neither a virtual unit nor a shadow set member, $GETDVI returns a null string. Because shadow set device names can include up to 64 characters, the buffer length field of this item descriptor should specify 64 (bytes).
DVI$_SHDW_READ_SOURCE	Returns the name of the member unit that is used for reads, at this point in time, as a longword. DVI

Item Code	Function
	$_SHDW_READ_SOURCE uses the unit that has the lowest value of the sum of its queue length and read cost for reads. This is a dynamic value.
DVI$_SHDW_SITE	Returns as a longword the site value for the specified value. This value is set by the **SET DEVICE** or **SET SHADOW** command.
DVI$_SHDW_TIMEOUT	Returns the customer-specified timeout value set for the device, as a long word. If you do not set a value by way of the SETSHOWSHADOW utility, the SYSGEN parameter SHADOW_MBR_TWO is used for member units and MVTIMEOUT is used for virtual units.

5.6.2. Obtaining the Device Names of Shadow Set Members

To obtain the device names of all members of a shadow set, you must make a series of calls to $GETDVI. In your first call to $GETDVI, you can specify either the virtual unit that represents the shadow set or the device name of a member of the shadow set.

5.6.2.1. Virtual Unit Names

If your first call specifies the name of the virtual unit, the item list should contain a DVI $_SHDW_NEXT_MBR_NAME item descriptor into which $GETDVI returns the name of the lowest-numbered member of the shadow set. The *devnam* argument of the next call to $GETDVI should specify the device name returned in the previous call's DVI$_SHDW_NEXT_MBR_NAME item descriptor. This second call's item list should contain a DVI$_SHDW_NEXT_MBR_NAME item descriptor to receive the name of the next-highest-numbered unit in the shadow set. You should repeat these calls to $GETDVI until $GETDVI returns a null string, which means that there are no more members in the shadow set.

5.6.2.2. Shadow Set Member Names

If your first call specifies the device name of a shadow set member, you must determine the name of the virtual unit that represents the shadow set before you can obtain the device names of all members contained in the shadow set. Therefore, if your first call specifies a member, it should also specify an item list that contains a DVI$_SHDW_MASTER_NAME item descriptor. $GETDVI returns to this descriptor the name of the virtual unit that represents the shadow set. You can now make the series of calls to $GETDVI described in *Section 5.6.2.1, "Virtual Unit Names"*. The *devnam* argument of each call specifies the name of the device returned in the previous call's DVI$_SHDW_NEXT_MBR_NAME item descriptor. You repeat these calls until $GETDVI returns a null string, indicating that there are no more members in the shadow set.

Chapter 6. Ensuring Shadow Set Consistency

Volume shadowing performs four basic functions. The two most important, as with any disk I/O subsystem, are to satisfy read and write requests. The other two functions, copy and merge, are required for shadow set maintenance.

Copy and merge operations are the cornerstone of achieving data availability. Under certain circumstances, Volume Shadowing for OpenVMS must perform a copy or a merge operation to ensure that corresponding LBNs on all shadow set members contain the same information. Although volume shadowing automatically performs these operations, this chapter provides an overview of their operation.

Copy and merge operations occur at the same time that applications and user processes read and write to active shadow set members, thereby having a minimal effect on current application processing.

6.1. Shadow Set Consistency

During the life of a shadow set, the state of any shadow set member relative to the rest of the members of the shadow set can vary. The shadow set is considered to be in a steady state when all of its members are known to contain identical data. Changes in the composition of the shadow set are inevitable because:

- Disk drives occasionally need corrective maintenance.
- New disks are added to replace other disks.
- System failures occur, requiring merge operations to take place within the shadow set.
- Controllers fail, requiring maintenance.
- System management functions, such as backup, are required.

For example, suppose an operator dismounts a member of a shadow set and then remounts the member back into the shadow set. During the member's absence, the remaining members of the shadow set may have experienced write operations. Thus, the information on the member being remounted into the shadow set differs from the information on the rest of the shadow set. Therefore, a copy (or minicopy) operation is required.

As another example, consider a situation where a shadow set is mounted by several systems in an OpenVMS Cluster configuration. If one of those systems fails, the data on the members of the shadow set may differ because of outstanding or incomplete write operations issued by the failed system. The shadowing software resolves this situation by performing a merge operation.

In any event, copy and merge operations allow volume shadowing to preserve the consistency of the data written to the shadow set. A shadow set is considered to be in a **transient state** when one or more of its members are undergoing a copy or a merge operation.

Additionally, volume shadowing maintains shadow set consistency by:

- Maintaining consistent data on shadow set members by automatically detecting and replacing bad blocks on one shadow set member and rewriting those bad blocks with good data from another shadow set member.

- Notifying all nodes when a member is added or removed from a shadow set, and ensuring the shadow set membership is consistent clusterwide.

Volume shadowing uses two internal mechanisms to coordinate shadow set consistency:

- Storage control blocks (SCBs)

  Volume shadowing uses a storage control block (SCB) as a primary method for controlling shadow set membership. Each physical disk contains an SCB in which the shadowing software records the names of all the current members of the shadow set. Each time the composition of the shadow set changes, the SCB on all members is updated. This feature simplifies clusterwide membership coordination and is also used by the **MOUNT** qualifier **/INCLUDE** to reconstruct a shadow set.

- Shadow set generation number

  Volume shadowing uses a shadow set generation number as a primary method of determining shadow set member validity and status. A shadow set generation number is an incrementing value that is stored on every member of a shadow set. Each time a membership change occurs to the shadow set (members are mounted, dismounted, or fail), the generation number on the remaining members is incremented. Thus, if a shadow set's generation number is 100 and a member is dismounted from the set, the generation numbers on the remaining members are incremented to 101. The removed member's generation number remains at 100. When mounting shadow sets, the shadowing software uses the generation numbers, found in the SCB on the physical units, to determine the need for and direction of copy operations.

Table 6.1, "Information in the Storage Control Block (SCB)" lists some of the information contained in the SCB.

Table 6.1. Information in the Storage Control Block (SCB)

SCB Information	Function
Volume label	Identifies a unique name for the volume. Every member of a shadow set must use the same volume label.
BACKUP revision number	A BACKUP/IMAGE restoration rearranges the location of data on a volume and sets a revision number to record this change. The Mount utility (MOUNT) checks the revision number of the proposed shadow set member against the numbers on current or other proposed shadow set members. If the revision number differs, the shadowing software determines whether a copy or merge operation is required to bring the data on the less current members up to date.
Volume shadowing generation number	When a member joins a shadow set, it is marked with a volume shadowing generation number. You can zero the generation number by using the **/OVERRIDE=SHADOW_MEMBERSHIP** qualifier with the **MOUNT** command.
Mount and dismount status	The SCB mount status field is used as a flag that is set when a volume is mounted and cleared when it is dismounted. There is also a count of the number of nodes that have mounted the shadow set write-enabled. The **MOUNT** command checks this field when a disk is mounted. If the flag is set, this indicates that the disk volume was incorrectly dismounted. This will occur in the event of system failure. When mounting shadow sets that were incorrectly

SCB Information	Function
	dismounted, or where the write count field is not correct, the shadowing software automatically initiates merge operations.

Upon receiving a command to mount a shadow set, the volume shadowing software immediately determines whether a copy or a merge operation is required; if either is required, the software automatically performs the operation to reconcile data differences. If you are not sure which disks might be targets of copy operations, you can specify the **/CONFIRM** or **/NOCOPY** qualifiers when you use the **MOUNT** command. To disable performing any copy operations, use the **/NOCOPY** qualifier. If you mount a shadow set interactively, use the **/CONFIRM** qualifier to instruct **MOUNT** to display the targets of copy operations and request permission before the operations are performed.

When you dismount an individual shadow set member, you produce a situation similar to a hardware disk failure. Because files remain open on the virtual unit, the removed physical unit is marked as *not* being properly dismounted.

After one of the devices is removed from a shadow set, the remaining shadow set members have their generation number incremented, identifying them as being more current than the former shadow set member. This generation number aids in determining the correct copy operation if you remount the member into a shadow set.

6.2. Copy Operations

The purpose of a copy operation is to duplicate data on a source disk to a target disk. At the end of a copy operation, both disks contain identical information, and the target disk becomes a complete member of the shadow set. Read and write access to the shadow set continues while a disk or disks are undergoing a copy operation.

The DCL command **MOUNT** initiates a copy operation when a disk is added to an existing shadow set. A copy operation is simple in nature: a source disk is read and the data is written to the target disk. This is usually done in multiple block increments referred to as LBN ranges. In an OpenVMS Cluster environment, all systems that have the shadow set mounted know about the target disk and include it as part of the shadow set. However, only one of the OpenVMS systems actually manages the copy operation.

Two complexities characterize the copy operation:

- Handling user I/O requests while the copy operation is in progress
- Dealing with writes to the area that is currently being copied without losing the new write data

Volume Shadowing for OpenVMS handles these situations differently, depending on the architecture that it is running on, via unassisted (*Section 6.2.1, "Unassisted Copy Operations"*) and assisted copy (*Section 6.2.2, "Assisted Copy Operations (Alpha and x86 Only)"*) operations.

OpenVMS introduced the host-based minicopy operation. Minicopy and its enabling technology, write bitmaps, are fully implemented on OpenVMS Integrity servers, OpenVMS Alpha, and OpenVMS x86 systems. For more information about the minicopy operation, see *Chapter 7, "Using Minicopy for Backing Up Data"*.

Volume Shadowing for OpenVMS supports both assisted and unassisted shadow sets in the same cluster. Whenever you create a shadow set, add members to an existing shadow set, or boot a system, the

shadowing software reevaluate's each device in the changed configuration to determine whether the device is capable of supporting the copy assist.

6.2.1. Unassisted Copy Operations

Unassisted copy operations are performed by an OpenVMS system. The actual transfer of data from the source member to the target is done through host node memory. Although unassisted copy operations are not CPU intensive, they are I/O intensive and consume a small amount of CPU bandwidth on the node that is managing the copy. An unassisted copy operation also consumes interconnect bandwidth.

On the system that manages the copy operation, user and copy I/Os compete evenly for the available I/O bandwidth. For other nodes in the cluster, user I/Os proceed normally and contend for resources in the controller with all the other nodes. Note that the copy operation may take longer as the user I/O load increases.

The volume shadowing software performs an unassisted copy operation when it is not possible to use the assisted copy feature (see *Section 6.2.2, "Assisted Copy Operations (Alpha and x86 Only)"*). The most common cause of an unassisted copy operation is when the source and target disk or disks are not on line to the same controller subsystem. For unassisted copy operations, two disks can be active targets of an unassisted copy operation simultaneously, if the members are added to the shadow set on the same command line. Disks participating in an unassisted copy operation may be on line to any controller anywhere in a cluster.

During any copy operation, a logical barrier is created that moves across the disk, separating the copied and uncopied LBN areas. This barrier is known as a **copy fence**. The node that is managing the copy operation knows the precise location of the fence and periodically notifies the other nodes in the cluster of the fence location. Thus, if the node performing the copy operation shuts down, another node can continue the operation without restarting at the beginning. During a copy operation, the I/O requests are processed as follows:

- Read I/O requests to either side of the copy fence are serviced only from a source shadow set member.
- Write I/O requests before or at the fence are issued in parallel to all members of the shadow set.
- Write I/O requests, after the fence, are completed first to source members, then to copy target members.

The time and amount of I/O required to complete an unassisted copy operation depends heavily on the similarities of the data on the source and target disks. It can take at least two and a half times longer to copy a member containing dissimilar data than it does to complete a copy operation on a member containing similar data.

6.2.2. Assisted Copy Operations (Alpha and x86 Only)

An assisted copy does not transfer data through the host node memory. The actual transfer of data is performed within the controller, by direct disk-to-disk data transfers, without having the data pass through host node memory. Thus, the assisted copy decreases the impact on the system, the I/O bandwidth consumption, and the time required for copy operations.

Shadow set members must be accessed from the same controller in order to take advantage of the assisted copy. The shadowing software controls the copy operation by using special MSCP copy

commands, called disk copy data (DCD) commands, to instruct the controller to copy specific ranges of LBNs. For an assisted copy, only one disk can be an active target for a copy at a time.

For OpenVMS Cluster configurations, the node that is managing the copy operation issues an MSCP DCD command to the controller for each LBN range. The controller then performs the disk-to-disk copy, thus avoiding consumption of interconnect bandwidth.

Shadowing automatically disables the copy assist if:

- The source and target disks are not accessed using the same controller.

  In the case of dual-ported disks, you can use the $QIO SET PREFERRED PATH feature to force both disks to be accessed via the same controller. See the PREFER program in SYS$EXAMPLES and refer to the *VSI OpenVMS I/O User's Reference Manual* for more information about setting a preferred path.

- The shadow set is mounted on a controller that does not support the copy assist.

- The shadow set member is mounted on an HSC controller with the copy assist disabled. (HSC controllers are the only controllers on which you can disable copy assists.)

- The number of assisted copies specified by the DCD connection limit, available only on HSC controllers, has been reached, at which point additional copies will be performed unassisted.

See *Section 6.4, "Controlling HSC Assisted Copy and Minimerge Operations"* for information about disabling and reenabling the assisted copy capability.

6.3. Merge Operations

The purpose of either a full merge or a minimerge operation is to compare data on shadow set members and to ensure that all of them contain identical data on every logical block (each block is identified by its logical block number [LBN]). A full merge or minimerge operation is initiated if either of the following events occurs:

- A system failure results in the possibility of incomplete writes.

  For example, if a write request is made to a shadow set but the system fails before a completion status is returned from all the shadow set members, it is possible that:

  - All members might contain the new data.
  - All members might contain the old data.
  - Some members might contain new data and others might contain old data.

  The exact timing of the failure during the original write request defines which of these three scenarios results. When the system recovers, Volume Shadowing for OpenVMS ensures that corresponding LBNs on each shadow set member contain the same data (old or new). It is the responsibility of the application to determine if the data is consistent from its point of view. The volume might contain the data from the last write request or it might not, depending on when the failure occurred. The application should be designed to function properly in both cases.

- If a shadow set enters mount verification with outstanding write I/O in the driver's internal queue, and the problem is not corrected before mount verification times out, the systems on which the

timeout occurred require other systems that have the shadow set mounted to put the shadow set into a merge transient state.

The merge operation is managed by one of the OpenVMS systems that has the shadow set mounted. The members of a shadow set are physically compared to each other to ensure that they contain the same data. This is done by performing a block-by-block comparison of the entire volume. As the merge proceeds, any blocks that are different are made the same — either both old or new — by means of a copy operation. Because the shadowing software does not know which member contains newer data, any full member can be the source member of the merge operation.

A full merge operation can be a very lengthy procedure. During the operation, application I/O continues but at a slower rate.

A minimerge operation can be significantly faster. By using information about write operations that were logged in volatile controller storage, the minimerge is able to merge only those areas of the shadow set where write activity was known to have occurred. This avoids the need for the entire volume scan that is required by full merge operations, thus reducing consumption of system I/O resources.

The shadowing software always selects one member as a logical master for any merge operation, across the OpenVMS Cluster. Any difference in data is resolved by a propagation of the information from the merge master to all the other members.

The system responsible for doing the merge operation on a given shadow set, updates the merge fence for this shadow set after a range of LBNs is reconciled. This fence “proceeds” across the disk and separates the merged and unmerged portions of the shadow set.

Application read I/O requests to the merged side of the fence can be satisfied by any source member of the shadow set. Application read I/O requests to the unmerged side of the fence are also satisfied by any source member of the shadow set; however, any potential data differences discovered by doing a data compare operation are corrected on all members of the shadow set before returning the data to the user or application that requested it.

This method of dynamic correction of data inconsistencies during read requests allows a shadow set member to fail at any point during the merge operation without impacting data availability.

Volume Shadowing for OpenVMS supports both assisted and unassisted merge operations in the same cluster. Whenever you create a shadow set, add members to an existing shadow set, or boot a system, the shadowing software reevaluates each device in the changed configuration to determine whether it is capable of supporting the merge assist.

6.3.1. Unassisted Merge Operations

For systems running software earlier than OpenVMS Version 5.5–2, the merge operation is performed by the system and is known as an **unassisted** merge operation.

To ensure minimal impact on user I/O requests, volume shadowing implements a mechanism that causes the merge operation to give priority to user and application I/O requests.

The shadow server process performs merge operations as a background process, ensuring that when failures occur, they minimally impact user I/O. A side effect of this is that unassisted merge operations can often take an extended period of time to complete, depending on user I/O rates. Also, if another node fails before a merge completes, the current merge is abandoned and a new one is initiated from the beginning.

Note that data availability and integrity are fully preserved during merge operations regardless of their duration. All shadow set members contain equally valid data.

6.3.2. Assisted Merge Operations (Alpha and x86 Only)

The merge operation includes enhancements for shadow set members that are configured on controllers that implement **assisted** merge capabilities. The assisted merge operation is also referred to as a **minimerge**. The minimerge feature significantly reduces the amount of time needed to perform merge operations. Usually, the minimerge completes in a few minutes. For more information, see *Chapter 8, "Host-Based Minimerge (HBMM)"*.

By using information about write operations that were logged in controller memory, the minimerge is able to merge only those areas of the shadow set where write activity was known to have been in progress. This avoids the need for the total read and compare scans required by unassisted merge operations, thus reducing consumption of system I/O resources.

Controller-based write logs contain information about exactly which LBNs in the shadow set had write I/O requests outstanding (from a failed node). The node that performs the assisted merge operation uses the write logs to merge those LBNs that may be inconsistent across the shadow set. No controller-based write logs are maintained for a one member shadow set. No controller-based write logs are maintained if only one OpenVMS system has the shadow set mounted.

Note

The shadowing software does not automatically enable a minimerge on a system disk because of the requirement to consolidate crash dump files on a non-system disk.

Dump off system disk (DOSD) is supported on OpenVMS. If DOSD is enabled, the system disk can be minimerged.

The minimerge operation is enabled on nodes running OpenVMS Version 5.5–2 or later. Volume shadowing automatically enables the minimerge if the controllers involved in accessing the physical members of the shadow set support it. Note that minimerge operations are possible even when shadow set members are connected to different controllers. This is because write log entries are maintained on a per controller basis for each shadow set member.

Volume Shadowing for OpenVMS automatically disables minimerges if:

- A shadow set member is mounted on a controller running a version of firmware that does not support minimerge.
- A shadow set member is mounted on a controller that has performance assists disabled.
- If any node in the cluster, with a shadow set mounted, is running a version of Volume Shadowing that has minimerge disabled.
- The shadow set is mounted on a standalone system. (Minimerge operations are not enabled on standalone systems.)
- The shadow set is mounted on only one node in the OpenVMS Cluster.

The following transient conditions can also cause a minimerge operation to be disabled:

- If an unassisted merge operation is already in progress when a node fails.

  In this situation, the shadowing software cannot interrupt the unassisted merge operation with a minimerge.

- When not enough write log entries are available in the controllers.

  The number of write log entries available is determined by controller capacity. The shadowing software dynamically determines when there are enough entries to maintain write I/O information successfully. If the number of available write log entries is too low, shadowing temporarily disables logging for that shadow set, and it returns existing available entries on this and every node in the cluster. After some time has passed, shadowing attempts to reenable write logging on this shadow set.

  A controller retains a write log entry for each write I/O request until that entry is deleted by shadowing, or the controller is restarted.

  A multiple-unit controller shares its write log entries among multiple disks. This pool of write log entries is managed by the shadowing software. If a controller runs out of write log entries, shadowing disables minimerges and performs an unassisted merge operation, should a node leave the cluster without first dismounting the shadow set. Note that write log exhaustion does not typically occur with disks on which the write logs are not shared.

- When the controller write logs become inaccessible for one of the following reasons, a minimerge operation is not possible.

  - Controller failure causes write logs to be lost or deleted.

  - A device that is dual ported to multiple controllers fails over to its secondary controller. (If the secondary controller is capable of maintaining write logs, the minimerge operations are reestablished quickly.)

6.4. Controlling HSC Assisted Copy and Minimerge Operations

This section describes how to control assisted copy and minimerge operations on an HSC controller. It is not possible to control these operations on an HSJ controller.

To disable both the merge and copy performance assists on the HSC controller, follow these steps on each HSC controller for which you want to disable the assists:

1. Press Ctrl/C to get to the HSC prompt.

2. When the HSC> prompt appears on the terminal screen, enter the following commands:

```
HSC> RUN SETSHO
SETSHO> SET SERVER DISK/NOHOST_BASED_SHADOWING
SETSHO-I Your settings require an IMMEDIATE reboot on exit.
SETSHO> EXIT
SETSHO-Q Rebooting HSC.  Press RETURN to continue, CTRL/Y to abort:
```

After you issue these commands, the HSC controller automatically reboots:

```
INIPIO-I Booting...
```

To reenable the assists, follow the same procedure on your HSC controller, but use the **/HOST_BASED_SHADOWING** qualifier on the **SET SERVER DISK** command.

Use the HSC command **SHOW ALL** to see whether the assists are enabled or disabled. The following example shows a portion of the **SHOW ALL** display that indicates the shadowing assists status:

```
HSC> SHOW ALL
    .
    .
    .
       5-Jun-1997 16:42:51.40 Boot:  21-Feb-1997 13:07:19.47   Up: 2490:26
Version: V860           System ID: %X000011708247     Name: HSJNOT
Front Panel:  Secure                                  HSC Type: HSC90
  .
  .
  .
Disk Server Options:
        Disk Caching: Disabled
        Host Based Shadowing Assists: Enabled
        Variant Protocol: Enabled
        Disk Drive Controller Timeout: 2 seconds
        Maximum Sectors per Track: 74 sectors
        Disk Copy Data connection limit: 4      Active: 0
    .
    .
    .
```

6.5. What Happens to a Shadow Set When a System Fails?

When a system, controller, or disk failure occurs, the shadowing software maintains data availability by performing the appropriate copy, merge, or minimerge operation. The following subsections describe the courses of action taken when failures occur. The course of action taken depends on the event and whether the shadow set is in a steady state or a transient state.

