HP-UX 11i v3 Native Multi-Pathing for Mass Storage

Abstract

This document describes the Native Multi-Pathing feature offered by the mass storage subsystem on HP-UX 11i v3. It is intended for system administrators or operators.

For a comprehensive description of all the features of the HP-UX 11i v3 mass storage subsystem refer to *The Next Generation Mass Storage Stack HP-UX 11i v3* white paper.

Terms and Definitions

Agile Addressing	The ability to address a logical unit with the same DSF regardless of the location of the LUN, that is, the device file for a LUN remains the same even if the LUN is moved from one Host Bus Adapter (HBA) to another, from one switch/hub port to another or presented via a different target port to the host. The LUN device file stays the same even if the N-Port ID of the target port changes in the case of Fibre Channel LUNs.
Agile Naming Model	DSF naming model introduced in 11i v3 to support agile addressing.
Agile View of The I/O Tree	View of the I/O tree using agile addressing to represent elements of the I/O tree.
DSF	Device Special File.
EVM	Event Management System.
Hard Partition	Feature part of the HP Partitioning Continuum for HP-UX 11i on HP 9000 and HP Integrity servers. (Complete documentation available at http://www.hp.com).
Hardware Path (H/W Path)	A series of numbers representing the physical or virtualized location of a device. Before 11i v3, the hardware path contained a maximum of 14 elements of 8 bits each. Starting with 11i v3, the hardware path contains up to 64 elements of 64 bits each.
HBA	Host Bus Adapter.
(Legacy) H/W Path	H/W Path in the legacy format (pre HP-UX 11i v3). Used for all components, mass storage or not.
I_T nexus	Defined by the T10 SAM standard as a nexus between a SCSI initiator port and a SCSI target port.
I_T_L nexus	Defined by the T10 SAM standard as a nexus between a SCSI initiator port, a SCSI target port, and a LUN.
Legacy or agile I/O Tree	The I/O Tree is the HP-UX representation of physical and virtual devices discovered by the operating system. The pre-11i v3 I/O tree view is present on HP-UX 11i v3 for backward compatibility reasons. The legacy I/O tree is limited to the pre-11i v3 I/O tree view. The agile I/O tree is limited to the agile view.

Legacy Naming Model / Legacy Format	DSF format convention used prior to HP-UX 11i v3. This model is maintained in HP-UX 11i v3 for backward compatibility purpose.
Legacy DSF	A lunpath dependent DSF that follows the legacy naming model conventions, wherein the DSF embeds the bus/target/lun/option for a specific lunpath to a mass storage device (Ex. /dev/dsk/c#t#d#).
LUN	Logical unit that refers to an end storage device such as disk, tape, floppy, cdrom, changer, and so forth. This is the logical unit itself and does not represent the path to the logical unit.
LUN Hardware Path	Hardware path to the LUN in the agile view of the I/O Tree. It has the form `64000/0xfa00/0x*`
LUN id	Equivalent to the logical unit number defined by the T10 SAM standard.
Lunpath	Path to a LUN. It is also known as an I_T_L nexus.
Lunpath Hardware Path	The hardware path of a Lunpath. In the agile view of the I/O tree, the lunpath hardware path format is: `<hba_path>.<Target port WWN or Target Id>.<0xLUN id>`
Path	An I_T or I_T_L nexus as defined in the T10 SAM standard.
Persistent DSF	DSF following the agile naming model conventions. Does not contain any encoding of bus, target identifier or device specific option information.
SAM	T10 SCSI Architecture Model standard (available at http://www.t10.org)
SCSI Class Driver	An HP-UX device driver which manages one or more specific classes of mass storage devices. For example: Disk Driver, Tape Driver, Changer Driver, Pass-Through Driver.
SCSI Interface Driver	An HP-UX device driver which manages one or more specific types of Host Bus Adapters. For example: Tachlite FC Driver, Qlogic FC Driver.
SPC-3	T10 "*SCSI Primary Commands – 3*" (T10 SPC-3) standard (available at http://www.t10.org)
Target Id	Target port identifier as defined in SCSI transport protocols.
Target Path	Path to a target port. It is also known as an I_T nexus.
Target Path Hardware Path	The hardware path of a Target Path. In the agile view of the I/O tree, the target path hardware path has the following format: `<hba_path>.<Target port WWN or Target Id>`
VPD	Vital Product Data – term defined by the T10 SPC-3 standard (section 7.6) (available at http://www.t10.org).