Transitions from Steady State

When a shadow set is in a steady state, the following transitions can occur:

- If you mount a new disk into a steady state shadow set, the shadowing software performs a copy operation to make the new disk a full shadow set source member.
- If a failure occurs on a standalone system (the system crashes), on a steady state shadow set, the shadow set SCB reflects that the shadow set has been incorrectly dismounted. When the system is rebooted and the set is remounted, a copy operation is not necessary, but a merge operation is necessary and initiated.
- If a failure occurs in a cluster, the shadow set is merged by a remaining node that has the shadow set mounted:
    - If performance assists are enabled, and the controller-based write logs are available, the shadowing software performs a minimerge.
    - If performance assists are not enabled, the shadowing software performs a merge operation.

Once the transition completes, the disks contain identical information and the shadow set returns to a steady state.

Transitions During Copy and Assisted Operations

The following list describes the transitions that can occur to a shadow set that is undergoing a copy or assisted copy operation. The transitions apply to both forms of copy operations except where noted:

- If you mount an additional disk into the shadow set that is already undergoing a copy operation, the shadowing software finishes the original copy operation before it begins another copy operation on the newly mounted disk.
- When a shadow set on a standalone system is undergoing a copy operation and the system fails, the copy operation aborts and the shadow set is left with the original members. For a standalone system, there is no recourse except to reboot the system and reinitiate the shadow set copy operation with a **MOUNT** command.
- When a shadow set is mounted on more than one node in the cluster and is undergoing a copy operation, if the node performing the copy operation dismounts the virtual unit, another node in the cluster that has that shadow set mounted continues the copy operation automatically.

  If a shadow set is undergoing a an assisted copy operation when this occurs, the minicopy will not continue. Instead, a full copy will continue from the point where the minicopy stopped, and all the remaining blocks will be copied.
- If a shadow set is mounted on more than one node in the cluster and is undergoing a copy operation, should the node performing the copy operation fail, another node in the cluster that has that shadow set mounted continues the copy operation automatically.

When a node failure occurs during a shadow set copy operation, merge behavior depends on whether or not the shadowing performance assists are enabled.

- If minimerge is enabled and can be performed, the shadowing software interrupts the copy operation to perform a minimerge and then resumes the copy operation.
- If the minimerge is not enabled, the shadowing software marks the set as needing a merge operation and finishes the copy operation before beginning the merge operation.

Transitions During Minimerge Operations

When a shadow set is undergoing a minimerge operation, the following transitions can occur:

- If a new member is mounted into a shadow set when a minimerge operation is in progress, the minimerge is completed before the copy operation is started.
- If another system failure occurs before a pending minimerge has completed, the action taken depends on whether or not the shadowing performance assists are enabled and if the controller-based write logs are available.
  - If performance assists are enabled and if the controller-based write logs are available for the last node failure, the shadowing software restarts the minimerge from the beginning and adds new LBNs to the write log file based on the entries taken from the nodes that failed.
  - If performance assists are disabled, the shadowing software reverts to a merge operation. The performance assists might be disabled if the controller runs out of write logs or if a failover occurs from a controller with write logs to one that does not.

Transitions During Merge Operations

The following list describes the transitions that can occur to the shadow set that is undergoing a merge operation when performance assists are not available:

- If you add a new disk to a shadow set that is undergoing a merge operation, the shadowing software interrupts the merge operation to perform a copy operation. The merge operation resumes when the copy operation is completed.
- If a node failure occurs when the shadow set is performing a merge operation, the shadowing software abandons the current merge operation and starts a new merge operation.

6.6. Examples of Copy and Merge Operations

Example 6.1, "Copy Operation: Creating a New Shadow Set" shows what happens when you create a shadow set by mounting two disk volumes that have never been a part of a shadow set. Because neither disk volume has been a part of a shadow set, the Mount utility (MOUNT) assumes that the first disk named in the **MOUNT** command is the source member. When the Mount utility checks the volume labels on the disks, it discovers that they are different from each other, and the utility automatically performs a copy operation.

In this example, DSA0 is the virtual unit name, 1DUA8 and 1DUA89 are the names of the disk volumes, and SHADOWDISK is the volume label.

Example 6.1. Copy Operation: Creating a New Shadow Set

```
$ MOUNT DSA0: /SHADOW=($1$DUA8:,$1$DUA89:) SHADOWDISK
%MOUNT-I-MOUNTED, SHADOWDISK    mounted on _DSA0:
%MOUNT-I-SHDWMEMSUCC, _$1$DUA8: (FUSS) is now a valid member
                      of the shadow set
%MOUNT-I-SHDWMEMCOPY, _$1$DUA89: (FUSS) added to the shadow
                      set with a copy operation
$ SHOW DEVICE DSA0:
Device                Device          Error    Volume      Free  Trans Mnt
 Name                 Status          Count     Label     Blocks Count Cnt
DSA0:                 Mounted             0  SHADOWDISK   890937     1   1
$1$DUA8:       (FUSS) ShadowSetMember     0  (member of DSA0:)

$1$DUA89:        (FUSS)  ShadowCopying        0  (copy trgt DSA0:  1%
 copied)
```

The **SHOW DEVICE** display in *Example 6.1, "Copy Operation: Creating a New Shadow Set"* shows the shadow set during the copy operation (transient state). Because the SCB information on `$1$DUA8` and `$1$DUA89` indicates that these devices have never been part of a shadow set, the shadowing software uses the first device named in the command line (`$1$DUA8`) as the source of the copy operation. The device status `ShadowSetMember` indicates that the `$1$DUA8` device is a source shadow set member, and `ShadowCopying` indicates that the physical device `$11$DUA89` is the target of a copy operation.

Suppose you want to add a new member to an existing shadow set, and the device you add is a previous member of this same shadow set. In this case, the volume label of the new member matches that of the current shadow set members, but the new member's MOUNT generation number is out of date compared with those of the current members. Thus, the MOUNT utility automatically performs a copy operation on that member.

Example 6.2, "Copy Operation: Adding a Member to an Existing Shadow Set" shows the format of the **MOUNT** command and MOUNT status messages returned when you add the 3DIA12 device to the shadow set represented by the DSA9999 virtual unit. Notice that you do not need to list the member units currently in the shadow set on the MOUNT command line.

Example 6.2. Copy Operation: Adding a Member to an Existing Shadow Set

```
$ MOUNT /SYSTEM DSA9999: /SHADOW=$3$DIA12: AXP_SYS_071
%MOUNT-I-MOUNTED, AXP_SYS_071 mounted on _DSA9999:
%MOUNT-I-SHDWMEMCOPY, _$3$DIA12: (SHAD03) added to the shadow
                      set with a copy operation
$ SHOW DEVICE DSA9999:
Device                Device         Error    Volume      Free  Trans Mnt
 Name                 Status         Count     Label     Blocks Count Cnt
DSA9999:              Mounted            0  AXP_SYS_071   70610      1   1
$3$DIA7:    (BGFUSS)  ShadowSetMember    0  (member of DSA9999:)
$3$DIA5:    (SHAD03)  ShadowSetMember    0  (member of DSA9999:)

$3$DIA12:   (SHAD03)  ShadowCopying        0  (copy trgt DSA9999:  0%
 copied)
```

Example 6.3, "No Copy Operation: Rebuilding a Shadow Set" shows what happens when a three-member shadow set is dissolved on one node and then is immediately remounted on another node. When the Mount utility checks the volume information on each member, it finds that the volume information is consistent across the shadow set. Thus, a copy operation is not necessary when the shadow set is mounted.

In *Example 6.3, "No Copy Operation: Rebuilding a Shadow Set"*, DSA10 is the virtual unit and 3DUA10, 3DUA11, and 3DUA12 are the member volumes. The first part of the example displays the output from a **SHOW DEVICE** command, which shows that the shadow set is mounted and in a steady state. Then the user dismounts the DSA10 shadow set and immediately remounts it.

Example 6.3. No Copy Operation: Rebuilding a Shadow Set

```
$ SHOW DEVICE D
Device                Device         Error    Volume      Free  Trans Mnt
 Name                 Status         Count     Label     Blocks Count Cnt
DSA10:                Mounted            0               292971     1   1
$3$DUA10:   (MYNODE)  ShadowSetMember   0  (member of DSA10:)
$3$DUA11:   (MYNODE)  ShadowSetMember   0  (member of DSA10:)
$3$DUA12:   (MYNODE)  ShadowSetMember   0  (member of DSA10:)

$ DISMOUNT /NOUNLOAD DSA10:
%%%%%%%%%%  OPCOM  24-MAR-1997 20:26:41.40  %%%%%%%%%%
$3$DUA10: (MYNODE) has been removed from shadow set.
%%%%%%%%%%  OPCOM  24-MAR-1997 20:26:41.69  %%%%%%%%%%
$3$DUA11: (MYNODE) has been removed from shadow set.
%%%%%%%%%%  OPCOM  24-MAR-1997 20:26:41.69  %%%%%%%%%%
$3$DUA12: (MYNODE) has been removed from shadow set.
%%%%%%%%%%  OPCOM  24-MAR-1997 20:26:41.69  %%%%%%%%%%

$ MOUNT /SYSTEM DSA10: /SHADOW=($3$DUA10:, $3$DUA11:, $3$DUA12:) %MOUNT-I-
MOUNTED, mounted on _DSA10:
%MOUNT-I-SHDWMEMSUCC, _$3$DUA10: (MYNODE) is now a valid member of
                      the shadow set
%MOUNT-I-SHDWMEMSUCC, _$3$DUA11: (MYNODE) is now a valid member of
                      the shadow set
```

```
%MOUNT-I-SHDWMEMSUCC, _$3$DUA12: (MYNODE) is now a valid member of
                      the shadow set
$
```

Example 6.4, "Merge Operation: Rebuilding a Shadow Set" shows the output from the **SHOW DEVICE** command at the time of the merge operation.

When a system fails, the volume information is left in a state that shows that each shadow set member was not properly dismounted. If you issue the **MOUNT** command again after the node reboots, the shadowing software automatically performs a merge operation on the shadow set.

Example 6.4. Merge Operation: Rebuilding a Shadow Set

```
$ SHOW DEVICE DSA42:
Device              Device          Error    Volume      Free  Trans Mnt
 Name               Status          Count     Label     Blocks Count Cnt
DSA42:              Mounted             0    ATHRUZ     565997     1   1

$4$DUA2:   (MYNODE) ShadowMergeMbr      0  (merging DSA42: 0% merged)
$4$DUA42: (YRNODE) ShadowMergeMbr      0  (merging DSA42: 0% merged)
```

Chapter 7. Using Minicopy for Backing Up Data

This chapter describes the minicopy feature of Volume Shadowing for OpenVMS. Minicopy and its enabling technology, bitmaps, are fully implemented on OpenVMS Integrity, OpenVMS Alpha, and OpenVMS x86 systems. In an OpenVMS Cluster system, only one system is required in order to use minicopy.

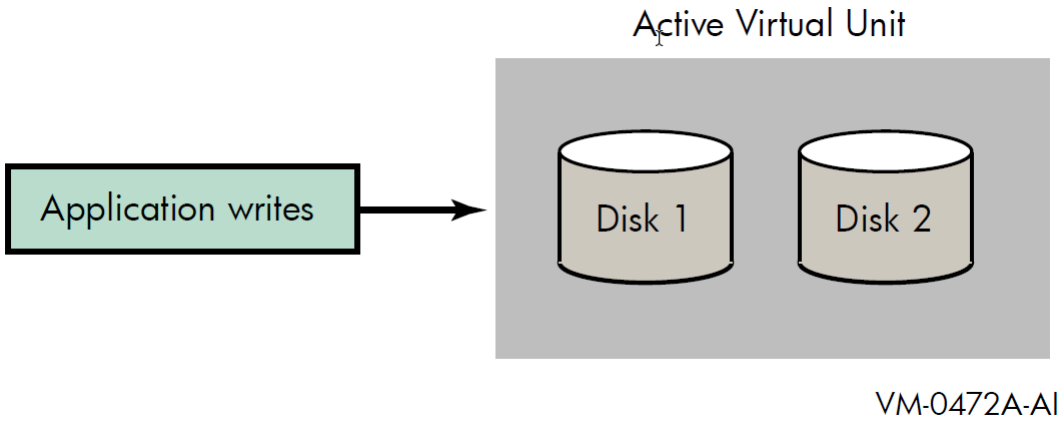
The primary purpose of minicopy is to reduce the time it takes to return a shadow set member to the shadow set. The shadow set member is typically removed for the purpose of backing up the data and is then returned to membership in the shadow set.

7.1. What Is Minicopy?

Minicopy operation is a streamlined copy operation. A bitmap tracks writes to a shadow set and is used to direct a minicopy operation when a shadow set member is returned to the shadow set. Instead of copying the entire contents of a device, only the changed blocks, identified by the bitmap, are copied. Minicopy ensures that the data on a shadow set member, when returned to the shadow set, is identical to the data in the shadow set.

Prior to the removal of a shadow set member, application writes are sent directly to the shadow set (also known as the virtual unit), as shown in *Figure 7.1, "Application Writes to a Shadow Set"*.

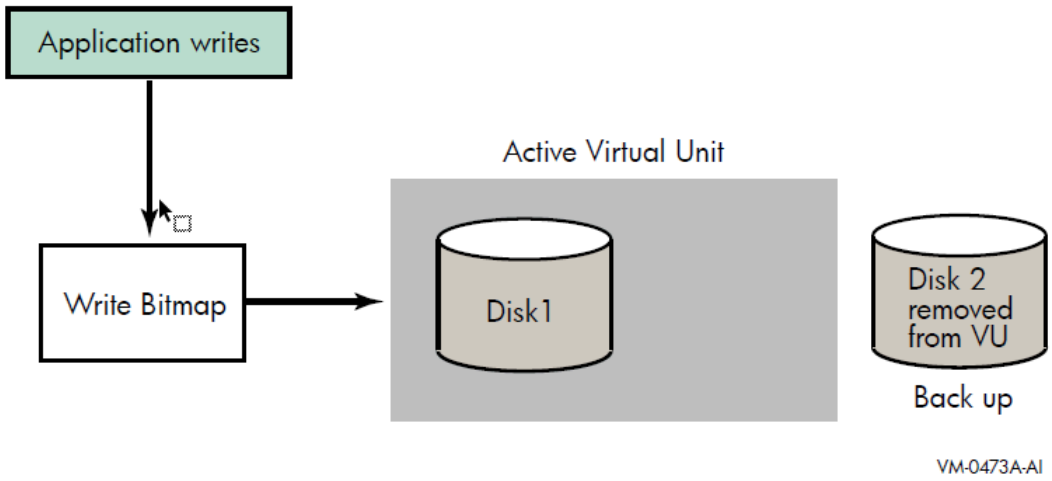
Figure 7.1. Application Writes to a Shadow Set



If you specify the minicopy qualifier (**/POLICY=MINICOPY[=OPTIONAL]**) when you dismount a shadow set member, a bitmap is created. Subsequent writes to the shadow set are recorded by the bitmap. Note that the bitmap records only the logical block numbers (LBNs) of the associated writes, not the contents. The address is noted by setting one or more bits in a bitmap; each bit corresponds to a range of 127 disk blocks.

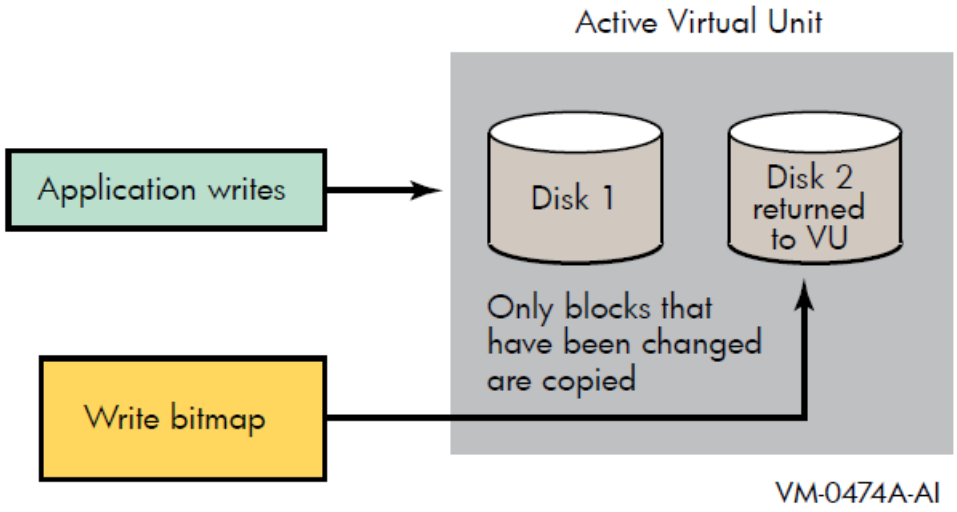
When data is written to any block in the range of 127 blocks, the bit in the bitmap that corresponds to that range is set. After the bit or bits are set, the data is written to the shadow set, as shown in *Figure 7.2, "Application Writes to a Write Bitmap"*.

Figure 7.2. Application Writes to a Write Bitmap



When the member is returned to the shadow set, the bitmap is used to direct the minicopy operation, as shown in *Figure 7.3, "Member Returned to the Shadow Set (Virtual Unit)"*. While the minicopy operation is taking place, the application continues to read and write to the shadow set.

Figure 7.3. Member Returned to the Shadow Set (Virtual Unit)



With the minicopy function, a full copy is no longer required when a member is returned to its shadow set, provided that the system managers follow the guidelines provided in *Section 7.11, "Guidelines for Using a Shadow Set Member for Backup"*. Note that, in this chapter, copy and full copy mean the same thing.

Several DCL commands can be used to manage bitmaps. System parameters are provided for managing the bitmap updates in an OpenVMS Cluster system and for setting an upper limit on shadow sets per node.

7.2. Different Uses for Copy and Minicopy

Prior to the introduction of minicopy, the copy operation was used for two purposes: to add members to a virtual unit, and to restore a member to the shadow set from which it was removed. In order for a member to rejoin the shadow set, its data must be made to match the data on the shadow set.

The copy operation is the principal method for creating a multiple member shadow set. (You can also use the DCL command **INITIALIZE/SHADOW** to create an empty multi-member shadow set.) The minicopy operation is now the preferred method for returning a member to a shadow set.

Typically, the reason for removing a shadow set member is to back up the data onto tape or disk.

To use a shadow set member to perform a backup operation, a system manager must perform the following steps:

- Using the **SHOW DEVICE** command, verify that the virtual unit is not marked for a merge operation.
- Stop the application I/O. The method for doing this is specific to the application and the computing environment.
- Remove a shadow set member.
- Reactivate the application.
- Back up the data of the shadow set member to disk or tape. While the backup is progressing, the application is writing data to the remaining members of the shadow set.
- Return the shadow set member to the shadow set when the backup is complete.

Note

For detailed information about the conditions under which this form of backup is supported, see *Section 7.11, "Guidelines for Using a Shadow Set Member for Backup"*.

7.3. Why Use Minicopy?

The minicopy operation can be used at the discretion of the system manager and at a time chosen by the system manager.

Because minicopy can significantly reduce the time it takes to return a member to a shadow set, it gives system managers greater flexibility in scheduling the removal and return of a shadow set member, and it improves availability.

The time needed to perform a minicopy is proportional to the amount of change that occurred to a shadow set in the disk's absence. A shorter copy time gives sites more flexibility in managing backups.

Table 7.1, "Comparison of Minicopy and Full Copy Performance" shows the results from one series of tests, comparing full copy and minicopy times for shadow sets over a spectrum of write activity. The results presented in *Table 7.1, "Comparison of Minicopy and Full Copy Performance"* and *Table 7.2, "Comparison of Minicopy and Hardware-Assist (DCD) Copy Performance"* should be used only as an indication of the performance gain you may experience using minicopy.

Table 7.1. Comparison of Minicopy and Full Copy Performance

Percentage of Bits Set	Time for Full Copy (seconds)	Time for Minicopy (seconds)	Minicopy Time as Percentage of Full Copy Time
100%	4196.09	3540.21	84.4%
90%	3881.95	3175.92	81.8%

Percentage of Bits Set	Time for Full Copy (seconds)	Time for Minicopy (seconds)	Minicopy Time as Percentage of Full Copy Time
80%	3480.50	2830.47	81.3%
75%	3290.67	2614.87	79.5%
70%	3194.05	2414.03	75.6%
60%	2809.06	2196.60	78.2%
50%	2448.39	1759.67	71.9%
40%	2076.52	1443.44	69.5%
30%	1691.51	1039.90	61.5%
25%	1545.94	775.35	50.2%
20%	1401.21	682.67	48.7%
15%	1198.80	554.06	46.2%
10%	1044.33	345.78	33.1%
5%	905.88	196.32	21.7%
2%	712.77	82.79	11.6%
1%	695.83	44.90	6.5%

Table 7.2, "Comparison of Minicopy and Hardware-Assist (DCD) Copy Performance" shows the results from another series of tests, comparing performance times of a hardware assisted copy (using MSCP disk copy data (DCD) commands on an HSJ controller) with a minicopy over a spectrum of write activity.

Table 7.2. Comparison of Minicopy and Hardware-Assist (DCD) Copy Performance

Percentage of Bits Set	DCD Copy Time (seconds)	Minicopy Time (seconds)	Minicopy Time as Percentage of DCD Copy Time
100%	1192.18	1181.61	99.1%
90%	1192.18	1097.03	92.0%
80%	1192.18	979.06	82.1%
70%	1192.18	862.66	72.4%
60%	1192.18	724.61	60.8%
50%	1192.18	627.24	52.6%
40%	1192.18	490.70	41.2%
30%	1192.18	384.45	32.3%
20%	1192.18	251.53	21.1%
10%	1192.18	128.11	10.7%
5%	1192.18	71.00	6.0%
0%	1192.18	8.32	0.7%

7.4. Procedure for Using Minicopy

To use the minicopy operation:

1. Start a write bitmap.

   A write bitmap is started by specifying the new qualifier **/POLICY=MINICOPY[=OPTIONAL]** to the **DISMOUNT** command when removing a member from a shadow set. You can also start a write bitmap with the **MOUNT** command when mounting a shadow set less one or two members, as described in *Section 7.6.2, "Creating a Bitmap With MOUNT"*.

2. Use the bitmap for a minicopy operation when you return the shadow set member to the shadow set.

   If a write bitmap exists for the shadow set, a minicopy operation is invoked by default by the following **MOUNT** command:

   ```
   $ MOUNT DSA42/SHAD=$4$DUA42 volume-label
   ```

   To guarantee that only a minicopy takes place, use the **/POLICY=MINICOPY** qualifier, as shown in the following example:

   ```
   $ MOUNT DSA42/SHAD=$4$DUA42 volume-label/POLICY=MINICOPY
   ```

   If a write bitmap does not exist for a minicopy, the mount fails.

   When a minicopy operation is completed, the write bitmap associated with the disk is deleted.

For a detailed description of how to use **/POLICY=MINICOPY[=OPTIONAL]** with the **MOUNT** and **DISMOUNT** commands, see *Section 7.6, "Creating Bitmaps"* and *Section 7.7, "Starting a Minicopy Operation"*.

7.5. Write Bitmaps and Dissimilar Device Shadowing Caution

DDS allows you to construct shadow sets of disk devices that are of dissimilar sizes.

Write bitmaps track application writes made to a shadow set virtual unit so that a member can be returned to that virtual unit without the overhead of a full copy. A write bitmap is created when the user issues a **DISMOUNT/POLICY=MINICOPY** command for a shadow set member or mounts a shadow set using the **MOUNT/POLICY=MINICOPY** command. When this bitmap is created, its size depends on the current size of the volume.

When a shadow set is mounted, the logical size of the shadow set virtual unit is set to the size of the smallest member unit. When a member of the shadow set is removed, the logical size of the virtual unit is recomputed based on the sizes of the remaining members of the set.

Consequently, the logical size of the virtual unit might increase.

When a write bitmap is created for a shadow set, its size is determined by the current size of the shadow set virtual unit. If the virtual unit's size subsequently increases, the bitmap does not cover the entire virtual unit. If the bitmap is then used to bring back a shadow set member with a minicopy operation, the portion of the virtual unit that is not covered by the bitmap is copied with a full copy operation.

The following example illustrates this problem:

- Shadow set DSA1: includes the following three members:

  1DGA20: (18 GB)

1DGA21: (36 GB)

1DGA22: (36 GB)

- 1DGA22: is removed from the shadow set with a minicopy bitmap using the following command:

  ```
  $ DISMOUNT/POLICY=MINICOPY $1$DGA22:
  ```

  The write bitmap is sized for 18 GB, the current size of the shadow set virtual unit.

- 1DGA20: is removed from the shadow set. To allow the file system to utilize the entire 36 GB of the remaining member, use the following command:

  ```
  $ SET VOLUME/SIZE DSA1
  ```

  1DGA20 can no longer be used in this shadow set because it is smaller than the new volume size.

- 1DGA22: is returned to the shadow set using the following command:

  ```
  $ MOUNT/SYSTEM DSA1:/SHADOW=$1$DGA22: label
  ```

  The logical size of DSA1: remains at 36 GB; however, the bitmap covers only the first 18 GB.

- The first 18 GB of 1DGA22: are copied using the minicopy bitmap; the remaining 18 GB are copied using a full copy operation.

If the removal of a smaller shadow set member is planned, removing it before removing a larger member with a minicopy bitmap causes a larger bitmap to be created and avoids the performance impact of a short bitmap. (In the preceding example, you would remove 1DGA20: before removing 1DGA22:.)

7.6. Creating Bitmaps

The DCL commands **DISMOUNT** and **MOUNT** are used for creating write bitmaps. The **MOUNT** command is used for starting a minicopy operation using a write bitmap (see *Section 7.7, "Starting a Minicopy Operation"*).

7.6.1. Creating a Bitmap With DISMOUNT

To create a bitmap, you must specify the **/POLICY=MINICOPY[=OPTIONAL]** qualifier with the **DISMOUNT** command. If you specify **/POLICY=MINICOPY=OPTIONAL**, a bitmap is created if there is sufficient memory. The disk is dismounted, regardless of whether a bitmap is created.

The following example shows the use of the **POLICY=MINICOPY=OPTIONAL** qualifier with the **DISMOUNT** command:

```
$ DISMOUNT $4$DUA1 /POLICY=MINICOPY=OPTIONAL
```

This command removes `$4$DUA1` from the shadow set and starts logging writes to a bitmap, if possible.

If you specify **/POLICY=MINICOPY** only (that is, if you omit =OPTIONAL) and there is not enough memory on the node to create a bitmap, the dismount fails.

7.6.2. Creating a Bitmap With MOUNT

You can create a bitmap with the **MOUNT** command under the following conditions:

- The shadow set that was previously mounted was correctly dismounted.

  A multiple member shadow set must have been mounted before on the same node, on another node in the same cluster, or on another node outside the cluster.

- The shadow set is not currently mounted on any other node in the cluster (if the node on which you are mounting the shadow set is in a cluster).

- When you mount the shadow set, you mount it minus one member.

- You specify the **/POLICY=MINICOPY[=OPTIONAL]** qualifier to the **MOUNT** command.

The bitmap created with this command is used for a minicopy operation when you later mount one of the former members of the shadow set into the set.

If you specify the **/POLICY=MINICOPY=OPTIONAL** qualifier and the shadow set is already mounted on another node in the cluster, the **MOUNT** command succeeds but a bitmap is not created.

7.7. Starting a Minicopy Operation

If a bitmap exists for a shadow set member, a minicopy operation starts by default when you specify the MOUNT command to return a shadow set member to the shadow set. This is equivalent to using the **/POLICY=MINICOPY=OPTIONAL** qualifier to the **MOUNT** command. If a bitmap is not available, a full copy occurs.

An example of using the **/POLICY=MINICOPY=OPTIONAL** qualifier with the **MOUNT** command follows:

```
$ MOUNT DSA5/SHAD=$4$DUA0/POLICY=MINICOPY=OPTIONAL volume_label
```

If the shadow set (DSA5) is already mounted and a bitmap exists for this shadow set member (4DUA0), the command adds the device 4DUA0 to the shadow set with a minicopy operation. If a bitmap is not available, this command adds 4DUA0 with a full copy.

To ensure that a **MOUNT** command succeeds only if a minicopy can take place, specify **/POLICY=MINICOPY** only (that is, omit =OPTIONAL). If a bitmap is not available, the mount will fail.

7.8. Master and Local Bitmaps

In an OpenVMS Cluster system, a **master bitmap** is created on the node that issues the **DISMOUNT** or **MOUNT** command that creates the bitmap. When a master bitmap is created, a **local bitmap** is automatically created on all other nodes in the cluster on which the shadow set is mounted, provided the nodes have sufficient memory.

A master bitmap contains a record of all the writes to the shadow set from every node in the cluster that has the shadow set mounted. A local bitmap tracks all the writes that the local node issues to a shadow set.

Note that if a node with a local bitmap writes to the same logical block number (LBN) of a shadow set more than once, only the LBN of the first is sent to the master bitmap. The minicopy operation uses the LBN for the update, not the number of changes to the same LBN.

When there is not enough memory on a node to create a local bitmap, the node sends a message for each directly to the master bitmap. This degrades application write performance.

7.9. Managing Bitmaps With DCL Commands

The **SHOW DEVICE**, **SHOW CLUSTER**, and **DELETE** commands have been extended for managing bitmaps.

7.9.1. Determining Bitmap Support and Activity

You can find out whether a write bitmap exists for a shadow set by using the DCL command **SHOW DEVICE/FULL *device-name***. If a shadow set supports write bitmaps, `device supports bitmaps` is displayed along with either `bitmaps active` or `no bitmaps active`. If the device does not support write bitmaps, no message pertaining to write bitmaps is displayed.

The following command example shows that no write bitmap is active:

```
$ SHOW DEVICE/FULL DSA0

Disk DSA0:, device type RAM Disk, is online, mounted, file-oriented device,
    shareable, available to cluster, error logging is enabled, device
 supports     bitmaps (no bitmaps active).

 Error count                0    Operations completed               47
 Owner process             ""    Owner UIC                      [SYSTEM]
 Owner process ID   00000000    Dev Prot          S:RWPL,O:RWPL,G:R,W
 Reference count            2    Default buffer size               512
 Total blocks            1000    Sectors per track                  64
 Total cylinders            1    Tracks per cylinder                32
 Volume label          "TST0"    Relative volume number              0
 Cluster size               1    Transaction count                   1
 Free blocks              969    Maximum files allowed             250
 Extend quantity            5    Mount count                         1
 Mount status          System    Cache name    "_$252$DUA721:XQPCACHE"
 Extent cache size         64    Maximum blocks in extent cache     96
 File ID cache size        64    Blocks currently in extent cache    0
 Quota cache size           0    Maximum buffers in FCP cache      404
 Volume owner UIC    [SYSTEM]    Vol Prot  S:RWCD,O:RWCD,G:RWCD,W:RWCD

  Volume Status:  ODS-2, subject to mount verification, file high-water
 marking, write-back caching enabled.

Disk $252$MDA0:, device type RAM Disk, is online, member of shadow set
 DSA0:.

 Error count                    0    Shadow member operation count
 128
 Allocation class             252


Disk $252$MDA1:, device type RAM Disk, is online, member of shadow set
 DSA0:.

 Error count                    0    Shadow member operation count
 157
```

```
 Allocation class             25
```

7.9.2. Displaying Bitmap IDs

You can find out the ID of each bitmap on a node with the DCL command **SHOW DEVICE/BITMAP *device-name***. The **/BITMAP** qualifier cannot be combined with other **SHOW DEVICE** qualifiers except **/FULL**. The **SHOW DEVICE/BITMAP** display can be brief or full; brief is the default.

If no bitmap is active, no bitmap ID is displayed. The phrase `no bitmaps active` is displayed.

The following example shows a **SHOW DEVICE/BITMAP** display:

```
$ SHOW DEVICE/BITMAP DSA1
Device     BitMap      Size     Percent of
 Name        ID       (Bytes)    Full Copy
DSA1:      00010001     652        11%
```

The following example shows a **SHOW DEVICE/BITMAP/FULL** display:

```
$ SHOW DEVICE DSA12/BITMAP/FULL
Device  Bitmap  Size   Percent of  Active Creation  Master  Cluster Local
 Delete  Bitmap
Name      ID   (bytes) Full Copy     Date/Time       Node    Size    Set
 Pending Name
DSA12: 00010001  652      11%      Yes  5-MAY-2000  13:30... 300F2   127
  2%     No   SHAD$TEST
```

Note

The bitmap name, which is only displayed when you specify **SHOW/DEVICE/FULL**, takes the form of SHAD$volume-name, followed by many (about 30) unreadable characters. These unreadable characters are used internally to represent the generation number of the bitmap, the time it was created, and other details. The bitmap name is only used internally. The bitmap ID is used by system managers.

7.9.3. Displaying Bitmap Status of Cluster Members

You can specify bitmap information in the **SHOW CLUSTER** display by issuing the **ADD BITMAPS** command, as shown in the following example:

```
$ SHOW CLUSTER/CONTINUOUS

Command > ADD BITMAPS
Command > ADD CSID

View of Cluster from system ID 57348  node: WPCM1   14-FEB-2000 13:38:53

      SYSTEMS                  MEMBERS
  NODE   SOFTWARE    CSID    STATUS    BITMAPS

 CSGF1   VMS X6TF    300F2   MEMBER    MINICOPY

 HSD30Y  HSD YA01    300E6

 HS1CP2  HSD V31D    300F4
```

```
 CSGF2   VMS X6TF    300D0   MEMBER    MINICOPY
```

In this example, `MINICOPY` means that nodes `CSGF1` and `CSGF2` are capable of supporting minicopy operations. If a cluster node does not support minicopy, the term `UNSUPPORTED` replaces `MINICOPY` in the display, and the minicopy function is disabled in the cluster.

7.9.4. Deleting Bitmaps

After a minicopy operation is completed, the corresponding bitmap is automatically deleted.

There may be times when you would like to delete one or more bitmaps. Reasons for deleting bitmaps include recovering the memory consumed by a bitmap and stopping the recording of the bitmap.

You can delete bitmaps with the DCL command **`DELETE`** with the **`/BITMAP`** qualifier. You use the bitmap qualifier to specify the ID of the bitmap you want to delete. For example:

```
$ DELETE/BITMAP/LOG 00010001
%DELETE-I-DELETED, 00010001 deleted
```

7.10. Performance Implications of Bitmaps

There are several aspects of bitmaps that affect performance; the message traffic that occurs between local and master bitmaps, the size requirements of each bitmap, asynchronous processing of SetBit messages, and reduced SetBit messages for sequential I\O.

The message traffic can be adjusted by changing the message mode. Single message mode is the default mode. Buffered message mode can improve the overall system performance, but the time to record the write of each process in the master bitmap usually takes longer. These modes are described in detail in *Section 3.4, "Bitmap System Parameters"*.

Note

Additional memory is required to support bitmaps, as described in *Section 1.3.1, "Memory Requirements"*. Depending on the memory usage of your system, it may require additional memory.

There can be multiple master bitmap nodes for a shadow set. In OpenVMS Version 8.3 and earlier, SetBit messages are sent to the multiple master bitmap nodes synchronously. Only when the response for the SetBit message is received from the first remote master bitmap node, is the message sent to the next master bitmap node. When this process completes for all the remote master bitmap nodes, the I/O resumes.

In OpenVMS Version 8.4, SetBit messages are sent to all multiple master bitmap nodes asynchronously. I/O resumes when the responses from all the master bitmap nodes are received, thus reducing I/O delay by the write bitmap code.

In earlier versions, if sequential writes are occurring to a disk, these writes often resulted in delivering Setbit messages that set sequential bits in the remote bitmap. In OpenVMS Version 8.4, the write bitmap code recognizes where a number of prior bits in the bitmap are set. In this case, additional bits are set so that if sequential writes should continue, fewer Setbit messages are required. Assuming that the sequential I/O continues, the number of Setbit messages are reduced by about a factor of 10, thus improving the I/O rate for sequential writes.

7.11. Guidelines for Using a Shadow Set Member for Backup

Volume Shadowing for OpenVMS can be used as an online backup mechanism. With proper application design and proper operating procedures, shadow set members removed from mounted shadow sets constitute a valid backup.

To obtain a copy of a file system or application database for backup purposes using Volume Shadowing for OpenVMS, the standard recommendation has been to determine that the virtual unit is not in a merge state, to dismount the virtual unit, then to remount the virtual unit minus one member.

However, VSI recognizes that this restriction is unacceptable when true 24/7 application availability is a requirement, and that it is unnecessary if appropriate data-consistency measures can be ensured through a combination of application software and system management practice.

7.11.1. Removing a Shadow Set Member for Backup

With currently supported OpenVMS releases, **`DISMOUNT`** can be used to remove members from shadow sets for the purpose of backing up data, provided that the following requirements are met:

- The shadow set *must not be in a merge state*. VSI also recommends that the shadow set not have a copy operation in progress.
- Adequate redundancy must be maintained after member removal. VSI recommends that the active shadow set never be reduced to less than two members; alternatively, the shadow sets should employ controller mirroring or RAID 5.

Follow these steps to remove the member:

1. Establish data consistency over the virtual units through system management procedures or application software, or both. This is a complex topic and is the subject of most of the rest of this chapter.
2. Ensure that the requirements regarding merge state and adequate redundancy are met.
3. Remove the members to be backed up from the virtual units.
4. Terminate the data consistency measures taken in step 1.

7.11.2. Data Consistency Requirements

Removal of a shadow set member results in what is called a **crash-consistent copy.** That is, the copy of the data on the removed member is of the same level of consistency as what would result if the system had failed at that instant. The ability to recover from a crash-consistent copy is ensured by a combination of application design, system and database design, and operational procedures. The procedures to ensure recoverability depend on application and system design and will be different for each site.

The conditions that might exist at the time of a system failure range from no data having been written, to writes that occurred but were not yet written to disk, to all data having been written. The following sections describe components and actions of the operating system that may be involved if a failure occurs and there are outstanding writes, that is, writes that occurred but were not written to disk. You must consider these issues when establishing procedures to ensure data consistency in your environment.

7.11.3. Application Activity

To achieve data consistency, application activity should be suspended and no operations should be in progress. Operations in progress can result in inconsistencies in the backed-up application data. While many interactive applications tend to become quiet if there is no user activity, the reliable suspension of application activity requires cooperation in the application itself. Journalling and transaction techniques can be used to address in-progress inconsistencies but must be used with extreme care. In addition to specific applications, miscellaneous interactive use of the system that might affect the data to be backed up must also be suspended.

7.11.4. RMS Considerations

Applications that use RMS file access must be aware of the following issues.

7.11.4.1. Caching and Deferred Writes

RMS can, at the application's option, defer disk writes to some time after it has reported completion of an update to the application. The data on disk will be updated in response to other demands on the RMS buffer cache and to references to the same or nearby data by cooperating processes in a shared file environment.

Writes to sequential files are always buffered in memory and are not written to disk until the buffer is full.

7.11.4.2. End of File

The end-of-file pointer of a sequential file is normally updated only when the file is closed.

7.11.4.3. Index Updates

The update of a single record in an indexed file may result in multiple index updates. Any of these updates can be cached at the application's option. Splitting a shadow set with an incomplete index update will result in inconsistencies between the indexes and data records. If deferred writes are disabled, RMS orders writes so that an incomplete index update may result in a missing update but never in a corrupt index. However, if deferred writes are enabled, the order in which index updates are written is unpredictable.

7.11.4.4. Run-Time Libraries

The I/O libraries of various languages use a variety of RMS buffering and deferred write options. Some languages allow application control over the RMS options.

7.11.4.5. $FLUSH

Applications can use the $FLUSH service to guarantee data consistency. The $FLUSH service guarantees that all updates completed by the application (including end of file for sequential files) have been recorded on the disk.

7.11.4.6. Journalling and Transactions

RMS provides optional roll-forward, roll-back, and recovery unit journals and supports transaction recovery using the OpenVMS transaction services. These features can be used to back out in-progress

updates from a removed shadow set member. Using such techniques requires careful data and application design. It is critical that virtual units containing journals be backed up along with the base data files.

7.11.5. Mapped Files

OpenVMS allows access to files as backing store for virtual memory through the process and global section services. In this mode of access, the virtual address space of the process acts as a cache on the file data. OpenVMS provides the $UPDSEC service to force updates to the backing file.

7.11.6. Database Systems

Database management systems, such as those from Oracle, are well-suited to backup by splitting shadow sets, since they have full journalling and transaction recovery built in. Before dismounting shadow set members, an Oracle database should be put into “backup mode” using SQL commands of the following form:

```
ALTER TABLESPACE tablespace-name BEGIN BACKUP;
```

This command establishes a recovery point for each component file of the tablespace. The recovery point ensures that the backup copy of the database can subsequently be recovered to a consistent state. Backup mode is terminated with commands of the following form:

```
ALTER TABLESPACE tablespace-name END BACKUP;
```

It is critical to back up the database logs and control files as well as the database data files.

7.11.7. Base File System

The base OpenVMS file system caches free space. However, all file metadata operations (such as create and delete) are made with a “careful write-through” strategy so that the results are stable on disk before completion is reported to the application. Some free space may be lost, which can be recovered with an ordinary disk rebuild. If file operations are in progress at the instant the shadow member is dismounted, minor inconsistencies may result that can be repaired with ANALYZE/DISK. The careful write ordering ensures that any inconsistencies do not jeopardize file Integrity server before the disk is repaired.

7.11.8. $QIO File Access and VIOC

OpenVMS maintains a virtual I/O cache (VIOC) to cache file data. However, this cache is write through. OpenVMS Version 7.3 introduces extended file cache (XFC), which is also write through.

File writes using the $QIO service are completed to disk before completion is reported to the caller.

7.11.9. Multiple Shadow Sets

Multiple shadow sets present the biggest challenge to splitting shadow sets for backup. While the removal of a single shadow set member is instantaneous, there is no way to remove members of multiple shadow sets simultaneously. If the data that must be backed up consistently spans multiple shadow sets, application activity must be suspended while all shadow set members are being dismounted. Otherwise, the data is not crash consistent across the multiple volumes. Command procedures or other automated techniques are recommended to speed the dismount of related shadow sets. If multiple shadow sets contain portions of an Oracle database, putting the database into backup mode ensures recoverability of the database.

7.11.10. Host-Based RAID

The OpenVMS software RAID driver presents a special case for multiple shadow sets. A software RAID set may be constructed of multiple shadow sets, each consisting of multiple members. With the management functions of the software RAID driver, it is possible to dismount one member of each of the constituent shadow sets in an atomic operation. Management of shadow sets used under the RAID software must always be done using the RAID management commands to ensure consistency.

7.11.11. OpenVMS Cluster Operation

All management operations used to attain data consistency must be performed for all members of an OpenVMS Cluster system on which the affected applications are running.

7.11.12. Testing

Testing alone cannot guarantee the correctness of a backup procedure. However, testing is a critical component of designing any backup and recovery process.

7.11.13. Restoring Data

Too often, organizations concentrate on the backup process with little thought to how their data is restored. Remember that the ultimate goal of any backup strategy is to recover data in the event of a disaster. Restore and recovery procedures must be designed and tested as carefully as the backup procedures.

Chapter 8. Host-Based Minimerge (HBMM)

This chapter describes minimerge operations, the conditions that cause this operation, and the difference between a minimerge and a full merge operation. It also provides the various policies and qualifiers associated and the guidelines for using HBMM. This chapter includes the following topics/sections:

- Overview of full merge and minimerge operations
- Overview of host-based minimerge (HBMM)
- HBMM policy specification syntax
- Rules governing HBMM policies
- Guidelines for establishing HBMM policies
- Configuring and managing HBMM
- Use of **/DEMAND_MERGE** when HBMM is enabled
- Visible impact of transient state events

8.1. Overview of Full Merge and Minimerge Operations

The purpose of either a full merge or a minimerge recovery operation is to compare data on shadow set members to ensure that all of them contain identical data on every logical block. Each block is identified by its logical block number (LBN). During recovery operations, application I/O continues but at a slower rate. A full merge or minimerge operation is managed by one of the OpenVMS systems that has the shadow set mounted. Throughout this manual, minimerge operation and merge operation refer to a minimerge recovery operation and a merge recovery operation, respectively.

A full merge or minimerge operation is initiated by any of the following events:

- A system failure that results in incomplete application writes.
- A shadow set that enters mount verification and then times out or aborts mount verification, under certain conditions (as described in *Section 8.1.2, "Merge Resulting from Mount Verification Timeout"*).
- A system manager issues a **SET SHADOW/DEMAND_MERGE** command.

8.1.1. Merge Resulting from a System Failure

When a system with a mounted shadow set fails, if a write request is made to a shadow set and the system fails before a completion status is returned to the application, the data might be inconsistent on the shadow set members:

- All members might contain the new data.