WWID	SCSI Logical Unit World Wide Identifier obtained from VPD INQUIRY Page 83h.
WWN	Worldwide Name as defined in SCSI transport protocols. It is an identifier that is worldwide unique.

Introduction

HP-UX 11i v3 has re-architected the mass storage subsystem to significantly enhance scalability, performance, availability, manageability, and serviceability in a SAN environment. The re-architected subsystem increases maximum configuration limits to address very large SAN configurations while delivering performance and availability with automatic Native Multi-pathing, parallel I/O scan, optimized I/O forwarding and CPU locality.

Multi-pathing is native to HP-UX 11i v3. It is built in to the mass storage subsystem and it is available to applications without any special configuration. Pre-11i v3 multi-pathing add-on products are no longer necessary on HP-UX 11i v3.

Native multi-pathing offers the following features:

- optimal distribution of I/O traffic across lunpaths to LUNs,
- dynamic discovery of lunpaths and LUNs,
- automatic monitoring of lunpaths,
- automatic lunpath failover and recovery,
- intelligent I/O retry algorithms to deal with failed lunpaths,
- lunpath authentication to avoid data corruption.

This paper presents an overview of native multi-pathing and describes its principal benefits and features. It also provides details on managing the solution.

Native Multi-Pathing Features and Benefits Overview

Native Multi-Pathing Features Overview

Multi-pathing is the ability to manage the various paths to a LUN device. A path to a LUN is also known as an I_T_L nexus. It corresponds to the route taken by an I/O request issued from an HP-UX host to a SCSI device.

Here is an overview of the features that native multi-pathing encompasses. For more details refer to the Native Multi-Pathing Features section below.

- **LUN WWID and DSF** - The various paths to LUN devices are correlated based on a world-wide unique identifier (WWID) that is used to create a persistent DSF offering agile addressing.

- **Dynamic I/O load-distribution** - The I/O load to a LUN is optimally and transparently distributed across the available lunpaths.

- **High availability of SCSI devices** – To optimize access to LUNs, the mass storage stack transparently performs lunpaths error detection, recovery and automated failover.

- **LUN failure management** - When LUN failure conditions occur, the mass storage stack automatically recovers whenever possible. If necessary, administrators can use the new `scsimgr` command to recover from the LUN failure.

- **Active-Passive device support**

- **SAN dynamic discovery and reconfiguration** – Proactive and automatic discovery of new paths, along with dynamic deletion of stale or faulty path components with tools like `rmsf`, allow applications I/O traffic to be dynamically balanced across the most up-to-date set of active lunpaths. New DSFs are automatically created for newly discovered LUN devices. The health of LUNs and lunpaths is also dynamically updated as LUNs and lunpaths availability changes. The LUNs and lunpaths health is also made available to user applications via tools like `ioscan`.

- **Full integration with HP-UX 11i v3** – Existing tools (for instance `ioscan, sar,` and `smh`) and HP-UX subsystems (for instance boot, dump, file systems (HFS), the Logical Volume Manager (LVM)) have been enhanced to use native multi-pathing. Furthermore new tools like `scsimgr` are provided to manage the native multi-pathing solution.

- **Compatibility with the legacy naming model** – Legacy lunpath DSFs are available on HP-UX 11i v3 for backward compatibility reasons. High availability is ensured by default on legacy DSFs through native multi-pathing. A tunable is provided to enable/disable native multi-pathing on legacy DSF.

- **Pre-HP-UX 11i v3 multi-pathing add-on products are no longer required**.

Benefits of Native Multi-Pathing

Optimal Use of System Resources

The mass storage subsystem optimally uses system resources such as memory and processors to perform I/O operations as efficiently as possible. For instance, on systems supporting cell local memory, you can tune the I/O load distribution to reduce memory, interrupt and device latencies using the "cell local round robin" I/O load balancing policy (see section Disk LUN load balancing selection for more details).

Optimal use of SAN resources

The I/O path selection is optimal to achieve best I/O data throughput. For each SCSI device class, the mass storage subsystem offers multiple I/O load balancing policies. A load balancing policy can be selected and tuned to take into account the idiosyncrasies of the SAN configuration.

Furthermore, new SAN resources are readily made available to the host thanks to the automated discovery of SCSI devices. Stale SAN resources can be deleted to free up system resources.