- All members might contain the old data.
- Some members might contain new data and others might contain old data.

The exact timing of the failure during the original write request determines the outcome. Volume Shadowing for OpenVMS ensures that corresponding LBNs on each shadow set member contain the same data (old or new), when the application issues a read to the shadow set.

Note

Volume Shadowing for OpenVMS guarantees that data is the same on all members of the shadow set, but it cannot guarantee that a write request in progress when a system failed is recorded on the shadow set. The volume might contain the data from the last write request, depending on when the failure occurred. In this regard, the shadow set does not differ from a non-shadowed device. The application must be designed to function properly in either case.

8.1.2. Merge Resulting from Mount Verification Timeout

A shadow set that enters mount verification and either times out or aborts mount verification enters a merge state, if the following conditions are true:

- There are outstanding write I/O requests in the shadow driver's internal queues on the system or systems on which it has timed out.
- The shadow set is mounted on other systems in the cluster.

The system on which the mount verification timed out (or aborted mount verification) notifies the other systems on which the shadow set is mounted that a merge operation is needed, and then it disables the shadow set. (It does not dismount it.)

For example, if a shadow set is mounted on eight systems and mount verification times out on two of them, those two systems check their internal queues for write I/O. If any write I/O is found, the shadow set is merged.

8.1.3. Merge Resulting from use of SET SHADOW/DEMAND_MERGE

The **SET SHADOW/DEMAND_MERGE** command initiates a merge of a specified shadow set or of all shadow sets. This qualifier is useful if the shadow set is created with the **INITIALIZE/SHADOW** command without using the **/ERASE** qualifier.

For more information about using the **SET SHADOW/DEMAND_MERGE** command, see the *VSI OpenVMS DCL Dictionary: N–Z*.

8.1.4. Comparison of Merge and Minimerge Operations

In a full merge operation, the members of a shadow set are compared with each other to ensure that they contain the same data. This is done by performing a block-by-block comparison of the entire volume. This can be a very lengthy procedure.

A minimerge operation is significantly faster. By using information about write operations that are logged in volatile controller storage or in a write bitmap on an OpenVMS system, volume shadowing merges only those areas of the shadow set where the write activity occurred. This avoids the need for the

entire volume scan that is required by full merge operations, thus reducing consumption of system I/O resources.

Minimerges existed as controller-based prior to the introduction of HBMM, and available only on the HSJ, HSC, and HSD controllers.

8.2. Overview of HBMM

HBMM depends on bitmaps and policies to provide the information required for minimerge operations. Depending on your computing environment, one HBMM policy, a DEFAULT policy that you specify, might be sufficient.

Before you can use HBMM for recovery of a shadow set, the following conditions must be in effect:

- An HBMM policy exists.
- An HBMM policy is assigned to a shadow set.
- The shadow set is mounted on one or more systems that are specified in the HBMM policy.

When a policy is assigned to a shadow set and the shadow set is mounted on several systems, bitmaps specific to that shadow set are created.

The systems selected from the master list, as specified in the HBMM policy definition, can perform a minimerge operation because they possess the master bitmaps. All other systems on which the shadow set is mounted possess a local bitmap for each master bitmap.

8.2.1. Bitmaps: Master and Local

For a given bitmap, there is one master version on a system in the cluster and a local version on every other system on which the shadow set is mounted. A minimerge operation can occur only on a system with a master bitmap. Multiple master bitmaps for the same shadow set are equivalent but they do have different bitmap IDs.

The following example shows two master bitmaps for `DSA12`, one on `RAIN` and one on `SNOW`, each with a unique bitmap ID:

```
$ SHOW DEVICE/BITMAP DSA12
Device          BitMap     Size     Percent     Type of   Master  Active
 Name             ID      (Bytes)  Populated    Bitmap     Node
DSA12:         00040013      4132      0.01%   Minimerge  RAIN    Yes
               00010014      4132      0.01%   Minimerge  SNOW    Yes
```

If only one master bitmap exists for the shadow set and the system with the master bitmap fails or is shut down, the remaining local bitmap versions are automatically deleted. Local bitmaps cannot be used for recovery.

If multiple master bitmaps are created for the shadow set and at least one remains, that master bitmap can be used for recovery. VSI recommends the use of multiple master bitmaps, especially for multiple-site cluster systems. Multiple master bitmaps increase the likelihood of an HBMM operation rather than a full merge in the event of a system failure.

Bitmaps require additional memory. The calculation is based on the shadow set volume size. For every gigabyte of storage of a shadow set mounted on a system, 2 KB of bitmap memory is required on that system for each bitmap. For example, a shadow set with a volume size of 200 GB of storage and 2 bitmaps uses 800 KB of memory on every system on which it is mounted.

8.2.2. HBMM Policies

An HBMM policy specifies the following attributes for one or more shadow sets:

- Names of systems that are eligible to host a master bitmap.
- Number of systems that host a master bitmap (not to exceed six). If this number is omitted in OpenVMS Version 8.3 and earlier, the first available six systems from the number of systems specified are selected. Starting from OpenVMS Version 8.4, you can have up to 12 systems in a shadow set and the first available 12 systems are used if the number is omitted.
- Threshold (in 512-byte blocks) at which the bitmaps are reset. If omitted, the threshold defaults to 1,000,000 blocks.

You can assign a name to a policy. However, the reserved names DEFAULT and NODEFAULT have specific properties that are described in *Section 8.4, "Rules Governing HBMM Policies"*. You can also create a policy without a name and assign it to a specific shadow set. An advantage of a named policy is that it can be reused by specifying only its name.

Multiple policies can be created to customize the minimerge operations in a cluster.

You can use the **SET SHADOW/POLICY** command with HBMM-specific qualifiers to define, assign, de-assign, and delete policies and to enable and disable HBMM on a shadow set. **SET SHADOW/POLICY** is the only user interface command for specifying HBMM policies. You cannot use the **MOUNT** command to define a policy.

You can define a policy before the shadow set is mounted. Policies can be assigned to shadow sets in other ways as well, as described in *Section 8.4, "Rules Governing HBMM Policies"*.

Three system parameters, namely, SHADOW_REC_DLY, SHADOW_PSM_DLY, and SHADOW_HBMM_RTC support HBMM. For more information about these system parameters, see the *Section 3.3, "Volume Shadowing Parameters"*.

8.3. HBMM Policy Specification Syntax

An HBMM policy specification consists of a list of HBMM policy keywords enclosed within parentheses. The HBMM policy keywords are MASTER_LIST, COUNT, and RESET_THRESHOLD. Of the three keywords, only MASTER_LIST must be specified. If COUNT and RESET_THRESHOLD are omitted, the default values are supplied. For examples of policy specifications, see *Section 8.6.1, "How to Define an HBMM Policy"* and the *VSI OpenVMS DCL Dictionary: N–Z*.

The use of these keywords and the rules for specifying them are described in this section.

```
MASTER_LIST=system-list
```

The MASTER_LIST keyword is used to identify a set of systems as candidates for a master bitmap. The system-list value can be a single system name; a parenthesized, comma-separated list of system names; or the asterisk (*) wildcard character. For example:

```
MASTER_LIST=node1
MASTER_LIST=(node1,node2,node3)
MASTER_LIST=*
```

When the system list consists of a single system name or the wildcard character, parentheses are optional.

An HBMM policy must include at least one MASTER_LIST. Multiple master lists are optional. If a policy has multiple master lists, the entire policy must be enclosed with parentheses, and each constituent master list must be separated by a comma, as shown in the following example:

```
(MASTER_LIST=(node1,node2), MASTER_LIST=(node3,node4))
```

There is no significance to the position of a system name in a master list.

```
COUNT=n
```

The COUNT keyword specifies the number of master bitmap systems to be chosen from the systems listed in a master system list. Therefore, the COUNT keyword must be associated with a specific master list by enclosing both with parentheses.

A COUNT value of n means that you want master bitmaps on any n systems in the associated master list. It does not necessarily mean that the first n systems in the list are chosen.

The COUNT keyword is optional. When omitted, the default value is the number of systems in the master list or the value of six, whichever is less. You cannot specify more than one COUNT keyword for any one master list.

The following two examples are valid policies:

```
(MASTER_LIST=(node1,node2,node3),COUNT=2)
(MASTER_LIST=(node1,node2,node3),COUNT=2),(COUNT=2,
 MASTER_LIST=(system4,system5,system6))
```

The following example is not valid because the COUNT keyword is not grouped with a specific master list:

```
(MASTER_LIST=(node1,node2 ), MASTER_LIST=(node4,node5 ), COUNT=1)
 RESET_THRESHOLD=n
```

The RESET_THRESHOLD keyword specifies the number of blocks that can be set before the bitmap is eligible to be cleared. Each bit that is set in a master bitmap corresponds to a set of blocks that needs to be merged. Therefore, the merge time can be influenced by this value.

Bitmaps are cleared when the RESET_THRESHOLD is exceeded, although the reset is not guaranteed to occur immediately when the threshold is crossed. For additional information about choosing a value for this attribute, see *Section 8.5.2, "Considerations for Setting a Bitmap RESET_THRESHOLD Value"* and *Section 3.3, "Volume Shadowing Parameters"*.

A single reset threshold value is associated with any given HBMM policy. Therefore, the RESET_THRESHOLD keyword cannot be specified more than once in a given policy specification. Because its scope is the entire policy, the RESET_THRESHOLD keyword cannot be specified inside a constituent master list when the policy uses multiple master lists.

When the RESET_THRESHOLD keyword is omitted, the value of 1,000,000 is used by default.

The following policy example includes an explicit reset threshold value:

```
(MASTER_LIST=*, COUNT=4, RESET_THRESHOLD=800000)
```

8.4. Rules Governing HBMM Policies

The following rules govern the creation and management of HBMM policies. The rules are based on the assumption that a shadow set is mounted on a system that supports HBMM.

Policies and Their Attributes

- A policy can be assigned to a shadow set by specifying only its attributes. The number of policies that you can assign in this way is limited only by the number of shadow sets that are supported on a system.
- A shadow set can have only one HBMM policy assigned to it at a time.
- Policies are in effect clusterwide.
- Policy names must conform to the following rules:
  - A policy name can range from 1 to 64 characters in length and is case-insensitive.
  - Only letters, numbers, the dollar sign ($), and the underscore (_) are allowed.
- A policy name must be specified in full; abbreviations are not allowed.
- A named policy can be assigned to a shadow set only by the **SET SHADOW/POLICY=HBMM=*policy-name*** command.
- The limit on user-defined, named policies is 128.

DEFAULT and NODEFAULT Policies

The named policies DEFAULT and NODEFAULT have special properties, as summarized in the following sections:

- DEFAULT
  - A DEFAULT policy is useful if the majority of the shadow sets in a cluster are expected to use an identical policy.
  - You can create a DEFAULT policy by defining a named policy with the reserved name DEFAULT. No predetermined DEFAULT policy is provided by VSI.
  - When a policy with the reserved name of DEFAULT is defined, this policy is assigned to a shadow set by any of the following operations:
    - Mount of a shadow set without an assigned policy

      The DEFAULT policy, if defined, is applied to a shadow set in the absence of an assigned policy (including the NODEFAULT policy). For example, when shadow set DSA1 is mounted on an HBMM-capable system, an attempt is made to apply an HBMM policy, if one exists, that is specific to DSA1. (To verify whether a device-specific policy exists and to display specific policies, see *Section 8.6.9, "How to Display Policies"*.)

      If a policy is not defined specifically for DSA1, an attempt is made to apply the DEFAULT policy. If the DEFAULT policy exists, the attributes of that policy are applied to DSA1.
    - End of merge of a shadow set without an assigned policy
    - Use of **SET SHADOW/ENABLE=HBMM** command
  - If a shadow set has a policy assignment and that policy assignment is deleted, it is then eligible for the DEFAULT policy, if one is established for your cluster.

- NODEFAULT Policy
  - The NODEFAULT policy specifies that the shadow set to which it is applied does not use HBMM; no HBMM bitmaps are created anywhere in the cluster for this shadow set.
  - In a cluster where a DEFAULT policy has been defined, the NODEFAULT policy can be used to prevent specific shadow sets from receiving the default policy.
  - The NODEFAULT policy cannot be deleted or redefined.

Assignment and Activation of a Policy

- A policy can be assigned to a shadow set before the shadow set is mounted on any system in the cluster.
- If a policy has been assigned, it is activated by the first mount of a shadow set on a bitmap master system.
- Assigning a policy implicitly enables HBMM on a mounted shadow set if it is mounted on a system that can create a master bitmap. Consider DSA1 that is mounted on system MAPLE.

  When DSA1 is mounted, no HBMM policy is set for DSA1, nor is there a DEFAULT policy that can be applied. Later, the following command is used:

  ```
  $ SET SHADOW DSA1:/POLICY=HBMM=(MASTER=(MAPLE), COUNT=1)
  ```

  Because `DSA1` is already mounted on system `MAPLE`, HBMM is enabled as a result of the policy assignment (see *Section 8.6.2, "How to Assign an HBMM Policy to a Shadow Set"*).
- Any attempt to enable HBMM using **`SET SHADOW DSA`*`n`*` /ENABLE=HBMM`** returns a failure if a shadow set is not mounted on a system that has a master bitmap, or if the policy has not been defined.
- As new systems join the cluster, they inherit the policies in existence in that cluster.

Changes to Policies

- Named policies can be created, changed, and deleted at will. Changes made to a named policy are not inherited by any mounted shadow set assigned the previous version of that named policy.
- The assignment of a policy to a mounted shadow set cannot be changed while HBMM is enabled for that shadow set. HBMM must first be disabled on that shadow set, and then a different policy can be assigned to it.
- Any policy change is clusterwide.

Life of a Policy

- All policies remain in effect in a cluster as long as at least one system remains active. However, if all systems are shut down, all policy definitions and assignments are deleted. The policies must be defined and assigned again when the systems form the cluster. Therefore, VSI recommends that you define your desired HBMM policies in your system startup procedures before you mount your shadow sets.

- Policy assignments persist across the disabling of HBMM or the dismounting of the shadow set as long as at least one system in the cluster remains active.

8.5. Guidelines for Establishing HBMM Policies

Establishing HBMM policies is likely to be an ongoing process as configurations change and as you learn more about how HBMM works and how it affects various operations on your systems. This section describes a number of considerations to help you determine what policies are appropriate for your configuration.

The settings depend on your hardware and software configuration, the computing load, and your operational requirements. These guidelines can assist you when selecting the initial settings for your configuration. As you observe the results in your configuration, you can make further adjustments to suit your computing environment.

8.5.1. Selecting the Systems to Host Master Bitmaps

There are several factors you must consider when selecting the number of master bitmaps to specify in a policy and the systems that host the master bitmaps. The first issue is how many master bitmaps must be used in the configuration. For OpenVMS Version 8.3 and earlier, six is the maximum number of HBMM master bitmaps per shadow set. Starting from OpenVMS Version 8.4, 12 is the maximum per shadow set. The use of each additional master bitmap has a slight impact on write performance and also consumes memory on each system (as described in *Section 8.2.1, "Bitmaps: Master and Local"*).

Using only one master bitmap creates a single point of failure; if the system hosting the master bitmap fails, then this shadow set undergoes a full merge. Therefore, the memory consumption must be weighed against the adverse effects of a full merge. Multiple master bitmaps provide the greatest defense against performing full merges.

Another issue when selecting a system to host the master bitmap is the I/O bandwidth of the various systems. Keep in mind that minimerges are always performed on a system that has a master bitmap. Therefore, low-bandwidth systems, such as satellite cluster members, are not good candidates.

The disaster tolerance of the configuration is also important in the decision process. Specifying systems to host master bitmaps at multiple sites help ensure that a minimerge is performed if connectivity to an entire site is lost. A two-site configuration must ensure that half the master bitmap systems are at each site, and a three-site configuration must ensure that one third of the master bitmaps are at each of the three sites.

8.5.2. Considerations for Setting a Bitmap RESET_THRESHOLD Value

When selecting a threshold reset value, you must balance the effects of bitmap resets on I/O performance with the time it takes to perform HBMM minimerges. The goal is to set the reset value as low as possible (thus decreasing merge times) while not affecting application I/O performance. Too low a value degrades I/O performance. Too high a value causes merges to take extra time.

HBMM bitmaps keep track of writes to a shadow set. The more bits that are set in the bitmap, the greater the amount of merging that is required in the event of a minimerge. HBMM clears the bitmap (after ensuring that all outstanding writes have completed so that the members are consistent) when

certain conditions are met (see the description of SHADOW_HBMM_RTC in *Section 3.3, "Volume Shadowing Parameters"*). A freshly cleared bitmap, with few bits set, performs a minimerge faster.

The bitmap reset, however, can affect I/O performance. Before a bitmap reset can occur, all write I/O to the shadow set must be paused and any write I/O that is in progress must be completed. Then the bitmap is cleared. This is performed on all systems on a per shadow set basis. Therefore, avoid a reset threshold setting that causes frequent resets.

You can view the number of resets performed by using the **SHOW SHADOW** command. The HBMM Reset Count appears in the last section of the display, as shown in the following example:

```
$ SHOW SHADOW DSA1031


_DSA1031:    Volume Label: HBMM1031
  Virtual Unit State: Steady State
  Enhanced Shadowing Features in use:
        Host-Based Minimerge (HBMM)

  VU Timeout Value     3600   VU Site Value      0
  Copy/Merge Priority  5000   Mini Merge   Enabled
  Served Path Delay    30

  HBMM Policy
    HBMM Reset Threshold: 1000000
    HBMM Master lists:
      Up to any 2 of the systems: LEMON, ORANGE
      Any 1 of the systems: MELON, PEACH
    HBMM bitmaps are active on LEMON, MELON, ORANGE
  HBMM Reset Count 2 Last Reset 13-JUL-2004 10:13:53.90
    Modified blocks since last bitmap reset: 11181
.
.
.
$
```

Writes that need to set bits in the bitmap are slightly slower than writes to areas that are already marked as having been written. Therefore, if many of the writes to a particular shadow set are concentrated in certain “hot” files, the reset threshold must be made large enough so that the same bits are not constantly set and then cleared.

On the other hand, if the reset threshold is too large, then the advantages of HBMM are reduced. For example, if 50% of the bitmap is populated (that is, 50% of the shadow set has been written to since the last reset), the HBMM merge takes approximately 50% of the time of a full merge.

You can change the RESET_THRESHOLD value while a policy is in effect by specifying the same policy with a different RESET_THRESHOLD value. (The syntax for specifying a policy, including the RESET_THRESHOLD keyword, is described in *Section 8.3, "HBMM Policy Specification Syntax"*.)

The following example shows how to:

- Display status information about shadow set DSA3233
- Create and assign an unnamed policy to DSA3233
- Confirm that the policy is assigned to DSA3233
- Change the RESET_THRESHOLD value of the assigned policy

- Confirm that the change to RESET_THRESHOLD is in effect

```
$!
$! To display status information about DSA3233
$!
$ Show Shadow DSA3233
_DSA30:   Volume Label: OSCAR
  Virtual Unit State:   Steady State
  Enhanced Shadowing Features in use:
        Host-Based Minimerge (HBMM)
        Extended Memberships
  VU Timeout Value      3600    VU Site Value          0
  Copy/Merge Priority   3233    Mini Merge       Enabled
  Recovery Delay Per Served Member                    30
  Merge Delay Factor     200    Delay Threshold      200
  Device $1$DGA32
    Read Cost              2    Site 0
    Member Timeout       120
  Device $1$DGA33              Master Member
    Read Cost              2    Site 0
    Member Timeout       120
$!
$! To create a policy and assign it to DSA3233
$!
$ SET SHADOW/POLICY=HBMM=(master_list=(ATHRUZ,ATWOZ,A2ZIPF),count=2,-
reset_threshold=420000) DSA3233:
$!
$! To confirm that the policy was assigned to DSA3233
$!
$ Show Shadow DSA3233
_DSA3233:   Volume Label: DSA3233
  Virtual Unit State:     Steady State
  Enhanced Shadowing Features in use:
        Host-Based Minimerge (HBMM)
  VU Timeout Value     3600   VU Site Value    0
  Copy/Merge Priority  3233   Mini Merge       Enabled
  Recovery Delay Per Served Member             30
  Merge Delay Factor   200    Delay Threshold  200
  HBMM Policy
    HBMM Reset Threshold: 420000
    HBMM Master lists:
      Up to any 2 of the nodes: ATHRUZ,ATWOZ,A2ZIPF
    HBMM bitmaps are active on ATHRUZ,ATWOZ
    Modified blocks since bitmap creation: 0
  Device $1$DGA32
    Read Cost          2   Site 0
    Member Timeout   120
  Device $1$DGA33          Master Member
    Read Cost          2   Site 0
    Member Timeout   120
$!
$! To change the Reset Threshold value
$!
$ SET SHAD/POLICY=HBMM=(master_list=(ATHRUZ,ATWOZ,A2ZIPF),count=2, -
reset_threshold=840000) DSA3233:
$!
$! To confirm the change to the Reset Threshold value
$!
```

```
$ Show Shadow DSA3233
_DSA3233:   Volume Label: DSA3233
  Virtual Unit State:     Steady State
  Enhanced Shadowing Features in use:
        Host-Based Minimerge (HBMM)
  VU Timeout Value     3600   VU Site Value         0
  Copy/Merge Priority  3233   Mini Merge      Enabled
  Recovery Delay Per Served Member                30
  Merge Delay Factor    200   Delay Threshold    200
  HBMM Policy
    HBMM Reset Threshold: 840000
    HBMM Master lists:
      Up to any 2 of the nodes: ATHRUZ,ATWOZ,A2ZIPF
    HBMM bitmaps are active on ATHRUZ,ATWOZ
    Modified blocks since bitmap creation: 0
  Device $1$DGA32
    Read Cost           2    Site 0
    Member Timeout    120
  Device $1$DGA33             Master Memeber
    Read Cost           2    Site 0
    Member Timeout    120
```

8.5.3. Using Multiple Policies

HBMM policies are defined to implement decisions regarding master bitmaps. Some sites might find that a single policy can effectively implement the decisions. Other sites might require greater granularity and therefore implement multiple policies.

Multiple policies are required when the cluster includes enough high-bandwidth systems that you want to ensure that the merge load is spread out. Note that minimerges occur only on systems that host a master bitmap. Therefore, if 12 systems with high bandwidth are set up to perform minimerge or merge operations (the system parameter SHADOW_MAX_COPY is greater than zero on all systems), you must ensure that the master bitmaps are spread out among these high-bandwidth systems.

Multiple HBMM policies are also useful when shadow sets need different bitmap reset thresholds. The list of master bitmap systems can be the same for each policy, but the threshold can differ.

8.6. Configuring and Managing HBMM

This section describes the major tasks for configuring and managing HBMM.

8.6.1. How to Define an HBMM Policy

The **SET SHADOW/POLICY=HBMM** command is used to define HBMM policies. You can define multiple policies for your environment. The following examples show how to define two policies, a DEFAULT policy and POLICY_1, a named policy.

To define the policy named DEFAULT:

```
$ SET SHADOW/POLICY=HBMM=(MASTER_LIST=*)/NAME=DEFAULT
```

In this example, a DEFAULT policy is created for the cluster. The use of the asterisk wildcard (*) means that any system can host a master bitmap. The omission of the keyword COUNT=n means that up to six systems (the default value and the current maximum supported) can host a master bitmap. The DEFAULT policy is inherited at mount time by shadow sets that have not been assigned a named policy.

The following example defines a named policy (POLICY_1), specifies the systems that are eligible to host a master bitmap, limits to two the number of systems to host a master bitmap, and specifies a higher threshold (default is 1,000,000 blocks) to be reached before clearing the bitmap.

```
$ SET SHADOW /POLICY=HBMM=( -
_$ (MASTER_LIST=(NODE1,NODE2,NODE3), COUNT=2), -
_$ RESET_THRESHOLD=1250000) -
_$ /NAME=POLICY_1
```

In OpenVMS Version 8.4, if you are using the DISMOUNT keyword, you can have up to 12 HBMM master bitmaps. For DISMOUNT keyword examples, see the *Section 8.10.2, "Examples of Multiuse and Dismount"*.

For the complete DCL syntax of the SET SHADOW/POLICY=HBMM command, see the *VSI OpenVMS DCL Dictionary: N–Z*.

8.6.2. How to Assign an HBMM Policy to a Shadow Set

You can assign a policy, named or unnamed, to a shadow set. To assign an existing named policy, use the following command:

```
$ SET SHADOW DSAn:/POLICY=HBMM=policy-name
```

To assign an unnamed policy to a shadow set, use the same command, but in place of the policy name, specify the attributes of the policy you want to use. For example:

```
$ SET SHADOW DSA1:/POLICY=HBMM=(MASTER_LIST=(NODE1, NODE2, NODE3), COUNT=2)
```

In this example, the default bitmap reset value of 1,000,000 blocks takes effect because the RESET_THRESHOLD keyword is omitted.

8.6.3. How to Activate HBMM on a Shadow Set

HBMM is automatically activated on a shadow set under the following conditions:

- An HBMM policy exists for a given shadow set, which is mounted on one or more systems defined in the master list.
- An HBMM policy is created for a mounted shadow set and at least one system that has it mounted is defined in the master list.

You can also activate HBMM using the **SET SHADOW/ENABLE=HBMM** command, provided a policy exists and the shadow set is mounted on a system defined in the master list of the shadow set policy, and the count has not been exceeded.

8.6.4. How to Disable HBMM on a Shadow Set

To disable HBMM on a shadow set, use the following command:

```
$ SET SHADOW DSAn:/DISABLE=HBMM
```

Reasons for disabling HBMM on a shadow set include:

- Changing the policy assigned to it.
- Deleting the policy assigned to it.

- Mounting the shadow set on a system that does not support HBMM. You must disable HBMM first and then dismount it from all the HBMM-capable systems on which it is mounted before you can mount it on a system that does not support HBMM.

HBMM remains disabled until you either re-enable it or define a new policy for the shadow set.

8.6.5. How to Remove a Policy Assignment from a Shadow Set

Before removing a policy assignment from a shadow set, HBMM must be disabled, if active. You can remove a policy assignment from a shadow set by entering the following command:

```
$ SET SHADOW DSAn:/POLICY=HBMM/DELETE
```

This command removes any policy set for this shadow set, making the shadow set eligible for the DEFAULT policy. If a DEFAULT policy exists, it is assigned the next time the shadow set is eligible for a policy, for example, at the end of a merge or when you issue the **SET SHADOW/ENABLE=HBMM** command.

8.6.6. How to Change a Policy Assignment of a Shadow Set

To change a policy assigned to a shadow set, you must first disable HBMM, as described in *Section 8.6.4, "How to Disable HBMM on a Shadow Set"*, and then assign another policy to the shadow set. To apply a different policy, specify the policy name or specify the policy attributes (thereby creating an "unnamed" policy), as described in *Section 8.6.2, "How to Assign an HBMM Policy to a Shadow Set"*. Specifying a new policy (or policy attributes) for a shadow set replaces the previous policy. The use of the command shown in *Section 8.6.5, "How to Remove a Policy Assignment from a Shadow Set"* is not required when you are changing the policy assignment.

8.6.7. How to Delete a Named Policy from the Cluster

You can delete a named policy with the **/DELETE** qualifier, as shown in the following example:

```
$ SET SHADOW /POLICY=HBMM/NAME=policy-name/DELETE
```

This command deletes the specified policy, which takes effect across the cluster. It does not delete the policy from any shadow set to which it is already assigned.

Note

You cannot delete the NODEFAULT policy.

8.6.8. How to Apply a Changed DEFAULT Policy

The DEFAULT policy can be changed at any time. However, if a previous definition of the DEFAULT policy is assigned to a shadow set, a subsequent change to the definition of the DEFAULT policy is not retroactively applied to that shadow set. In this regard, the DEFAULT policy behaves just like any other named policy.

This section shows how to apply a changed DEFAULT policy.

Initially, the following DEFAULT policy is assigned to DSA20 when it is mounted, as shown by the following example:

```
$ SET SHADOW/POLICY=HBMM=(MASTER=(NODE1,NODE2,NODE3),COUNT=2)/NAME=DEFAULT
$ MOUNT/SYSTEM DSA20:/SHADOW=($1$DGA20,$1$DGA21) VOL_20
```

Subsequently, the DEFAULT policy is redefined by the following command. This redefined policy allows any node in the cluster to be eligible for an HBMM master bitmap:

```
$ SET SHADOW/POLICY=HBMM=(MASTER=*,COUNT=2)/NAME=DEFAULT
```

You can apply the redefined DEFAULT policy to DSA20 using the following commands:

```
$ SET SHADOW DSA20:/DISABLE=HBMM
$ SET SHADOW DSA20:/POLICY=HBMM/DELETE
$ SET SHADOW DSA20:/ENABLE=HBMM
```

Note

You must explicitly delete the HBMM policy assigned to DSA20 in order for DSA20 to become eligible for the current DEFAULT policy. This step is required because, when HBMM is disabled on DSA20, the policy (MASTER=(NODE1,NODE2,NODE3),COUNT=2) remains assigned to DSA20.

An alternative way to apply the updated DEFAULT policy to DSA20 is to take advantage of the fact that the DEFAULT policy is a named policy. This method requires only two commands, as shown:

```
$ SET SHADOW DSA20:/DISABLE=HBMM
$ SET SHADOW DSA20:/POLICY=HBMM=DEFAULT
```

8.6.9. How to Display Policies

You can display policies using the **SHOW SHADOW** command. You can display:

- The policy assigned to a specified shadow set
- The definition of a named policy
- All shadow sets in a cluster with policy assignments, together with the definition of each policy
- All named policies and their definitions that exist on a cluster

Displaying the Policy of a Specific Shadow Set

To display the policy assigned to a specific shadow set, issue the following command:

```
$ SHOW SHADOW DSAn:/POLICY=HBMM
```

An example of the resulting output:

```
$ SHOW SHADOW DSA999:/POLICY=HBMM
HBMM Policy for device _DSA999:
HBMM Reset Threshold: 1000000
HBMM Master lists:
Up to any 2 of the nodes: NODE1,NODE2,NODE3
Any 1 of the nodes: NODE4,NODE5
Up to any 2 of the nodes: NODE6,NODE7,NODE8
```

Displaying the Definition of a Named Policy

To display the definition of a named policy, issue the following command:

```
$ SHOW SHADOW/POLICY=HBMM/NAME=policy-name
```

The following display shows the definition of the PEAKS_ISLAND policy:

```
$ SHOW SHADOW/POLICY=HBMM/NAME=PEAKS_ISLAND
HBMM Policy PEAKS_ISLAND
HBMM Reset Threshold: 750000
HBMM Master lists:
Up to any 2 of the nodes: NODE1,NODE2,NODE3
Any 1 of the nodes: NODE4,NODE5
Up to any 2 of the nodes: NODE6,NODE7,NODE8
```

Displaying All Shadow Sets with Policy Assignments

To display all shadow sets in a cluster with policy assignments, along with the definition of each policy, use the following command:

```
$ SHOW SHADOW/POLICY=HBMM
```

The following display results from this command:

```
$ SHOW SHADOW/POLICY=HBMM
HBMM Policy for device _DSA12:
HBMM Reset Threshold: 1000000
HBMM Master lists:
Up to any 2 of the nodes: NODE1,NODE2
HBMM bitmaps are active on NODE1,NODE2
Modified blocks since bitmap creation: 254

HBMM Policy for device _DSA30:
HBMM Reset Threshold: 1000000
HBMM Master lists:
Up to any 2 of the nodes: FLURRY,FREEZE,HOTTUB

HBMM Policy for device _DSA99:
HBMM Reset Threshold: 1000000
HBMM Master lists:
Up to any 2 of the nodes: NODE1,NODE2,NODE3
Any 1 of the nodes: NODE4,NODE5
Up to any 2 of the nodes: NODE6,NODE7,NODE8

HBMM Policy for device _DSA999:
HBMM Reset Threshold: 1000000
HBMM Master lists:
Up to any 2 of the nodes: NODE1,NODE2,NODE3
Any 1 of the nodes: NODE4,NODE5
Up to any 2 of the nodes: NODE6,NODE7,NODE8
```

Displaying All Named Policies on a Cluster

To display the named policies that exist on a cluster, along with their definitions, issue the following command:

```
$ SHOW SHADOW/POLICY=HBMM/NAME
```

The named policies are displayed in the order in which they were created. The following display results from this command:

```
$ SHOW SHADOW/POLICY=HBMM/NAME
```

```
HBMM Policy DEFAULT
HBMM Reset Threshold: 1000000
HBMM Master lists:
Up to any 6 nodes in the cluster

HBMM Policy PEAKS_ISLAND
HBMM Reset Threshold: 1000000
HBMM Master lists:
Up to any 2 of the nodes: NODE1,NODE2,NODE3
Any 1 of the nodes: NODE4,NODE5
Up to any 2 of the nodes: NODE6,NODE7,NODE8

HBMM Policy POLICY_1
HBMM Reset Threshold: 1000000
HBMM Master lists:
Up to any 2 of the nodes: NODE1,NODE2,NODE3
Any 1 of the nodes: NODE4,NODE5

HBMM Policy ICE_HOTELS
HBMM Reset Threshold: 1000000
HBMM Master lists:
Up to any 2 of the nodes: QUEBEC,ICELND,SWEDEN
Any 1 of the nodes: ALASKA,GRNLND
```

8.6.10. How to Display the Merge Status of Shadow Sets

You can check the merge status of each shadow set member by issuing the SHOW SHADOW/MERGE DSAn command. The **/MERGE** qualifier returns one of the following messages:

- Merge is not required.
- Merge is pending.
- Merge is in progress on node file-name.

An example of the display produced by the **SHOW SHADOW/MERGE DSA*n*** command:

```
$ SHOW SHADOW/MERGE
Device    Volume     Device
 Name      Label     Status
_DSA1010  MINIMERGE  Merging (10%)
```

If a copy operation (instead of the merge operation) is currently active, the display shows the percentage of the merge that has completed and the percentage of the copy that has completed with the designation `Copy Active`, as follows:

```
$ SHOW SHADOW/MERGE
Device    Volume   Device
 Name      Label   Status
_DSA1010  FOOBAR   Merging (23%), Copy Active (77%) on CSGF1
```

8.6.11. How to Prevent Merge Operations on a System

You can prevent merge operations on a system in two ways:

- Set SHADOW_MAX_COPY to zero.
- Set the priority for merge and copy operations to zero for every shadow set mounted on the system using the **SET SHADOW/PRIORITY=0 DSA*n*** command for each shadow set.

8.6.12. Considerations for Multiple-Site OpenVMS Cluster Systems

Only systems that have an HBMM master bitmap for a particular shadow set are able to perform HBMM recovery on that shadow set. If a merge recovery is required on a shadow set and no systems in the cluster have an HBMM master bitmap for that shadow set, a full merge is performed.

Therefore, to minimize the need to perform a full merge, you must use policies that maintain at least one HBMM master bitmap at each site in a multiple-site OpenVMS Cluster system. The ability to specify multiple master lists in an HBMM policy is designed for this purpose. You must specify a separate MASTER_LIST for each site.

For example, consider a three-site OpenVMS Cluster system with 12 cluster members:

- Site 1: Member systems NYN1, NYN2, NYN3, and NYN4
- Site 2: Member systems CTN1, CTN2, CTN3, and CTN4
- Site 3: Member systems NJN1, NJN2, NJN3, and NJN4

The following definition of a DEFAULT policy provides up to two HBMM master bitmaps at each site:

```
$ SET SHADOW/NAME=DEFAULT/POLICY=HBMM=( -
_$ (MASTER_LIST=(NYN1,NYN2,NYN3,NYN4), COUNT=2), -
_$ (MASTER_LIST=(CTN1,CTN2,CTN3,CTN4), COUNT=2), -
_$ (MASTER_LIST=(NJN1,NJN2,NJN3,NJN4), COUNT=2) )
```

Specifically, this policy requests master bitmaps at any two of the systems in the first master list, any two of the systems in the second master list, and any two of the systems in the third master list.

Note that you cannot accomplish this type of distribution by listing the systems in a particular order within a single MASTER_LIST. This is because the order in which the systems are specified in a master list does not affect the order in which the systems are considered when HBMM master bitmaps are created. If an event occurs that requires the creation of an HBMM master bitmap, the bitmap is created in a random order by systems that have the shadow set mounted. In the following example, the likelihood of system NYN1 getting a master bitmap is the same for either POLICY_A or POLICY_B:

```
$ SET SHADOW/NAME=POLICY_A/POLICY=HBMM=( -
_$ (MASTER_LIST=(NYN1,CTN1,NJN1,NYN2,CTN2,NJN2),COUNT=3) )

$ SET SHADOW/NAME=POLICY_B/POLICY=HBMM=( -
_$ (MASTER_LIST=(NJN2,CTN2,NYN2,NJN1,CTN1,NYN1),COUNT=3) )
```

8.7. Use of /DEMAND_MERGE When HBMM Is Enabled

If a shadow set is HBMM-enabled and is actively using HBMM, then the **SET SHADOW/DEMAND_MERGE DSA*n*:** command causes a minimerge operation to occur. To

force a full merge instead of a minimerge operation, you must disable HBMM on the shadow set before issuing the **SET SHADOW/DEMAND_MERGE DSA*n*:** command. For information about disabling HBMM, see *Section 8.6.4, "How to Disable HBMM on a Shadow Set"*.

The **/DEMAND_MERGE** qualifier of the **SET SHADOW** command is used primarily to force a merge operation on shadow sets that are created with the **INITIALIZE/SHADOW** command without specifying the **/ERASE** qualifier. The **/DEMAND_MERGE** qualifier ensures that all blocks on the shadow set are the same, including those blocks that are not currently allocated to files. System managers can use this command at their convenience during off-peak demands on their computing environment.

If the **/ERASE** qualifier is not used when the shadow set is created with the **INITIALIZE/SHADOW** command, and the **SET SHADOW/DEMAND_MERGE DSA*n*:** command is not executed, then the overhead of a full merge operation on this shadow set is even higher than is normally encountered after a system failure.

System managers can also use the **SET SHADOW/DEMAND_MERGE DSA*n*:** command for the following reasons:

- If the **ANALYZE/DISK/SHADOW** command finds differences between the members of the shadow set.
- If they want to measure the impact that a minimerge or a full merge has on their I/O throughput.

8.8. Visible Impact of Transient State Events

Table 8.1, "Visible Impact of Transient State Events" summarizes the user-visible impact of transient state events from the viewpoint of a shadow set on one system on an OpenVMS Cluster system. For each type of transient state event, the effects on the shadow set, when a merge (full merge, HBMM, or controller minimerge) or copy (full or minicopy) operation is already underway, are listed. The terms Canceled, Restarted, Continued, and Suspended, have the same meaning in this table as in Volume Shadowing for OpenVMS messages:

- Canceled — Operation is stopped so that it can be restarted or continued on any system that is eligible.
- Restarted — Operation must start over again on the same system at LBN 0 when the operation is resumed.
- Continued — Operation continues at the LBN where it left off when canceled or suspended.
- Suspended — Operation is stopped such that the operation for that SS can be initiated, restarted, or continued only on the same system where the suspended operation is active.

The following are the characteristics of merge and copy operations:

- If both a merge and a copy are pending on a shadow set, the merge is done before the copy if and only if the merge is a minimerge. This applies to controller-based minimerges, host-based minimerges, full copies, and minicopies.
- If an event that specifies a delay occurs during the delay for some earlier event, no additional delay is incurred. The merges or copies required for the current event are considered when the earlier delay expires.

- If an event that specifies no delay occurs during the delay for some earlier event, the merges or copies required for the “no-delay” event are not considered until the earlier delay expires.

Table 8.1. Visible Impact of Transient State Events

Event[1]	Shadow Set (SS) Focus	New work required	What happens prior to merge /copy on SS?				De-lay[2]
			Prior full merge or HBMM	Prior controller minimerge	Prior full copy	Prior minicopy	
Failure of other system that had at least one mounted SS in common with this system.	All SSs that were mounted on failed system.	Merge required.	Canceled and is restarted.	If on failed system, it restarts. Otherwise, minimerge continues with added work.	Canceled but is eventually continued.	Canceled but is eventually continued. Continued as full copy if minicopy master bitmap was on failed system.	Yes
	All other SSs with prior merge or copy state.	No new work.	Canceled but is continued.	No change.	Canceled but is continued.	Canceled but is continued.	Yes
Failure of a system that did not have any SS mounted in common with this system.	All other SSs with prior merge or copy state.	No new work.	No change.	No change.	No change.	No Change.	Yes.
SS aborted on another system, with writes in restart queue on the aborting system; SS is also mounted on this system.	Aborted SS.	Merge required.	Canceled and is restarted.	If on failed system, it restarts. Otherwise, minimerge continues with added work.	Canceled but is continued.	Canceled but is continued.	Yes.
	All other SSs with prior merge or copy state.	No new work.	Canceled but is continued.	No change.	Canceled but is continued.	Canceled but is continued.	Yes
Other system dismounts a SS that has a merge or copy in progress on its system; SS is also mounted on this system.	SS dismounted on other system.	No new work.	Continued.	Restarted.	Continued.	Continued.	No

Event[1]	Shadow Set (SS) Focus	New work required	What happens prior to merge /copy on SS?				De-lay[2]
			Prior full merge or HBMM	Prior controller minimerge	Prior full copy	Prior minicopy	
	All other SSs with prior merge or copy state.	No change.	No change.	No change.	No change.	No change.	No
A member is added to a SS that is mounted on this system.	Specified SS.	Copy required.	Canceled but is continued.	No change.	No change.	No change.	No
	All other SSs with prior merge or copy state.	No new work.	No change.	No change.	No change.	No change.	No
Mount a requires a merge or copy; SS is not mounted on any other system.	SS that Specified SS.	Copy and/or merge required.	Restarted as full merge.	Restarted as full merge.	Restarted.	Restarted as full copy.	No
SET SHADOW /DEMAND_MERGE command issued on any system for SS mounted on this system.	Specified SS does not use controller minimerge.	Merge required.	Restarted.	Not applicable.	Canceled but is continued.	Canceled but is continued.	No
	Specified SS uses controller minimerge.	Full merge required.	Restarted.	Suspended and restarted as full merge.	Canceled but is continued.	Canceled but is continued.	No
	All other SSs with prior merge or copy state.	No change.	No change.	No change.	No change.	No change.	No
SET SHADOW /EVAL=RESOURCES command issued on this system.	All SSs mounted on this system with prior merge or copy state.	No change.	Canceled but is continued.	No change.	Canceled but is continued.	Canceled but is continued.	Yes

[1]Each event is described from the perspective of one system in a cluster.

[2]Delay represents a predetermined length of time that elapses before the operation begins. It is the total of the values specified for the SHADOW_REC_DLY and RECNXINTERVAL system parameters.

8.9. Automatic Minicopy on Volume Processing

Automatic Minicopy on volume processing means that an existing HBMM bitmap functions as a minicopy bitmap when connectivity to one or more shadow set members is lost and is not restored during the shadow member timeout period.

Before the introduction of this feature, it was a lengthy process to return expelled members to a shadow set after connectivity was restored. The expelled members are returned only by undergoing a full copy. The availability of a bitmap enables the use of a minicopy operation, which takes less time than a full copy operation.

When connectivity is lost, the shadow set is paused for volume processing, that is, writes and reads are temporarily suspended until connectivity is restored or the timeout period expires (established by the value of SHADOW_MBR_TMO), whichever comes first. If connectivity is not restored by the end of the timeout period, the member or members are expelled from the shadow set, read and write I/O to the remaining member or members resumes, and the bitmap keeps track of the writes. The bitmap, whose name has changed from HBMMx to rrsex, functions as a minicopy bitmap for the member or members that are expelled.

Note

While one or two members are expelled and after all members are restored to membership in the shadow set, the HBMM bitmap functionality remains in effect. The HBMM bitmap functionality is useful in the case of an expelled member only when the shadow set has three members and one member is expelled.

When connectivity is restored to one of the expelled shadow set members, you can mount it back into the shadow set. If the expelled member's metadata matches a bitmap that exists, it is used for a minicopy operation to restore that member to the shadow set. If a second shadow set member was removed at the same time, that member can also use that bitmap. After the members are restored to the shadow set, the name of the bitmap reverts to its HBMM bitmap name.

When one or more members are expelled from a shadow set, you must minimize the time for the following reasons:

- During a period of reduced membership of the shadow set, data availability is at risk.
- If a shadow set member is expelled, reads and writes to the remaining members continue.