Scalability

The mass storage subsystem can theoretically address up to 2^{24} (16 million) LUNs. There is no architectural limit on the number of lunpaths allowed to a LUN. However, you may refer to the release notes of HP-UX 11i v3 to find out the maximum number of LUNs and lunpaths that were tested (http://docs.hp.com/en/oshpux11iv3.html).

However, the mass storage subsystem has not removed any scalability limitations present in previous releases of HP-UX for legacy DSFs.

Built-in High Availability of SAN Resources

The mass storage subsystem quickly identifies failing SAN components and action is taken to recover from the error to minimize the impact on applications using the SAN resources. The mass storage subsystem proactively monitors and reports lunpath error conditions and provides error recovery mechanisms. When a lunpath fails, the mass storage subsystem switches the I/O flow to other available lunpaths (**path failover**) while recovery is attempted on the failing lunpath. Depending upon the circumstances, a failing lunpath component can either automatically recover (**self-healing**), or the mass storage subsystem notifies the system administrator who can take appropriate action.

Increased I/O performance

The optimal use of system and SAN resources in the selection of lunpaths leads to significant improvements in I/O throughput. See the *HP-UX 11i v3 Mass Storage I/O Performance Improvements* white paper for detailed information.

Ease of Management

Native multi-pathing is easy to manage for the following reasons:

- The agility of LUN addressing achieved through the use of LUN WWID makes LUN DSFs immune to certain SAN topology changes, such as for instance the addition of new lunpaths to a LUN device.

- Existing HP-UX commands such as `ioscan`, `sar`, `insf`, and `rmsf` have been enhanced to handle LUN multi-pathing. For instance, `ioscan` has a new option, the map option specified by `-m`, to display the mapping between lunpath hardware paths and LUN hardware paths. The `sar` command has a new option (-L) to display data throughput of lunpaths.

- New tools have been introduced. The new command line utility `scsimgr` manages the mass storage subsystem. It is integrated with HP System Management Homepage `to` offer a graphical user interface. See the *scsimgr SCSI Management and Diagnostics Utility* white paper.

- System administrators no longer have to learn commands specific to multi-pathing add-on products.

- The mass storage subsystem performs quick components fault notification via statistics, diagnostics messages, tunables.

- Tools such as `ioscan` and `scsimgr`, and mechanisms internal to the mass storage subsystem, give an up-to-date view of the SAN components connected to the host at any time. As the SAN topology evolves, the host system view of the SAN is updated. Furthermore, `ioscan` and `scsimgr` provide easy ways to display the relationships between SAN components.

- Dynamic discovery of SCSI devices automatically provides system administrators with the most up-to-date view of SAN resources.

Native Multi-Pathing Features

LUN WWID and DSF

The various lunpaths to LUN devices are correlated based on a world-wide unique identifier (WWID) that is associated with each LUN device. Indeed, the host can determine that different lunpaths lead to the same LUN only if a LUN can be uniquely identified by the operating system. The LUN WWID is based on SPC-3 commands Inquiry and VPD Inquiry Page 83h data.

Based on this LUN WWID, the mass storage subsystem creates one persistent DSF for each LUN irrespective of the number of lunpaths to the LUN device. The association between a LUN WWID and a LUN DSF is persistently stored on the host.

Using LUN WWID and LUN DSFs has the following advantages:

- **LUN addressing scalability**: Since LUN DSF use opaque minor numbers, the mass storage susystem can theoretically address up to 2^{24} (16 million) LUNs. The pre-11.31i v3 limitations of 32k lunpaths only exists for the legacy naming model.

- **LUN agile addressing**: A LUN DSF remains unaffected by certain SAN topology changes, such as the LUN device being moved from one target port to another target port or, in the case of a Fibre Channel port, a target N-Port ID changing.

- **Abstraction of lunpaths management**: If additional lunpaths (via the addition of new SCSI controller or new SCSI target ports) are offered to a given LUN, or if existing paths components to the same LUN are removed, the LUN DSF remains unaffected.

- **One DSF per LUN irrespective of the number of lunpaths**. Compared to 11i v2, the number of LUN DSFs is no longer proportional to the number of lunpaths. It reflects the number of SCSI devices connected to the host.

Some old SCSI devices do not support VPD Inquiry Page 83h data. For such devices, the mass storage subsystem creates one LUN DSF per lunpath to the LUN device.

See the *HP-UX 11i v3 Mass Storage Device Naming* white paper for more information on persistent DSFs.