  The more writes that take place before the expelled member or members are returned, the longer it takes to restore the member or members to the shadow set. This is especially significant in a disaster tolerant (DT) configuration.

To enable automatic bitmap creation on volume processing, you must establish an HBMM policy for the shadow sets, and include the new MULTIUSE keyword in the policy.

8.10. Multiuse Property for Host-Based Minicopies

On OpenVMS Version 8.3 and later, you can implement HBMM write bitmaps to perform minicopies, under certain conditions. By specifying the MULTIUSE property, you can prevent full copies from

occurring when a member is removed from a shadow set as a result of loss of connectivity (For example, a MEDOFFL occurs when a link to the remote site is lost). If MULITUSE cannot initiate a minicopy, it reverts back to a full copy to ensure that the data is safe.

To use minicopies using the MULTIUSE property:

- Ensure that all VMS cluster members are running OpenVMS Version 8.3 or higher (for Alpha and IA-64) and OpenVMS Version 9.2 or higher (for x86-64) with the latest volume shadowing kits.
- Enable HBMM; the Multiuse property uses HBMM write bitmaps.
- Define an HBMM policy where you specify the Multiuse property:

  ```
  $ SET SHADOW DSAnnn/POLICY=HBMM=((Master=(Node1, Node2), Count=2,
   Multiuse=1), -
                                  (Master=(Node3, Node4), Count=2,
   Multiuse=2) )
  ```

  In the syntax:

  - `Node1` and `Node2` are at Site A
  - `Node3` and `Node4` are at Site B
  - `Count` refers to the number of master bitmaps that are created at the site. This number must be less than or equal to the number of nodes listed. The total number of master bitmaps is limited to six. This can be increased up to a maximum of 12 using the DISMOUNT=*n* keyword. For more information on the DISMOUNT keyword, see *Table 4.3, "SET SHADOW Command Qualifiers"* and also *Section 8.10.2, "Examples of Multiuse and Dismount"*.
  - `Multiuse` refers to the number of master bitmaps that can be converted to multiuse bitmaps, when a member is automatically removed from the shadow set. This number must be less than or equal to the COUNT for that site.

When a shadow set member is removed, of the two master HBMM bitmaps created for a shadow set that uses this policy, only one of the two HBMM master bitmaps at Site A is converted to multiuse bitmaps. At Site B, both the master bitmaps are eligible for use as multiuse bitmaps.

Until a member is removed from the set, output from the **`SHOW DEVICE/BITMAP`** command shows the bitmap as a minimerge bitmap. It is not marked as multiuse until a member is removed and the bitmap is actually converted.

A multiuse bitmap can be used to perform an HBMM recovery (if a node fails and causes a merge) or a multiuse bitmap can be used to bring the former member back into the shadow set using a minicopy. A multiuse bitmap cannot use minicopy to bring a new member into the set. In addition, if the disk is removed due to a fatal drive error, then the bitmaps are not converted to multiuse and it is unlikely that the broken disk is returned.

8.10.1. Multiuse Property and DISMOUNT Keyword

The DISMOUNT keyword specifies the number of HBMM bitmaps to be converted to multiuse bitmaps during the manual removal of members.

If MULTIUSE is omitted, then automatic minicopy on volume processing is not enabled. As a result, no HBMM bitmap is converted to multiuse bitmap. If DISMOUNT is omitted, only a maximum of 6 HBMM bitmaps can be used as multiuse bitmaps.

For examples on the DISMOUNT keyword, see the *Section 8.10.2, "Examples of Multiuse and Dismount"*.

8.10.2. Examples of Multiuse and Dismount

Example 8.1. Using MULTIUSE and DISMOUNT Keywords (I)

```
$ SET SHADOW DSA1/POLICY=HBMM=(MASTER=*,COUNT=12,MULTIUSE=12,DISMOUNT=1)
```

In this example, a policy is set in which all 12 bitmaps can be used as multiuse bitmaps. When you execute the command **DISMOUNT/POLICY=MINICOPY**, 1 minimerge bitmap is converted to multiuse bitmap. You can use this multiuse bitmap with the **MINICOPY** command to add the dismounted member back to the shadow set. In other words, it specifies that all 12 bitmaps can be used during the automatic and 1 bitmap during the manual removal of the shadow set member.

```
$ SHOW SHADOW

_DSA1:   Volume Label: DDD
  Virtual Unit State:   Steady State
  Enhanced Shadowing Features in use:
        Host-Based Minimerge (HBMM)
        Automatic Minicopy (AMCVP)
        Dismount uses Multiuse Bitmaps

VU Timeout Value      3600   VU Site Value         0
Copy/Merge Priority   5000   Mini Merge      Enabled
Recovery Delay Per Served Member                  30
Merge Delay Factor     200   Delay Threshold    200

HBMM Policy
  HBMM Reset Threshold: 1000000
  HBMM Master lists:
    Up to any 12 nodes in the cluster - Multiuse: 12 Dismount: 1
  HBMM bitmaps are active on NODEA,KRISNA,MEERAA
  Modified blocks since bitmap creation: 0

Device $1$MDA50       Master Member
  Read Cost       1   Site 0
  Member Timeout  120

Device $1$MDA51
  Read Cost       1   Site 0
  Member Timeout  120

$ SHOW DEV/BIT
Device   BitMap   Size   Percent        Type of   Master  Active
 Name     ID    (Bytes)  Populated     Bitmap      Node
DSA1:  000A0001    12        0.01%    Minimerge   NODEA    Yes
       000A0002    12        0.01%    Minimerge   KRISNA   Yes
       00090003    12        0.01%    Minimerge   MEERAA   Yes

$ SHOW DEV DSA1
Device             Device       Error   Volume   Free   Trans  Mnt
Name               Status       Count   Label   Blocks  Count  Cnt
DSA1:              Mounted          0   DDD     10139   1      3
$1$MDA50: (NODEA)  ShadowSetMember  0  (member of DSA1:)
$1$MDA51: (NODEA)  ShadowSetMember  0  (member of DSA1:)
```

```
NODEA$dismount $1$MDA51:/poli=mini

$ SHOW DEV/BIT
Device   BitMap   Size   Percent        Type of   Master  Active
 Name     ID    (Bytes)  Populated     Bitmap      Node
DSA1:  000A0001    12        0.01%    Multiuse    NODEA   Yes
       000A0002    12        0.01%    Minimerge   KRISNA  Yes
       00090003    12        0.01%    Minimerge   MEERAA  Yes
$
```

Example 8.2. Using MULTIUSE and DISMOUNT Keywords (II)

```
$ SET SHADOW DSA10/
POLICY=HBMM=((MASTER=(*),COUNT=12,MULTIUSE=12,DISMOUNT=12))
```

In this example, a policy is set in which all 12 bitmaps can be used as multiuse bitmaps. When you execute the command **DISMOUNT/POLICY=MINICOPY**, 12 minimerge bitmaps are converted to multiuse bitmaps. You can use this multiuse bitmap with the MINICOPY command to add the dismounted member back to the shadow set. In other words, it specifies that 12 bitmaps can be used during the automatic or manual removal of the shadow set member.

```
$SHOW DEVICE DSA10/BIT

Device   BitMap   Size   Percent        Type of   Master  Active
 Name     ID    (Bytes)  Populated     Bitmap      Node
DSA10: 00010085   6196       0.01%    Minimerge   LEXUS   Yes
       00010086   6196       0.01%    Minimerge   DARWIN  Yes
       00010087   6196       0.01%    Minimerge   NAPALM  Yes
       00010088   6196       0.01%    Minimerge   SPIFF   Yes
       00010089   6196       0.01%    Minimerge   CALVIN  Yes
       0001008A   6196       0.01%    Minimerge   LOPEZ   Yes
       0001008B   6196       0.01%    Minimerge   OBELIX  Yes
       0001008C   6196       0.01%    Minimerge   KRUSTY  Yes
       0001008D   6196       0.01%    Minimerge   GIMLI   Yes
       0001008E   6196       0.01%    Minimerge   HOMER   Yes
       0001008F   6196       0.01%    Minimerge   OOTY    Yes
       00010090   6196       0.01%    Minimerge   HOBBES  Yes

$DISMOUNT $1$DGA4996: /POLICY=MINI
$SHOW DEVICE DSA10/bit
Device   BitMap   Size   Percent        Type of   Master  Active
 Name     ID    (Bytes)  Populated     Bitmap      Node
DSA10: 00010085   6196       0.01%    Multiuse   LEXUS    Yes
       00010086   6196       0.01%    Multiuse   DARWIN   Yes
       00010087   6196       0.01%    Multiuse   NAPALM   Yes
       00010088   6196       0.01%    Multiuse   SPIFF    Yes
       00010089   6196       0.01%    Multiuse   CALVIN   Yes
       0001008A   6196       0.01%    Multiuse   LOPEZ    Yes
       0001008B   6196       0.01%    Multiuse   OBELIX   Yes
       0001008C   6196       0.01%    Multiuse   KRUSTY   Yes
       0001008D   6196       0.01%    Multiuse   GIMLI    Yes
       0001008E   6196       0.01%    Multiuse   HOMER    Yes
       0001008F   6196       0.01%    Multiuse   OOTY     Yes
       00010090   6196       0.01%    Multiuse   HOBBES   Yes
```

When the minicopy completes and the dismounted member is added back to the shadow set, the “multiuse” bitmap is converted to the “minimerge” bitmap.

```
$SHOW DEVICE DSA301/BIT
Device   BitMap   Size   Percent        Type of   Master   Active
 Name     ID    (Bytes)  Populated     Bitmap      Node
DSA301: 00010085   6196       0.01%    Minimerge   LEXUS   Yes
        00010086   6196       0.01%    Minimerge   DARWIN  Yes
        00010087   6196       0.01%    Minimerge   NAPALM  Yes
        00010088   6196       0.01%    Minimerge   SPIFF   Yes
        00010089   6196       0.01%    Minimerge   CALVIN  Yes
        0001008A   6196       0.01%    Minimerge   LOPEZ   Yes
        0001008B   6196       0.01%    Minimerge   OBELIX  Yes
        0001008C   6196       0.01%    Minimerge   KRUSTY  Yes
        0001008D   6196       0.01%    Minimerge   GIMLI   Yes
        0001008E   6196       0.01%    Minimerge   HOMER   Yes
        0001008F   6196       0.01%    Minimerge   OOTY    Yes
        00010090   6196       0.01%    Minimerge   HOBBES  Yes
```

The following example shows that using any further commands to create bitmaps fails because all the 12 bitmap slots are utilized.

```
$DISM $1$DGA4993: /POLICY=MINI
%DISM-W-CANNOTDMT, $1$DGA4993: cannot be dismounted
%SYSTEM-F-WBMERR, WBM error during dismount
```

Chapter 9. Performing System Management Tasks on Shadowed Systems

This chapter explains how to accomplish system maintenance tasks on a standalone system or an OpenVMS Cluster system that uses volume shadowing.

9.1. Upgrading the Operating System on a System Disk Shadow Set

It is important to upgrade the operating system at a time when your system can afford to have its shadowing support disabled. This is because you *cannot* upgrade to new versions of the OpenVMS operating system on a shadowed system disk. If you attempt to upgrade a system disk while it is an active member of a shadow set, the upgrade procedure will fail.

Procedure for Upgrading Your Operating System

This procedure is divided into four parts.

- Preparing a shadowed system disk for the upgrade.
- Performing the upgrade.
- Enabling volume shadowing on the upgraded system.
- Booting other nodes in an OpenVMS Cluster system from the upgraded disk.

Part 1: Preparing a Shadowed System Disk

1. On OpenVMS cluster systems, choose the node on which you want to perform the upgrade.
2. Create a non-shadowed system disk to do the upgrade using either of these methods:
   - Prepare a copy of the current system disk to use as the target of the upgrade procedure. See *Section 9.3.2, "Using Copy Operations to Create a Backup"*.
   - Use **BACKUP** to create a compressed copy of the shadow set on a single scratch disk (a disk with no useful data). See *the section called "Example 3"* in *Section 9.3.4, "Using BACKUP/IMAGE on a Shadow Set"* for an example.
3. Enter the **MOUNT/OVERRIDE=SHADOW_MEMBERSHIP** command on the upgrade disk to zero the shadowing-specific information on the storage control block (SCB) of the disk. Do not mount the disk for systemwide or clusterwide access; omit the **/SYSTEM** and **/CLUSTER** qualifiers on the **MOUNT** command line.
4. Use the DCL command **SET VOLUME/LABEL=*volume-label device-spec*[:]** to change the label on the upgrade disk. (The **SET VOLUME/LABEL** command requires write access

[W] to the index file on the volume. If you are not the volume owner, you must have either a system UIC or the SYSPRV privilege.) For OpenVMS cluster systems, ensure that the volume label is a unique name across the cluster.

Note

If you have to change the volume label of a disk that is mounted across the cluster, be sure you change the label on all nodes in the OpenVMS cluster system. For example, you could propagate the volume label change to all nodes in the cluster with one SYSMAN utility command, after you define the environment as the cluster:

```
SYSMAN> SET ENVIRONMENT/CLUSTER
SYSMAN> DO SET VOLUME/LABEL=new-label disk-device-name:
```

---

5. Ensure that the boot command line or file boots from the upgrade disk. The manner in which you store the boot command information depends on the architecture/hypervisor you are running OpenVMS. For more information about boot commands, refer to the OpenVMS installation guide for the appropriate architecture.

   If volume shadowing is enabled on the node, disable it according to the instructions in step 6. Otherwise, proceed to Performing the Upgrade.

6. Prepare to perform the upgrade procedure by disabling system disk shadowing (if it is enabled) on the node to be upgraded.

Note

You cannot perform an upgrade on a shadowed system disk. If your system is set up to boot from a shadow set, you must disable shadowing the system disk before performing the upgrade. This requires changing SYSGEN parameter values interactively using the SYSGEN utility.

Invoke SYSGEN by entering the following command:

```
$ RUN SYS$SYSTEM:SYSGEN
```

Enter the following command:

```
SYSGEN> USE upgrade-disk:[SYSn.SYSEXE]filename
```

where *filename* is:

- ALPHAVMSSYS.PAR on OpenVMS Alpha
- X86_64VMSSYS.PAR on OpenVMS x86_64
- IA64VMSSYS.PAR on OpenVMS IA64

The **USE** command defines the system parameter file from which data is to be retrieved. You should replace the variable *upgrade-disk* with the name of the disk to be upgraded. For the variable *n* in [SYS*n*.SYSEXE], use the system root directory you want to boot from (this is generally the same root you booted from before you started the upgrade procedure).

Disable shadowing of the system disk by setting the SYSGEN parameter SHADOW_SYS_DISK to 0, as follows:

```
SYSGEN> SET SHADOW_SYS_DISK 0
```

Enter the following command:

```
SYSGEN> WRITE upgrade-disk:[SYSn.SYSEXE]filename
```

where *filename* is:

- ALPHAVMSSYS.PAR on OpenVMS Alpha
- X86_64VMSSYS.PAR on OpenVMS x86_64
- IA64VMSSYS.PAR on OpenVMS IA64

Type EXIT or press Ctrl/Z to exit the SYSGEN utility and return to the DCL command level.

You must also change parameters in the MODPARAMS.DAT file *before* shutting down the system. Changing parameters before shutdown ensures that the new system parameter values take effect when AUTOGEN reads the MODPARAMS.DAT file and reboots the nodes. Edit *upgrade-disk*:[SYS*n*:SYSEXE]MODPARAMS.DAT and set SHADOWING and SHADOW_SYS_DISK to 0.

Even if you plan to use the upgraded system disk to upgrade the operating system on other OpenVMS Cluster nodes, you should complete the upgrade on one node before altering parameters for other nodes. Proceed to Part 2.

Part 2: Performing the Upgrade

1. Boot from and perform the upgrade on the single, nonshadowed disk. Follow the upgrade procedure described in the OpenVMS upgrade and installation manual.

2. If you are upgrading a system that already has the volume shadowing software installed and licensed, then skip to Part 3.

   Otherwise, you must register the Volume Shadowing for OpenVMS Product Authorization Key (PAK) or keys. PAK registration is described in the release notes and cover letter supplied with your installation kit.

Part 3: Enabling Volume Shadowing on the Upgraded System

Once the upgrade is complete and the upgraded node has finished running AUTOGEN, you can enable shadowing for the upgraded node using the following steps.

1. Invoke the System Generation utility (SYSGEN) by entering the following command:

   ```
   $ RUN SYS$SYSTEM:SYSGEN
   SYSGEN> USE CURRENT
   SYSGEN>
   ```

   The **USE CURRENT** command initializes the SYSGEN work area with the source information from the current system parameter file on disk. (To find out the current value of system parameters, use the **SHOW** command [for example, **SHOW SHADOWING**] to see the current system parameter values as well as the minimum, maximum, and default values of the parameters.)

To enable shadowing, set the system parameter SHADOWING to 2. If the system disk is to be a shadow set, set the system parameter SHADOW_SYS_DISK to 1, and set the SHADOW_SYS_UNIT parameter to the unit number of the virtual unit, as follows (assume the system disk virtual unit is DSA54):

```
SYSGEN> SET SHADOWING 2
SYSGEN> SET SHADOW_SYS_DISK 1
SYSGEN> SET SHADOW_SYS_UNIT 54
SYSGEN> WRITE CURRENT
```

Type EXIT or press Ctrl/Z to exit the SYSGEN utility and return to the DCL command level.

2. To ensure that volume shadowing is enabled each time AUTOGEN executes, edit the SYS$SYSTEM:MODPARAMS.DAT file to set the shadowing parameters. For OpenVMS Cluster systems, set system parameters in MODPARAMS.DAT on each node that uses volume shadowing. See *Chapter 3, "Preparing to Use Volume Shadowing"* for more information about editing the MODPARAMS.DAT file.

3. Shut down the system on which you performed the upgrade, and reboot.

Part 4: Booting Other Nodes in the OpenVMS Cluster from the Upgraded Disk

If other nodes boot from the upgraded disk, the OpenVMS upgrade procedure automatically upgrades and runs AUTOGEN on each node when it is booted. The procedure for booting other nodes from the upgraded disk differs based on whether the upgraded disk has been made a shadow set.

1. If the upgraded disk is not yet a shadow set:

   a. Disable shadowing (if it is enabled) for the system disk on the nodes to be upgraded.

   b. Alter the boot files for those nodes so they boot from the upgraded disk.

   c. Make sure the system parameters in the node-specific SYS$SYSTEM:MODPARAMS.DAT files are correct (as described in *Section 3.4.1, "Setting System Parameters"*). When the OpenVMS upgrade procedure invokes AUTOGEN, it will use these parameter settings.

   d. Boot the nodes from the upgraded disk.

2. If the upgraded disk is already a shadow set member, additional steps are required:

   a. For each node to be booted from the upgraded disk, edit ALPHAVMSSYS.PAR for Alpha systems, and MODPARAMS.DAT to enable system disk shadowing. Set SHADOWING to 2, SHADOW_SYS_DISK to 1, and SHADOW_SYS_UNIT to the number of the system disk's virtual unit name. Remember to modify the files on the upgraded disk, not on the system disk, prior to upgrade.

   b. On Alpha computers, you can use the **SET BOOTDEF_DEV** console command. For more information, see the hardware information or the upgrade and installation manual for your system.

3. Boot each node. With shadowing enabled in each node's ALPHAVMSSYS.PAR on the upgraded disk, the node will be able to boot from the shadowed (upgraded) system disk.

Once you have successfully upgraded the system or systems and you have completed other post-upgrade work (such as layered product installations), perform the following steps:

1. Mount additional shadow set members into the shadow set, if necessary. Do not use a command procedure to add members to a system disk shadow set. For more information, see *Section 3.6, "Booting from a System Disk Shadow Set"*.

2. Back up your new system disk shadow set. If you usually use online BACKUP for this task, you can use one of the procedures described in *Section 9.3, "Performing Backup Operations on a Shadow Set"*. If you usually use standalone BACKUP at this point, refer to *Section 9.3.1, "Restrictions on BACKUP Procedures"*.

9.2. Modifying Data on Individual Shadow Set Members

Generally, users and applications access a shadow set through the virtual unit. Occasionally, you may want to change the data on an individual shadow set member and then pass the changed data to other shadow set members.

The following series of commands demonstrates how you can dissolve and recreate the shadow set to perform specialized processes on one shadow set member and transfer the change to the other shadow set members.

The following command mounts a shadow set with three shadow set members:

```
$ MOUNT DSA9:/SHADOW=($45$DUA2:,$45$DUA4:,$45$DUA8:) LURK1
```

The following command dissolves the shadow set mounted in the previous command and makes the individual shadow set members available:

```
$ DISMOUNT DSA9:
```

The following command mounts one former shadow set member as a disk volume outside of the shadow set:

```
$ MOUNT/OVERRIDE=SHADOW_MEMBERSHIP $45$DUA2: LURK1
```

In this command, in order to have write access, you must use the **/OVERRIDE=SHADOW_MEMBERSHIP** qualifier to zero the shadow set generation number. At this point, the disk is mounted as a nonshadowed volume and can be modified as required.

Before creating a new shadow set, dismount the 45DUA2 physical disk, as follows:

```
$ DISMOUNT/NOUNLOAD $45$DUA2
$ MOUNT DSA9:/SHADOW=$45$DUA2: LURK1
```

The second command recreates the shadow set with 45DUA2 as the only member.

Note that mounting 45DUA2 with the **/OVERRIDE=SHADOW_MEMBERSHIP** qualifier automatically zeroed the volume shadowing generation number. If you were to specify *all* the former members of the shadow set in the same command line, the **MOUNT** command would consider 45DUA2 an unrelated volume and would determine that it requires a copy operation. This would overwrite the earlier modifications.

To save the current contents of 45DUA2, add the other two former shadow set members to the new shadow set with a subsequent **MOUNT** command:

```
$ MOUNT DSA9:/SHADOW=($45$DUA4:,$45$DUA8:) LURK1
```

In this command, 45DUA4 and 45DUA8 are added to the shadow set DSA9. This recreates the original shadow set, except that each shadow set member now has the benefit of the changed data that was done to the single shadow set member.