Dynamic I/O Load-Distribution

The mass storage subsystem dynamically distributes the I/O load across the available lunpaths to a LUN according to a settable policy. This distribution is transparent to the application generating the I/O load.

Dynamic I/O load balancing leads to significant improvements in I/O throughput. See the *HP-UX 11i v3 Mass Storage I/O Performance Improvements* white paper for more information.

To aid in optimal resource utilization, the SCSI stack supports several load balancing policies and tunables settable with `scsimgr`. For instance, disk devices use the round-robin load balancing policy as the default policy. However, administrators have the flexibility to change and tune the default load balancing policy of LUNs using `scsimgr`.

The `sar` command has been enhanced to display details about the I/O performance details on each lunpath. The `scsimgr` command shows the I/O distribution based on both the number of I/O operations and the amount of data transferred for each lunpath.

Policies Supported for Disk Devices

Disk devices support the following I/O load balancing policies:

- **Round-robin** – This policy distributes the I/O load equally across all active lunpaths irrespective of the current load on each lunpath. It is suitable when lunpaths have similar I/O operation turnaround characteristics.

- **Least command load** – This policy selects the lunpath with the least I/O load for the next I/O operation. It is suitable when lunpaths have asymmetric performance characteristics.

- **Cell aware round robin** - This policy is applicable to servers supporting hard partitions, which have high latencies for non-local memory access operations. The lunpath chosen to issue an I/O operation is in the same locality in which the I/O is issued. This policy helps optimize memory access latency.

- **Preferred path**: This policy is applied to certain types of targets that present an optimized/un-optimized controller model (different from active-passive). An optimized/un-optimized controller pair is one in which the optimized controller is favored for accessing that LUN since it yields better performance.

The default disk device load balancing policy is round-robin, even on servers supporting hard partitioning. However, the administrator can change it to any of the above listed.

The administrator has a lot of flexibility in setting the scope of load balancing policies for disks. A load balancing policy can be set by for all disk devices, or for a set of disk devices meeting some specific criteria, such as vendor id, product id, and firmware revision, or for a specific disk device.

Policies Supported for Tapes, Changer and Pass-Through Devices

Because of the serial nature of the I/O flow to tape and changer devices, only one path selection mechanism is supported by `estape` and `eschgr` drivers: **path lock down**. When opening a tape or changer LUN DSF, the mass storage subsystem internally selects the optimal lunpath onto which all the I/O operations are sent.

Devices claimed by the pass-through driver (`esctl`) also use path lockdown as the I/O load balance policy.

High Availability of SCSI devices

To provide applications with continuous access to the LUNs, the mass storage subsystem has built-in LUN access high availability.

By default, without requiring special upper layers, the mass storage subsystem increases the availability of LUN devices to applications by doing lunpath failovers, detecting and removing failing

lunpaths from the application I/O traffic, by monitoring offline lunpaths, and automatically making lunpaths that come online available to application I/O traffic.

The SCSI subsystem monitors SCSI components, such as SCSI controllers, target ports, lunpaths and LUNs. As failing components are identified, the mass storage subsystem reports errors by logging messages in the system log, then the SCSI subsystem resorts to path failover and recovery mechanisms to provide applications with continuous access to the LUN end devices; only when certain critical errors happen, is administrator intervention required.

In summary, after detecting a SCSI component error, the operating system reports the error to system administrators and offers a palette of pro-active recovery actions: automatic path failover or dynamic replacement of the failing component.

Path Error Reporting

HP-UX 11i v3 offers new and enhanced mechanisms to report failures on SCSI components. The goal is to assist administrators in performing quick and efficient diagnostic to take the most appropriate action.

- **Error messages** - A comprehensive set of error messages of various severity levels are used to report a wide range of errors. These messages can be monitored in syslog and STM.

- **Statistics** - A detailed set of statistics is available for each SCSI component to help troubleshooting, and to quickly identify a faulting component. Administrators can use `scsimgr` to display these statistics.

- **EVM event**s – The mass storage subsystem generates events to which other modules in the kernel or user space can subscribe, to get notified about changes on a LUN and lunpath properties. The SCSI stack monitors every LUN and every lunpath availability change. It also monitors LUN property changes such as LUN size.

- **I/O error triggered events** – The mass storage subsystem also reports failures on the lunpaths and LUN upon detection of certain I/O errors.

Path Failover

When a lunpath goes offline, I/O operations issued on that lunpath will fail. The policy of how the mass storage subsystem deals with this scenario is dependent upon three factors:

- **Path bound I/O operations**
  User applications can request the mass storage subsystem to issue I/O operations on a specific lunpath. Such I/O operations are called path bound I/O operations. When a path bound I/O fails, the SCSI stack retries it a certain number of times on the same lunpath before failing it back to the upper layer (for example applications, file systems, volume managers). There is no path failover. I/O operations sent to a LUN using the path lock down load balancing policy are path bound I/O operations.

- **I/O operations not bound to a path**
  Path failover is applied to I/O operations that are not bound to a lunpath . When an not bound to a path I/O operation fails, if the I/O can be retried (see I/O retry policy below), the I/O is failed over the next lunpath selected by the LUN load balancing policy path selection algorithm.

- **I/O retry policy**
  The mass storage subsystem retries a failing I/O operation a certain number of times before returning failure to the application using one of two retry policies:

    - **time based** - the mass storage subsystem retries the I/O operation within a certain time interval which is either set by upper layer modules such as the volume manager or the file system, or determined by a default LUN attribute. For disk LUNs, the *esd_secs* LUN attribute holds the time credit for an I/O operation across different retries. For tape LUNs, the *read_secs* attribute and *write_secs* attribute hold the read and write time credits.

    - **count based** - The I/O operation is retried less than a high-water mark threshold . For disk LUNs, I/O operations can be retried indefinitely (if disk LUN *infinite_retries_enable* attribute is set), or a finite number of times (corresponding to the disk LUN *max_retries* attribute value).

LUN Failure Management

Managing Loss of Accessibility to a LUN

When all the lunpaths to a LUN are taken offline, the LUN becomes inaccessible. The mass storage subsystem will still accept I/O operations to this LUN during a **transient grace period**. This mechanism gives some time for the LUN to recover and shields applications from SAN transient conditions that may cause a temporary loss of accessibility to the LUN. If at least one lunpath becomes active before the end of the grace period, incoming I/O operations can flow again. After this grace period expires, pending I/O operations and further incoming I/O operations to this LUN are returned with a failure indication until a lunpath comes back online. Furthermore the stack provides more flexibility to the customer by allowing administrators to tune the value of the transient grace period. This allows the mass storage subsystem to provide high availability customized to the local SAN.

Managing Authentication Failure

Whenever a LUN is opened, the SCSI stack authenticates that the LUN represented by the DSF is still the same device. The goal is to prevent data written on the physical LUN device from being corrupted by mistake when LUN devices are swapped. The authentication consists of getting the WWID of the LUN from the LUN device and comparing it with the WWID associated with the DSF at the time of the DSF creation.

If any change in LUN behavior is detected, a LUN authentication failure is printed on the console. To prevent data corruption, any pending I/O operation to the LUN is failed and no further I/O operation can be sent to the LUN until the LUN is re-authenticated properly or until the LUN identifier is changed by the administrator. System administrators can use "`scsimgr replace_wwid`" to change the "identifier" associated with a given LUN DSF (See *"scsimgr SCSI Management and Diagnostics Utility"* white paper).

Media Based Errors

If the SCSI stack detects the LUN disk device could not commit a write from its cache to the media, then it freezes the I/O traffic to the disk to prevent data corruption. When the error condition on the LUN has been cleared, the system administrator must run "`scsimgr enable -D <lun DSF>`" to resume I/O operations on the LUN.

Active-Passive Device Support

Active-passive devices require device specific mechanisms to activate passive lunpaths upon failure of active lunpaths. The mass storage subsystem provides tailored support of multi-pathing with active-passive devices via a plug-ins mechanism. Refer to the "*Writing Active/Passive Switch Plug-Ins*" white paper for more information. An alternative is to use the device as active-active if this functionality is available as this does not require a plug-in.

SAN Dynamic Discovery and Reconfiguration

SCSI Devices Dynamic Discovery

At boot time, SCSI devices connected to the host are automatically discovered and corresponding SCSI components are instantiated by the operating system. Once the system is up and running, administrators can add new SCSI devices, disconnect existing SCSI devices, or replace path components, such as a failing Fibre Channel HBA. Certain topology change events are automatically detected by the mass storage subsystem while others require the system administrator's intervention.