9.3. Performing Backup Operations on a Shadow Set

You should think of a shadow set as a single, highly available disk. As such, backup techniques for nonshadowed disks apply to shadow set virtual units. However, to preserve the consistency and integrity of the shadow set, avoid removing a physical member of the shadow set without dismounting the virtual unit unless you have scrupulously followed the guidelines in *Section 7.11, "Guidelines for Using a Shadow Set Member for Backup"*. If you leave some disk members of a shadow set active during the backup operation, data integrity is compromised because some disks in the shadow set may have files open. Refer to *Section 4.10.4, "Dismounting and Remounting With One Less Member for Backup"* for information about obtaining a member of a shadow set for the source of a backup operation.

The following list describes options that are available when backing up shadow sets that are not available with nonshadowed disks.

- To obtain a defragmented backup of a shadowed disk, begin by closing files and stopping application access to the disks. Dismount the virtual unit to dissolve the shadow set. Use the **/NOUNLOAD** qualifier to avoid spinning down the members of the shadow set. Remount the virtual unit as a private device, and use BACKUP/IMAGE (see *Section 9.3.4, "Using BACKUP/IMAGE on a Shadow Set"*) with the virtual unit as the source of the backup operation. This is the recommended method of backing up shadow sets.

- To minimize the amount of time that data is unavailable to applications, consider remounting the shadow set with one less member (see *Section 4.10.4, "Dismounting and Remounting With One Less Member for Backup"*). Then back up the dismounted member. This technique keeps the shadow set in service at the same time that you perform a backup operation. Once the backup is complete, remount the member into the shadow set. The shadowing software performs a copy, or minicopy, operation to make that member consistent with the other members of the shadow set.

  If a spare disk of the type present in the shadow set is available, consider mounting the spare disk into the shadow set to minimize the time that the shadow set runs with reduced membership. Then, the member that served as the source of the backup can become a spare disk.

- To ensure complete integrity of the backup of the system disk, you must shut down the systems that boot from it. For system disk shadow sets, you should also dismount the virtual unit by any other systems that have it mounted. Then remount the virtual unit as a private device on one of the systems that was not shut down, and use it as the source for a BACKUP/IMAGE operation (see *Section 9.3.4, "Using BACKUP/IMAGE on a Shadow Set"*).

  In addition, to provide system disk shadowing quickly as you perform a backup operation, remount the shadow set minus one member. Back up that member and either remount it into the shadow set or mount a spare disk. You can use the menu-driven BACKUP procedure on one of the systems that is down while the other systems are rebooted.

- To do an incremental backup, use the virtual unit, not a single member of the shadow set. This is because incremental backups alter information in file headers. If you perform an incremental backup on a removed member of a shadow set, that member needs to be the target of a copy operation.

HSC BACKUP and RESTORE techniques are not recommended for saving and restoring the contents of a shadow set member. These HSC utilities are applicable to the disk geometry only, not to the OpenVMS file system. Although HSC BACKUP and RESTORE techniques save and restore the contents of an entire disk volume (including blocks that may not be in use by the file system on that volume), they do not save and restore specific files, groups of files, directories, or subdirectories. In addition, these utilities do not defragment a disk. Moreover, the utilities cannot restore the context of a shadow set virtual unit.

The following sections describe several approaches to shadow set backup operations.

9.3.1. Restrictions on BACKUP Procedures

On Alpha computers, you cannot use the standalone, menu-driven procedure included on the OpenVMS Alpha operating system distribution compact disc to perform BACKUP operations on shadow sets.

Note the following restrictions for standalone BACKUP that use volume shadowing:

- Do not boot standalone BACKUP from an alternative root on a shadowed system disk while other nodes are booting from the same shadowed system disk. If you do this, the boot attempt fails.
- Standalone BACKUP does not mount virtual units. This makes access to virtual units impossible from standalone BACKUP.
- Do not assume that standalone BACKUP prevents you from accessing a shadow set member unit. You must prevent standalone BACKUP from sending output to a disk mounted on any other OpenVMS Cluster member, either as a directly accessible disk or as the member of a shadow set.

9.3.2. Using Copy Operations to Create a Backup

This example shows how to use volume shadowing copy operations to create an offline identical disk volume that you can then use as a backup of your shadow set. The following command creates a shadow set with one shadow set member:

```
$ MOUNT DSA0:/SHADOW=$1$DUA10: SHADOWFACTS
%MOUNT-I-MOUNTED, SHADOWFACTS  mounted on _DSA0:
%MOUNT-I-SHDWMEMSUCC, _$1$DUA10: (DISK01) is now a
                      valid member of the shadow set
```

The following command adds a second member, `$1$DUA11`, to the shadow set:

```
$ MOUNT DSA0:/SHADOW=$1$DUA11: SHADOWFACTS
%MOUNT-I-SHDWMEMCOPY, _$1$DUA11: (DISK02) added to the shadow
                      set with a copy operation
```

At this point you must wait for the copy operation to complete before dismounting the shadow set. When the copy operation is complete, messages are sent to the system console and to any operators enabled to receive them.

The following command dismounts the shadow set, leaving `$1$DUA10` and `$1$DUA11` with logically identical volumes:

```
$ DISMOUNT DSA0:
```

At this point you can re-create the shadow set with one of the volumes and keep the other as a backup, or use it as a source for the backup operation.

9.3.3. Using the OpenVMS Backup Utility

Generally you can use the OpenVMS Backup utility (BACKUP) with shadow sets as you do with regular volumes. (See the *VSI OpenVMS System Manager's Manual, Volume 1: Essentials* for a description of how to back up volumes.) You can create BACKUP save sets or copies from shadow sets by using the shadow set virtual unit name instead of a physical device name as the input specifier. However, you cannot always restore to a shadow set by listing the virtual unit name as an output specifier. The main restriction to any backup restoration is that you cannot mount the target volume with the **/FOREIGN** qualifier. The proper procedure for a BACKUP/IMAGE restoration is described in *Section 9.3.4, "Using BACKUP/IMAGE on a Shadow Set"*.

The format for a BACKUP command is as follows:

```
BACKUP input-specifier output-specifier
```

The format is the same as for any BACKUP operation. The following command, for example, designates a virtual unit for the input specifier:

```
$ BACKUP/RECORD  DSA2:[*…]/SINCE=BACKUP   MTA0:23DEC.BCK
```

This command saves all files on the shadow set DSA2 that have been created or modified since the last backup and records the current time as their new backup date.

9.3.4. Using BACKUP/IMAGE on a Shadow Set

You must take special precautions when you restore a shadow set from a BACKUP/IMAGE save set. (See the *VSI OpenVMS System Manager's Manual, Volume 1: Essentials* and *VSI OpenVMS System Management Utilities Reference Manual, Volume 1: A-L* for a description of BACKUP/IMAGE operations with physical volumes.) A BACKUP/IMAGE operation marks the target volume as more current than the other shadow set members. This designates it as the source of copy operations if you re-create the shadow set with it.

Although you can create BACKUP save sets or copies from shadow set virtual units, you cannot mount your shadow set with the **/FOREIGN** qualifier to allow a BACKUP/IMAGE restoration.

You should either restore to a physical disk and then re-create the shadow set with the restored disk as a shadow set member (Example 2) or, if the save operation was a copy to a compatible disk, re-create the shadow set with that disk as a member (Example 3). The target of the BACKUP/IMAGE operation becomes the source of copy operations if you re-create the shadow set with it.

Example 1

This example shows how to perform a backup on a former shadow set member after you rebuild the shadow set.

```
$ MOUNT DSA0:/SHADOW=($1$DUA10:, $1$DUA11:)  GHOSTVOL
%MOUNT-I-MOUNTED, GHOSTVOL     mounted on _DSA0:
%MOUNT-I-SHDWMEMSUCC, _$1$DUA10: (DISK01) is now a valid
                      member of the shadow set
%MOUNT-I-SHDWMEMSUCC, _$1$DUA11: (DISK02) is now a valid
                      member of the shadow set
```

The previous command mounts the shadow set DSA0. Make sure all copy operations are finished before you dismount the shadow set by using the following command:

```
$ DISMOUNT DSA0:
```

This command dismounts the shadow set.

```
$ MOUNT/SYSTEM DSA0/SHADOW=$1$DUA10: GHOSTVOL
%MOUNT-I-MOUNTED, GHOSTVOL    mounted on _DSA0:
%MOUNT-I-SHDWMEMSUCC, _$1$DUA10: (DISK01) is now a valid
                      member of the shadow set
```

This command puts the shadow set back on line without `$1$DUA11`. You can now perform the backup to tape while the shadow set is on line.

```
$ MOUNT $1$DUA11: GHOSTVOL
%MOUNT-W-VOLSHDWMEM, mounting a shadow set member volume
                     volume write locked
%MOUNT-I-MOUNTED, GHOSTVOL mounted on _$1$DUA11:
$ MOUNT/FOREIGN  MTA0:
%MOUNT-I-MOUNTED, …
```

These two commands mount the former shadow set member and a magnetic tape in preparation for a **`BACKUP`** command.

```
$ BACKUP/IMAGE $1$DUA11: MTA0:SAVESET.BCK
```

This command produces a `BACKUP/IMAGE` save set from `$1$DUA11` while the shadow set is on line with `$1$DUA10`.

Example 2

This example shows how to restore a shadow set from an image save set. Restoring an image save set *directly* to a shadow set is not supported because the BACKUP output medium (the shadow set) must be mounted as a foreign volume.

```
$ DISMOUNT DSA0:
$ MOUNT/FOREIGN MTA0:
%MOUNT-I-MOUNTED, …

$ MOUNT/FOREIGN/OVERRIDE=SHADOW_MEMBERSHIP $1$DUA10:
%MOUNT-I-MOUNTED, …
```

These two commands mount the save-set magnetic tape as the input specifier and the former shadow set member as the output specifier for the restore operation.

```
$ BACKUP/IMAGE MTA0:SAVESET.BCK $1$DUA10:
```

This command restores `$1$DUA10` from the save set.

```
$ DISMOUNT/NOUNLOAD $1$DUA10:
```

This command dismounts the restored volume in preparation for mounting into a shadow set.

Note

Do not attempt to add the restored volume to an existing shadow set without first dissolving the original shadow set. Mounting a restored volume into an existing shadow set will result in a copy operation erasing the restored disk.

```
$ MOUNT/SYSTEM DSA0/SHADOW=($1$DUA10:, $1$DUA11:) GHOSTVOL
%MOUNT-I-MOUNTED, GHOSTVOL    mounted on _DSA0:
%MOUNT-I-SHDWMEMSUCC, _$1$DUA10: (DISK01) is now a valid member of
                      the shadow set
%MOUNT-I-SHDWMEMCOPY, _$1$DUA11: (DISK02) added to the shadow set
                      with a copy operation
```

This command mounts the shadow set with the restored shadow set member. The output of the image backup operation has a newer generation number than other previous members of the shadow set. Therefore, `$1$DUA10` (the restored volume) is the source of a copy operation when you form the shadow set.

Example 3

This example illustrates a BACKUP/IMAGE copy operation on a shadow set. The image backup operation stores output files contiguously, eliminating disk fragmentation. Because you must mount the output device of such operations with the **/FOREIGN** qualifier, you must take special steps as shown with the following commands:

```
$ MOUNT DSA0:/SHADOW=($1$DUA10:,$1$DUA11:)  MEANDMY
%MOUNT-I-MOUNTED, MEANDMY     mounted on _DSA0:
%MOUNT-I-SHDWMEMSUCC, _$1$DUA10: (DISK03) is now a valid
                      member of the shadow set
%MOUNT-I-SHDWMEMSUCC, _$1$DUA11: (DISK04) is now a valid
                      member of the shadow set
$ MOUNT/FOREIGN $1$DUA20:
%MOUNT-I-MOUNTED, …
```

The first command mounts the shadow set `DSA0`. The second command mounts, on `$1$DUA20`, the volume to be the output of the BACKUP/IMAGE operation. The **/FOREIGN** qualifier is required.

```
$ BACKUP/IMAGE/IGNORE=INTERLOCK  DSA0: $1$DUA20:
```

This command performs the image backup using the virtual unit name as the input specifier. The image backup copy of a shadow set has a newer backup revision number than the existing members in the shadow set.

Note

If any writes occur between the start of the backup operation and the dismount of both the volume containing the image backup copy and the shadow set, the backup image will not contain all the data on the shadow set. You can prevent any writes from occurring during this period by mounting the shadow set with the **/NOWRITE** qualifier prior to mounting the volume that will serve as the backup volume.

```
$ DISMOUNT $1$DUA20:
$ DISMOUNT DSA0:
```

These commands dismount the target of the image backup and the shadow set, in preparation for re-creating the shadow set.

```
$ MOUNT/SYSTEM DSA0/SHADOW=($1$DUA10:,$1$DUA11:,$1$DUA20:) MEANDMY
%MOUNT-I-MOUNTED, MEANDMY     mounted on _DSA0:
%MOUNT-I-SHDWMEMSUCC, _$1$DUA20: (DISK05) is now a valid
                      member of the shadow set
%MOUNT-I-SHDWMEMCOPY, _$1$DUA10: (DISK03) added to the shadow
                      set with a copy operation
```

```
%MOUNT-I-SHDWMEMCOPY, _$1$DUA11: (DISK04) added to the shadow
                      set with a copy operation
```

This command rebuilds the shadow set with the image backup disk as one of the shadow set members. The other former shadow set members receive copy operations.

9.4. Crash Dumping to a Shadowed Disk

If a multiple-member system disk shadow set is mounted and the system fails, the resulting crash dump information is initially written to the dump file on only one of the shadow set members. Once the dump operation has successfully completed, the unit number of the member with the written dump file is printed on the console device. Error messages display if the dump cannot be written (for example, because the path to the dump unit is unavailable or is unsuitable).

Note

The crash dump file is normally written to the original boot device, provided that it is available and on line. If that device has been removed from the shadow set, the dump file is written to the current master member of the shadow set, provided that it is available and on line.

If you are using HBMM, you can enable a minimerge on a shadowed system disk and write a dump to a non-shadowed, non-system disk of your choice by doing the following:

- Set the SHADOW_SYS_DISK system parameter to 4097.
- Set the DUMPSTYLE system parameter to the appropriate setting for your system for a nonshadowed, nonsystem disk of your choice.
- Configure a disk for dump off system disk (DOSD), as described in the *VSI OpenVMS System Manager's Manual, Volume 2: Tuning, Monitoring, and Complex Systems*.

If you accidentally enable a minimerge to a system disk that receives a crash dump and you have not set up DOSD, you may be able to recover if you know which disk contains the valid dump. Remove that member, remount it, and remove the dump from that member.

Once the system is rebooted, the shadowing software automatically begins a merge operation. This merge operation automatically propagates the dump file to all of the other members and also corrects any other inconsistencies caused by the system failure.

You can reboot the system from either the original boot device or the current master member device. At boot time, if the paths to all of the members of the shadow set are on the same type of adapter, the shadowing software correctly designates the current master and dump device on all of the booting nodes. At boot time, several OPCOM messages display information about the status of the dump device and the reboot condition of the system.

You cannot reboot the system unless the boot device is a current member of the shadow set. When a multiple member system disk shadow set loses its boot device, a warning is printed on the console device, and an OPCOM message is displayed.

Caution

Do not add shadow set members to an existing system disk shadow set in any startup command procedure. Upon system reboot, all of the data, including the dump file, can be overwritten and therefore

lost if volume shadowing automatically performs a copy operation. For more information, see *Section 3.6, "Booting from a System Disk Shadow Set"*.

On some systems, you can stipulate that multiple devices be members of the same system disk shadow set. Please refer to the system-specific manual for further details.

If you use the System Dump Analyzer (SDA) to access the dump file on the virtual unit during the merge operation, you can enter the SDA command **ANALYZE/CRASH** to examine the dump while the shadow set is undergoing a merge operation. If SDA accesses portions of the dump file that have not yet been merged, shadowing resolves inconsistent data across the shadow set before the read is returned to SDA.

You can also use the Crash Log Utility Extractor (CLUE) commands to access the dump file on the virtual unit during a merge operation. CLUE commands can automatically create a footprint of the crash to a .LIS file and store it for future reference.

Note

Accessing the dump file with the SDA command **COPY** or the SDA command **ANALYZE/CRASH** on a merging system disk significantly degrades I/O performance on the volume. Accessing the dump file with the DCL command **COPY** on a merging system disk will have the same effect.

Chapter 10. Performance Information for Volume Shadowing

Volume Shadowing for OpenVMS is designed primarily to be a data availability product and not a performance product. Recognizing that the topics of performance and data availability cannot be completely separated from each other, this chapter discusses the performance effects that can result on systems using Volume Shadowing for OpenVMS.

10.1. Factors That Affect Performance of a Shadow Set

Several factors affect the performance of a shadow set, including the following:

- I/O access path (local versus remote)
- Size of I/O requests
- Data access patterns (random or sequential)
- Read-to-write ratio
- Shadow set configuration
- State of a shadow set (steady or transient)
- Whether or not you use the shadowing copy and merge performance assists (see *Section 10.3.2, "Improving Performance for Merge and Copy Operations"*)
- Whether you use the minicopy operation (see *Chapter 7, "Using Minicopy for Backing Up Data"*)
- Whether you use HBMM (see *Chapter 8, "Host-Based Minimerge (HBMM)"*)
- Other work load on the system utilizing common resources (CPUs, disks, controllers, interconnects)

The following sections examine how the state of a shadow set and its configuration can affect resource utilization and performance. Some guidelines for controlling the use of system resources are also provided in *Section 10.4, "Guidelines for Managing Shadow Set Performance"*. Because there is no significant difference in the performance of a nonshadowed disk and a one-member shadow set, all discussions that follow apply to multiple-member shadow sets.

10.2. Performance During Steady State

A shadow set is in a steady state when all of its members are consistent and no copy operation or merge operation is in progress. The performance of a shadow set in a steady state compares favorably with that of a nonshadowed disk due to the following factors:

- Read and write I/O requests processed by a shadow set utilize a very small amount of extra CPU processing time as compared with a nonshadowed disk.

- A shadow set can often process read requests more efficiently than a nonshadowed disk because it can use the additional devices to respond to multiple read requests simultaneously.

For a shadow set in a steady state, the shadowing software handles read and write operations in the following manner:

- Write I/O requests are issued concurrently to all members of the shadow set. Because each member must be updated before the I/O request is considered complete, the overall completion time for a write operation is determined by the member unit with the longest access time from the node issuing the write request. Depending on how the shadow set is configured and the access paths to the individual member units, you might observe a slight increase in the time it takes to complete write I/O requests.

  The steady state performance is generally better to a member that is locally connected because the access path is shorter and more direct than the access path to a served member. For example, you might notice degraded write performance on shadow sets that include some members that are accessed through an MSCP server across a network link, where each member is locally connected to a separate node.

- Read I/O requests are issued to only one member unit. Volume Shadowing for OpenVMS attempts to access the member unit that can provide the best completion time. In terms of I/O throughput, a two-member shadow set can satisfy nearly twice as many read requests as a nonshadowed disk (and even more throughput is possible with a three-member shadow set). The shadow set can use the additional disk read heads to respond to multiple read requests at the same time. Thus, a steady-state shadow set can provide better performance when an application or user reads data from the disk. However, the performance gains occur mainly when the read requests queued to the shadow set come in batches such that there are as many read requests as there are member units.

However, even though the read performance of a shadow set in steady-state has the potential for better performance, the primary purpose of volume shadowing is to provide data availability. It is not appropriate to use volume shadowing as a means to increase the read I/O throughput of your applications (by explicitly increasing the I/O work load). This is because the same level of performance cannot be expected during situations when copy or merge operations must take place to add new members or preserve data consistency, or when members are removed from the shadow set. *Section 10.3, "Performance During Copy and Merge Operations"* discusses performance considerations when the shadow set is in a transient state.

10.3. Performance During Copy and Merge Operations

A shadow set is in a transient state when some or all of its members are undergoing a copy or merge operation. During merge operations, Volume Shadowing for OpenVMS ensures consistency by reading the data from one member and making sure it is the same as the data contained in the same LBNs on the other members of the shadow set. If the data is different, the shadowing software updates the LBN on all members before returning the I/O request. For copy operations, the shadowing software reads data from a source member and writes the data to the same LBN on target members.

Whilst performing a merge or copy operation, the shadowing software continues to process application and user I/O requests. The I/O processing necessitated by a copy operation can result in decreased performance as compared with the possible performance of the same shadow set under steady-state conditions. However, if your shadow set members are configured on controllers that support the shadowing assisted copy and assisted merge operations, you can significantly improve the speed with

which a shadow set performs these operations. Volume Shadowing for OpenVMS supports both assisted and unassisted merge and copy operations.

The following lists describe how the performance of a shadow set might be affected while an unassisted merge or copy operation is in progress, respectively. See *Chapter 6, "Ensuring Shadow Set Consistency"* for a description of assisted copy and merge operations.

Copy Operations:

- A copy operation is started on a two- or three-member shadow set either when you mount the shadow set to create it or to add a new member to an existing shadow set. During a copy operation, members that are targets of the operation cannot provide data availability until the operation completes. Therefore, the shadowing software performs the copy operation as quickly as possible to make the shadow set fully available.

- During a copy operation, the shadowing software gives equal priority to user and application I/O requests and to I/O requests necessary to complete the copy operation. The performance of a shadow set during a copy operation is reduced because:

  - The shadowing software must follow special protocols for user read and write I/O requests during a copy operation.

  - Copy operation I/O requests are large in size and have the same priority as user and application I/O requests.

  In addition, other system resources are utilized during a copy operation. Depending on the access path to the individual shadow set members, these resources could include the disk controller, interconnects, interconnect adapters, and systems.

- Since you explicitly start copy operations when you mount a new shadow set or add members to an existing set, you can control when the shadowing software performs a copy operation. Therefore, you can minimize the effect on users and applications in the system by limiting the number of copy operations that occur at the same time. For example, when you create new sets or add new members, try to add the sets or members during periods of low system activity, and do not mount several sets at the same time.

- You can further minimize the effect on users and applications in the system by using the minicopy operation. The minicopy operation can significantly reduce the time it takes to return a shadow set member to shadow set. By the use of write bitmap technology, the minicopy operation copies only the data that was changed while the member was dismounted. For more information, see *Chapter 7, "Using Minicopy for Backing Up Data"*.

Merge Operations:

- In contrast to copy operations, merge operations are not under the control of a user or program. The shadowing software automatically initiates a merge operation on a shadow set as a result of the failure of a node on which the shadow set is mounted.

- As in the case of a copy operation, the volume shadowing software ensures that all I/O requests to the shadow set follow appropriate protocols to ensure data consistency. However, when a shadow set is undergoing a merge operation, full data availability exists in the sense that individual members of the set are valid data sources and are accessible by applications and users on the system. Therefore, it is not urgent for the shadowing software to finish the merge operation, especially when the system is being heavily used. Because of this major distinction from a copy operation, the shadowing

software implicitly places a higher priority on user activity to the shadow set. Volume Shadowing for OpenVMS does this by detecting and evaluating system load, and then dynamically controlling or **throttling** the merge operation so that other I/O activity can proceed without interference.

- Since the merge throttle slows merge operations when there is heavy application and user I/O activity on the system, merge operations can take longer than copy operations. The merge throttle allows application and user activity to continue unimpeded by the merge operation when heavy work loads are detected.

- On the other hand, the read performance of a shadow set during a merge operation is reduced because the shadowing software must perform data integrity checks on all members for every read request. The volume shadowing software reads the data from the same LBN on all members of the shadow set, compares the data, and repairs any inconsistencies before returning the read data to the user.

10.3.1. Improving Performance of Unassisted Merge Operations

During an unassisted shadow set merge operation, read I/O performance available to applications is reduced by two factors:

- The need to perform data consistency checks on all read I/Os

- Contention for I/O bandwidth by the shadow set merge operation

The shadow set merge operation employs a throttling mechanism to limit the impact of merge I/O on applications. The merge process is throttled by introducing a delay between merge I/Os when system load is detected.

Depending on the requirements of your application load, it may be desirable to minimize the impact of the merge I/O on your applications and allow the merge to take longer to complete; conversely, it may be desirable to make the merge complete quickly and accept the impact on applications. The following two parameters, specified with logical names, allow you to make this tradeoff for all shadow sets on your system:

- SHAD$MERGE_DELAY_THRESHOLD specifies the threshold I/O time at which the merge process becomes throttled. The threshold is expressed as a multiplier on the “ideal” I/O time measured by the system on the shadow set. The default value of 200 is equivalent to a multiplier of 1. This parameter can be set to values from 0 to 20000.

- SHAD$MERGE_DELAY_FACTOR specifies the length of the I/O delay. The I/O delay time is computed by subtracting the threshold from the currently observed merge I/O time. The delay factor acts as a divisor to the delay time; the default value of 200 is equivalent to a divisor of 1. This parameter can be set to values from 2 to 100000.

The delay between merge I/O operations is computed as follows:

```
delay-time = (current I/O time - ideal I/O time *
 MERGE_DELAY_THRESHOLD/200) * 200/MERGE_DELAY_FACTOR
```

Increasing either parameter causes merge operations to run faster and place a heavier load on the system; conversely, decreasing them causes merge operations to run more slowly. Setting the parameters to 200 or lower slows merge operations much more gradually than in previous OpenVMS versions.

In addition to the previous two logical names which specify the parameters for all shadow sets on your system, you can specify parameters for specific shadow sets (designated by "_DSAnnnn" with logical names of the form:

- SHAD$MERGE_DELAY_THRESHOLD_DSAnnnn
- SHAD$MERGE_DELAY_FACTOR_DSAnnnn

You can use the same ranges of values for these parameters that you use for SHAD$MERGE_DELAY_THRESHOLD and SHAD$MERGE_DELAY_FACTOR.

The applicable logical names are sampled by the shadow copy server every 1000 I/Os, so that an in-progress copy or merge responds to a parameter change after a short delay.

10.3.2. Improving Performance for Merge and Copy Operations

There are two types of performance assists: the merge assist and the copy assist. The merge assist improves performance by using information that is maintained in controller-based write logs to merge only the data that is inconsistent across a shadow set. When a merge operation is assisted by the write logs, it is referred to as a **minimerge.** The copy assist reduces system resource usage and copy times by enabling a direct disk-to-disk transfer of data without going through host node memory.

Assisted merge operations are usually too short to be noticeable. Improved performance is also possible during the assisted copy operation because it consumes less CPU and interconnect resources. Although the primary purpose of the performance assists is to reduce the system resources required to perform a copy or merge operation, in some circumstances you may also observe improved read and write I/O performance.

Volume Shadowing for OpenVMS supports both assisted and unassisted shadow sets in the same OpenVMS Cluster configuration. Whenever you create a shadow set, add members to an existing shadow set, or boot a system, the shadowing software reevaluates each device in the changed configuration to determine whether it is capable of supporting either the copy assist or the minimerge. Enhanced performance is possible only as long as all shadow set members are configured on controllers that support performance assist capabilities. If any shadow set member is connected to a controller without these capabilities, the shadowing software disables the performance assist for the shadow set.

When the correct revision levels of software are installed, the copy assist and minimerge are enabled by default, and are fully managed by the shadowing software.

10.3.3. Effects on Performance

The copy assist and minimerge are designed to reduce the time needed to do copy and merge operations. In fact, you may notice significant time reductions on systems that have little or no user I/O occurring during the assisted copy or merge operation. Data availability is also improved because copy operations quickly make data consistent across the shadow set.

Minimerge Performance Improvements

The minimerge feature provides a significant reduction in the time needed to perform merge operations. By using controller-based write logs, it is possible to avoid the total volume scan required by earlier merge algorithms and to merge only those areas of the shadow set where write activity was known to be in progress at the time the node or nodes failed.

Unassisted merge operations often take several hours, depending on user I/O rates. Minimerge operations typically complete in a few minutes and are usually undetectable by users.

The exact time taken to complete a minimerge depends on the amount of outstanding write activity to the shadow set when the merge process is initiated, and on the number of shadow set members undergoing a minimerge simultaneously. Even under the heaviest write activity, a minimerge will complete within several minutes. Additionally, minimerge operations consume minimal compute and I/O bandwidth.

Copy Assist Performance Improvements

Copy times vary according to each configuration and generally take longer on systems supporting user I/O. Performance benefits are achieved when the source and target disks are on different HSJ internal buses.

10.4. Guidelines for Managing Shadow Set Performance

Sections *Section 10.2, "Performance During Steady State"* and *Section 10.3, "Performance During Copy and Merge Operations"* describe the performance impacts on a shadow set in steady state and while a copy or merge operation is in progress. In general, performance during steady state compares with that of a nonshadowed disk. Performance is affected when a copy or a merge operation is in progress to a shadow set. In the case of copy operations, you control when the operations are performed.

However, merge operations are not started because of user or program actions. They are started automatically when a system fails, or when a shadow set on a system with outstanding application write I/O enters mount verification and times out. In this case, the shadowing software reduces the utilization of system resources and the effects on user activity by throttling itself dynamically. Minimerge operations consume few resources and complete rapidly with little or no effect on user activity.

The actual resources that are utilized during a copy or merge operation depend on the access path to the member units of a shadow set, which in turn depends on the way the shadow set is configured. By far, the resources that are consumed most during both operations are the adapter and interconnect I/O bandwidths.

You can control resource utilization by setting the SHADOW_MAX_COPY system parameter to an appropriate value on a system based on the type of system and the adapters on the machine. SHADOW_MAX_COPY is a dynamic system parameter that controls the number of concurrent copy or merge threads that can be active on a single system. If the number of copy threads that start up on a particular system is more than the value of the SHADOW_MAX_COPY parameter on that system, only the number of threads specified by SHADOW_MAX_COPY will be allowed to proceed. The other copy threads are stalled until one of the active copy threads completes.

For example, assume that the SHADOW_MAX_COPY parameter is set to 3. If you mount four shadow sets that all need a copy operation, only three of the copy operations can proceed; the fourth copy operation must wait until one of the first three operations completes. Because copy operations use I/O bandwidth, this parameter provides a way to limit the number of concurrent copy operations and avoid saturating interconnects or adapters in the system. The value of SHADOW_MAX_COPY can range from 0 to 200. The default value is OpenVMS version specific.

Chapter 3, "Preparing to Use Volume Shadowing" explains how to set the SHADOW_MAX_COPY parameter. Keep in mind that, once you arrive at a good value for the parameter on a node, you should

also reflect this change by editing the MODPARAMS.DAT file so that when invoking AUTOGEN, the changed value takes effect.

In addition to setting the SHADOW_MAX_COPY parameter, the following list provides some general guidelines to control resource utilization and the effects on system performance when shadow sets are in transient states.

- Create or add members to shadow sets when your system is lightly loaded.
- The amount of data that a system can transfer during copy operations varies depending on the type of disks, interconnect, controller, the number of units in the shadow set, and the shadow set configuration on the system. For example, approximately 5% to 15% of the Ethernet or CI bandwidth might be consumed for each copy operation (for disks typically configured in CI or Ethernet environments).
- When you create unassisted, three-member shadow sets consisting of one source member and two target devices, add both target devices at the same time in a single mount command rather than in two separate mount commands. Adding all members at once optimizes the copy operations by starting a single copy thread that reads from the source member once, and performs write I/O requests to the target members in parallel.
- For satellite nodes in a mixed-interconnect or local area OpenVMS Cluster system, set the system parameter SHADOW_MAX_COPY to a value of 0 for nodes that do not have local disks as shadow set members.
- Do not use the **MOUNT/CLUSTER** command to mount *every* shadow set across the cluster unless all nodes must access the set. Instead, use the **MOUNT/SYSTEM** command to mount the shadow sets on only those nodes that need to access a particular set. This reduces the chances of a shadow set going into a merge state. Because a shadow set goes into a merge state only when a node that has the set mounted fails, you can reduce the chances of this happening by limiting the number of nodes that mount a shadow set, especially when there is no need for a node to access the shadow sets.
- Because a copy operation can occur only on nodes that have the shadow set mounted, create and mount shadow sets on the nodes that are local (have direct access) to the shadow set members. This allows the copy threads to run on these nodes, resulting in faster copy operations with fewer resources utilized.
- If you have shadow sets configured across nodes that are accessed through the MSCP server, you might need to increase the value of the MSCP_BUFFER system parameter in order to avoid fragmentation of application I/O. Be aware that *each* shadow set copy or merge operation normally consumes 127 buffers.
- Dual-pathed and dual-ported shadowed disks in a OpenVMS Cluster system can provide additional coverage against the failure of nodes that are directly connected to shadowed disks. This type of configuration provides higher data availability with reasonable performance characteristics.
- Use the preferred path option to ensure dual-ported drives are accessed via the same controller so that the shadowing software will perform assisted copy operations.

Appendix A. Messages

This appendix lists volume shadowing status messages that are displayed on the console device. For other system messages that are related to volume shadowing, use the Help Message utility. For information about the **HELP/MESSAGE** command and qualifiers, see DCL help (type **HELP HELP/MESSAGE** at the DCL prompt). Messages that can occur before a system is fully functional are also included in *OpenVMS System Messages: Companion Guide for Help Message Users*.

A.1. Mount Verification Messages

The following mount verification messages have approximately the same meaning for shadow sets as they do for regular disks. They are sent to the system console (OPA0:) and to any operator terminals that are enabled to receive disk operator messages.

- `virtual-unit`: is off line. Mount verification in progress.
- `virtual-unit`: has completed mount verification.
- `virtual-unit`: has aborted mount verification.

A.2. OPCOM Message

The following OPCOM message is returned in response to shadow set operations. This message results when the shadowing code detects that the boot device is no longer in the system disk shadow set. If the boot device is not added back into the system disk shadow set, the system may not reboot, and the dump may be lost if the system crashes.

`virtual-unit`: does not contain the member named to VMB. System may not reboot.

Explanation: This message can occur for the following reasons:

- The boot device is dismounted or failed out of the system disk shadow set.
- Shadowing finds the boot device missing from the system disk shadow set membership during any dismount operations on the system disk.

User Action: Do one of the following:

- Mount the boot device back into the shadow set as soon as possible.
- If you cannot mount the boot device back into the shadow set, change the device name in VMB (primary bootstrap) so the system can reboot when necessary.

A.3. Shadow Server Messages

Shadow server operations can display the following status messages on the system console (OPA0:) and on terminals enabled to receive operator messages.

Shadow server messages are always informational messages and include the prefix %SHADOW_SERVER-I-SSRV `message-abbreviation`. The following example includes the

OPCOM banner and the shadow server message to illustrate what the messages look like when they are output to the console:

```
%%%%%%%%%%   OPCOM 24-MAR-1990 15:01:30.99   %%%%%%%%%%
 (from node SYSTMX at 24-MAR-1990 15:01:31.36)
Message from user SYSTEM on SYSTMX
%SHADOW_SERVER-I-SSRVINICOMP, shadow server has completed initialization.
```

The following messages are returned by the shadow server in response to shadow set operations. Several of the messages refer to a **copy thread number**; this is a unique identifier denoting a copy or merge operation. The messages in this section are listed in alphabetical order by message abbreviation. For simplicity, the messages shown here do not include the SHADOW_SERVER-I- prefix.

SSRVCMPFCPY, completing copy operation on device _ `virtual-unit`: at LBN: `LBN-location`, ID number: `copy-thread-number`

Explanation: The copy operation has completed.

User Action: None.

SSRVCMPMRG, completing merge operation on device _ `virtual-unit`: at LBN: `LBN-location`, ID number: `copy-thread-number`

Explanation: The merge operation has completed.

User Action: None.

SSRVCOMPLYFAIL, still out of compliance for per-disk license units, new shadow members may be immediately removed

Explanation: The number of shadow set members on the node has exceeded the number of VOLSHAD-DISK license units for more than 60 minutes. Attempts to bring the node into compliance by removing unlicensed members from their shadow sets have failed. If any new members are mounted, they might be removed immediately.

User Action: Ensure that the number of VOLSHAD-DISK license units on each node is equal to the number of shadow set members mounted on that node. If necessary, dismount shadow set members until the number of mounted members equals the number of VOLSHAD-DISK license units loaded on the node. If you need more VOLSHAD-DISK license PAKs, contact a Digital support representative.

SSRVINICOMP, shadow server has completed initialization

Explanation: The shadow server has been initialized at boot time.

User Action: None.

SSRVINICPY, initiating copy operation on device _ `virtual-unit`: at LBN: `LBN-location`, I/O Size: `number-of-blocks` blocks, ID number: `copy-thread-number`

Explanation: A copy operation is beginning on the shadow set whose virtual unit number is listed in the message.

User Action: None.

SSRVINIMRG, initiating merge operation on device _ `virtual-unit`: at LBN `logical-block-number`, I/O Size: `number-of-blocks` blocks, ID number: `copy-thread-number`

Explanation: A merge operation is beginning on the shadow set. The merge can occur after a copy operation has completed.

User Action: None.

SSRVINIMMRG, initiating minimerge operation on device _ `virtual-unit`: at LBN `LBN-location`, I/O size: `number-of-blocks` blocks, ID number: `copy-thread-number`

Explanation: A shadowing minimerge is beginning on the device indicated. The message identifies the minimerge with the name of the shadow set virtual unit, and the LBN location of the minimerge, the size of the I/O request (in blocks), and the ID number of the copy thread. For example:

```
%SHADOW_SERVER-I-SSRVINIMMRG, initiating minimerge  operation on
device _DSA2: at LBN 0, I/O size: 105 blocks, ID number: 33555161
```

User Action: None.

SSRVINSUFPDL, insufficient per-disk license units loaded, shadow set member(s) will be removed in *number* minutes

Explanation: The number of shadow set members mounted exceeds the number of VOLSHAD-DISK license units loaded on the node. If this condition is not corrected before the number of minutes displayed in this message has elapsed, Volume Shadowing will remove unlicensed members from shadow sets in an attempt to make the node compliant with the number of loaded VOLSHAD-DISK license units.

User Action: Dismount shadow set members until the number of mounted members is equal to the number of VOLSHAD-DISK license units on the node.

SSRVNORMAL, successful completion of operation on device _ `virtual-unit`: at LBN `LBN-location`, ID number: `copy-thread-number`

Explanation: The copy or merge operation has completed.

User Action: None.

SSRVRESCPY, resuming copy operation on device _ `virtual-unit`: at LBN: `logical-block-number` I/O size: `number-of-blocks` blocks, ID number: `copy-thread-number`

Explanation: A copy operation is resuming. The message identifies the copy with a unique sequence number, the name of the shadow set virtual unit, the LBN location of the copy, and the size of the I/O request (in blocks). For example:

```
%SHADOW_SERVER-I-SSRVRESFCPY, resuming Full-Copy copy sequence number
16777837 on device _DSA101:, at LBN 208314  I/O size: 71 blocks
```

User Action: None.

SSRVSPNDCPY, suspending operation on device _ `virtual-unit`: at LBN: `logical-block-number`, ID number: `copy-thread-number`

Explanation: A copy operation is being interrupted before it completes. (If a crash occurs during a copy operation, a minimerge assist can interrupt the copy operation to resolve inconsistencies. The shadowing software can resume the copy operation when the minimerge completes.) The following message identifies the copy operation with the name of the shadow set virtual unit, the LBN location of the copy, and a unique ID number.

```
%SHADOW_SERVER-I-SSRVSPNDCPY, suspending operation on
device _DSA101:. at LBN: 208314, ID number: 16777837
```

User Action: None.

SSRVSPNDMMRG, suspending minimerge operation on device _ `virtual-unit`: at LBN: `logical-block-number` ID number: `copy-thread-number`

Explanation: A minimerge is interrupted before it completes. The message identifies the minimerge with the name of the shadow set virtual unit, the LBN location of the minimerge, and a unique ID number. For example:

```
%SHADOW_SERVER-I-SSRVSPNDMMRG, suspending minimerge operation
on device _DSA101:. at LBN: 3907911, ID number: 16777837
```

User Action: None.

SSRVSPNDMRG, suspending merge operation on device _ `virtual-unit`: at LBN: `LBN-location`, ID number: `copy-thread-number`

Explanation: A merge operation has been suspended while the shadow set undergoes a copy operation.

User Action: None.

SSRVTRMSTS, reason for termination of operation on device: _ `virtual-unit`:, abort status

Explanation: This message always accompanies the SSRVTERM message to provide further information about the copy termination.

User Action: Possible actions vary depending on the reason for the error. You might need to check and repair hardware or restart the copy operation.

SSRVTERMCPY, terminating operation on device: _ `virtual-unit`:, ID number: `copy-thread-number`

Explanation: The copy thread is aborting. See the accompanying SSRVTRMSTS message for more information.

User Action: None.

SSRVTERMMRG, terminating operation on device: _ `virtual-unit`:, ID number: `copy-thread-number`

Explanation: The merge thread is aborting. See the accompanying SSRVTRMSTS message for more information.

User Action: None.

SSRVTERMMMRG, terminating operation on device: _ `virtual-unit`:, ID number: `copy-thread-number`

Explanation: The minimerge thread is aborting. See the accompanying SSRVTRMSTS message for more information.

User Action: None.

A.4. VOLPROC Messages

Shadowing operations can display the following status messages on the system console (OPA0:) and on terminals enabled to receive disk operator messages.

Shadowing messages always include the prefix %SHADOW-I-VOLPROC and can sometimes be followed by "Volume Processing in Progress." The messages are displayed in the following format:

```
%SHADOW-I-VOLPROC, message-text
```

- The %SHADOW prefix indicates that the shadowing software is the facility that produced the error.
- `I` is a one-letter code indicating the status or the severity of the error. The VOLPROC messages are always informational (I) errors.
- VOLPROC is an abbreviation for the volume-processing facility.
- The variable `message-text` is the description of the status message. For most volume-processing errors, the text includes the virtual unit number or member unit number of the disk or device causing the error.

The following example shows a complete volume-processing status message:

```
%SHADOW-I-VOLPROC, DSA13: shadow set has changed state. Volume processing
 in progress.
```

The following messages are returned by the VOLPROC in response to shadow set operations. The messages in this section are listed in alphabetical order beginning with the first word after the shadow set member name or the virtual unit name. For simplicity, the messages do not include the %SHADOW-I-VOLPROC prefix.

`shadow-set-member`: contains the wrong volume.

Explanation: The shadowing software discovered a volume label mismatch after failover.

User Action: Check the disk drives and unit numbers.

`shadow-set-member`: has aborted volume processing.

Explanation: The shadow set is dissolved. A shadow set member was not restored to operational status before the MVTIMEOUT system parameter setting expires; thus, the mount operation aborts for the shadow set.

User Action: Check error logs and the shadow set membership; the disk or controller might need repair.

`shadow-set-member`: has been write-locked.

Explanation: The data on the disk is protected against write I/O operations.

User Action: Remove the write lock on the volume.

`shadow-set-member`: has completed volume processing.

Explanation: The shadow set state change is complete.

User Action: Check the shadow set membership; the disk or controller might need repair.

`shadow-set-member`: is offline.

Explanation: A shadow set member is off line. The shadowing software attempts to fail over.

User Action: None.

`shadow-set-member`: shadow copy has been completed.

Explanation: A shadow copy operation has completed.

User Action: None.

`shadow-set-member`: shadow set has been reduced.

Explanation: The specified shadow set member has been removed.

User Action: If the member failed out of the set (not dismounted), look for the cause of the failure and repair it.

`virtual-unit`: all shadow set copy operations are completed.

Explanation: All pending shadow set copy operations have completed. The same logical block on any shadow set member contains the same data.

User Action: None.

`virtual-unit`: shadow copy has been started.

Explanation: Indicates the start of a shadow copy operation.

User Action: None.

virtual-unit: shadow master has changed. Dump file will be written if system crashes. Volume Processing in progress.

Explanation: The shadowing software has determined a new master disk for the system disk shadow set. You can write a dump file for this system only if the master is the same disk as the one the system booted from. This is because the boot drivers are not connected with the shadow driver, and different boot drivers from the ones that interact with the booted system disk might be needed to interact with the new master disk. For example, a system disk could be served and also locally connected, causing the served path to use different drivers from the local path.

User Action: None.

virtual-unit: shadow master has changed. Dump file will not be written if the system crashes. Volume processing in progress.

Explanation: Indicates that the disk from which you booted is no longer in the shadow set. If a system failure occurs, a dump file cannot be written to the removed disk.

User Action: Return the disk to the shadow set.

virtual-unit: shadow set has changed state. Volume processing in progress.

Explanation: The state of the shadow set is in transition. The membership of the shadow set is changing because of either the addition or removal of members from the shadow set, or failover to another device after a hardware error. Further messages provide details if a change occurs.

User Action: None.