The mass storage subsystem asynchronously detects some topology changes in the SAN. For instance, the addition of a Fibre Channel port to a Fibre Channel switch triggers a Fibre Channel Request Status Change Notifications (RSCN) that is automatically detected by the SCSI stack. Upong receiving the RSCN, the SCSI services automatically discover the LUNs connected to the newly added target port.

However, some SAN topology changes are not automatically detected by the operating system. They require the administrator to run `ioscan`. For instance, after adding Parallel SCSI LUNs, the administrator must run `ioscan` to discover the newly added LUNs.

Both automatic SCSI device discovery and the `ioscan` command have the following results:

- The mass storage subsystem registers the corresponding paths components in both the legacy and the agile I/O tree views.
- Legacy lunpaths DSF and LUN DSFs are automatically created to make the new devices readily accessible to applications.
- The mass storage subsystem makes the new lunpaths available to I/O traffic with no interruption to applications, and, in the case of automatic device discovery, without requiring special actions from the system administrator.

The complexity of the SAN components under the LUN is hidden to the administrator:

- The dynamic discovery of components is transparent to the administrator. If needed, running `ioscan` (without the –k option) automatically creates the new LUN DSFs.
- Newly discovered active lunpaths are automatically used in the lunpath selection scheme of I/O load balancing. Therefore, applications sending I/O operations through existing LUN DSFs are not affected by the discovery of new lunpaths.
- New LUN DSFs corresponding to newly discovered LUNs are seemlessly created.

SAN Component Deletion

Throughout the life of a system, SAN components may be replaced or removed. For instance, lunpaths to a LUN device may become stale because the target port involved has been replaced. Administrators can delete SCSI target paths and SCSI lunpaths using `rmsf`. They can also replace and delete SCSI controllers using the OL* process.

The I/O stack transparently handles deletion or disabling of lunpaths . As long as there is at least one available lunpath to a LUN, I/O traffic is not be affected. This allows customers to replace faulty SCSI HBAs (via OL* operations) or faulty SCSI target ports without impacting applications.

See corresponding man pages on `rmsf(1M)` and `pdweb(1M)`.

Easy Monitoring of LUNs and Lunpaths Accessiblity

To provide administrators with a real-time status of the availability of lunpath or a LUN components, the mass storage subsystem dynamically updates the "health" property of lunpath and LUN I/O nodes. The "health" property conveys availability status values such as online, offline, unusable, disable or standby. Without performing a full scan of the SAN configuration, the administrator can display the health property of lunpaths and LUN components by running "`ioscan -P health`".

See section Lunpath and LUN Health for more details.

Full Integration with HP-UX 11i v3

Multi-pathing is fully integrated with HP-UX 11i v3. Here are a few examples of subsystems and utilities that have evolved toward using multi-pathing.

crashconf(1M)

The dump subsystem is aware of multi-pathed devices and supports automatic dump device path failover. If a configured lunpath goes offline, the dump subsystem automatically selects an alternate available hardware lunpath and reconfigures the dump device. The dump subsystem also takes advantage of multi-pathing through the concurrent dump functionality which significantly reduces dump time.

For more information on changes to the dump subsystem, see the *"HP-UX 11i v3 Crash Dump Improvement"* white paper.

setboot(1M)

The `setboot` command is aware of multi-pathed devices and supports automatic boot path failover. If the hardware lunpath written into stable storage goes offline, `setboot` retrieves an alternate available lunpath to the LUN and writes it into the system stable storage.

Refer to the "*setboot(1M) in HP-UX 11i v3*" white paper for more information.

LVM

In the HP-UX 11i v3 release, LVM supports both legacy and persistent DSFs. Since multi-pathing applies by default to legacy and persistent LUN DSFs, LVM uses native multi-pathing by default. All the LVM commands (`pvcreate, vgcreate` and `vgextend`) are backward compatible, and work transparently with both legacy and persistent DSFs. New options have been added `to vgimport` and `vgscan` to select the persistent DSF naming model. HP highly recommends using persistent DSFs for LVM configurations. The LVM alternate links (PVlinks) feature is still supported in HP-UX 11i v3.

See the "*the LVM Migration from Legacy to Agile Naming Model HP-UX 11i v3*" white paper for more information.

File Systems

In HP-UX 11i v3, HFS supports both legacy and persistent LUN DSFs. Therefore, HFS takes advantage of multi-pathing by default. Refer to the release notes of Symantec for the support of VxFS on HP-UX 11iv3.

Commands

Existing commands such as `ioscan and sar` have evolved to use multi-pathing. New options have been introduced. For information on the changes, see the command's associated man page and the HP-UX 11i v3 Release Notes.

Compatibility with the Legacy Naming Model

By default, native multi-pathing applies to legacy DSFs even though a legacy DSF corresponds to a lunpath to a LUN. When an application accesses a legacy DSF, the mass storage subsystem internally applies the configured LUN level multi-pathing (I/O load balancing, automated path failure detection and recovery) to send I/O requests to the end LUN. This offers applications migrating to HP-UX 11i v3 the opportunity to easily take advantage of multi-pathing: no special configuration is needed.

At the same time the mass storage subsystem is flexible to accommodate the strict backward compatibility needs of some applications by allowing disabling of native multi-pathing on legacy DSFs via a tunable. See section "Setting Native Multi-Pathing support on legacy DSFs".

Pre-HP-UX 11i v3 Multi-Pathing Add-on Products are no longer required

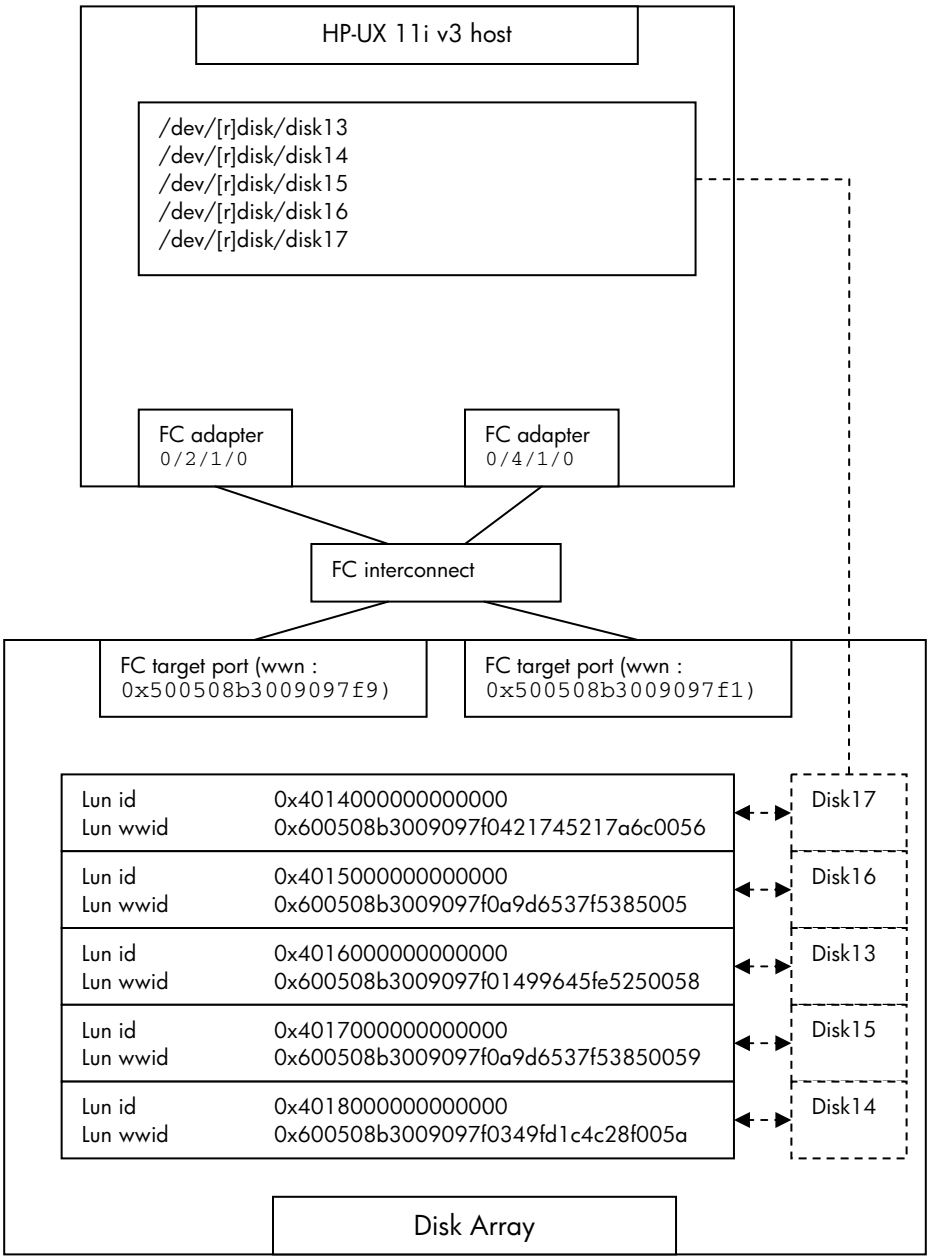
HP add-on AutoPath® and SecurePath® products will no longer be supported with HP-UX 11i v3. For more information, see the "*Migrating from HP Storage Works Secure Path for Active-Active Disk Arrays to Native Multipathing in HP-UX 11i v3*" white paper.

To determine if other add-on multi-pathing products are supported on HP-UX 11i v3, see their associated release notes.

Managing HP-UX 11i v3 Native Multi-Pathing

To illustrate the management of multi-pathing on HP-UX 11iv3, consider a real world example. The SAN is comprised of:

- a server running HP-UX 11i v3. It is connected to the SAN via two host bus adapters (HBAs)
- a disk array with five LUN devices connected to the SAN via two target ports.



Provided that all the LUNs are configured to be visible to the host via each HBA and each target port, each LUN can be accessed via four different lunpaths corresponding to all the possible combinations of HBAs and target ports. In HP-UX 11i v3, only one persistent DSF per LUN is exported to applications. For instance, the administrator will see the following persistent DSFs:

- `/dev/[r]disk/disk13`
- `/dev/[r]disk/disk14`
- `/dev/[r]disk/disk15`
- `/dev/[r]disk/disk16`
- `/dev/[r]disk/disk17`

For each LUN device, the `esdisk` driver selects by default the round-robin dynamic IO load balancing policy.

Viewing Native Multi-pathing Related Information

Hardware Paths to Lunpaths, Targetpaths and LUNs

Run `ioscan` to see the hardware paths for SCSI HBA, target paths, lunpaths and LUNs in the **agile view**.

There are two Fibre Channel SCSI HBAs:

```
# ioscan -kfnC fc
Class     I  H/W Path  Driver S/W State   H/W Type     Description
==========================================================
fc        0  0/2/1/0   td    CLAIMED     INTERFACE    HP Tachyon XL2 Fibre Channel Mass
Storage Adapter
fc        3  0/4/1/0   td    CLAIMED     INTERFACE    HP Tachyon XL2 Fibre Channel Mass
Storage Adapter
```

The **agile view** shows two target ports with world-wide names **0x500508b3009097f1** and **0x500508b3009097f9** and four target paths:

```
# ioscan -kfnNC tgtpath
Class     I  H/W Path       Driver S/W State   H/W Type     Description
==========================================================
...
tgtpath   7  0/2/1/0.0x500508b3009097f1  estp   CLAIMED     TGT_PATH     fibre_channel
target served by td driver
tgtpath   3  0/2/1/0.0x500508b3009097f9  estp   CLAIMED     TGT_PATH     fibre_channel
target served by td driver
tgtpath   8  0/4/1/0.0x500508b3009097f1  estp   CLAIMED     TGT_PATH     fibre_channel
target served by td driver
tgtpath   6  0/4/1/0.0x500508b3009097f9  estp   CLAIMED     TGT_PATH     fibre_channel
target served by td driver
```

The lunpaths are represented by a concatenation of the target path hardware path and the LUN 64 bit address (eg. `0/2/1/0.0x500508b3009097f9 + LUN address` **0x4014000000000000).** The following `ioscan` output shows a few lunpaths:

```
# ioscan -kfnNC lunpath
Class     I  H/W Path  Driver S/W State   H/W Type     Description
==========================================================
...
lunpath  15  0/2/1/0.0x500508b3009097f1.0x0                 eslpt   CLAIMED     LUN_PATH
LUN path for ctl2
lunpath  16  0/2/1/0.0x500508b3009097f1.0x4014000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk17
lunpath  19  0/2/1/0.0x500508b3009097f1.0x4015000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk16
lunpath  17  0/2/1/0.0x500508b3009097f1.0x4016000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk13
lunpath  18  0/2/1/0.0x500508b3009097f1.0x4017000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk15
lunpath  20  0/2/1/0.0x500508b3009097f1.0x4018000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk14
lunpath   0  0/2/1/0.0x500508b3009097f9.0x0                 eslpt   CLAIMED     LUN_PATH
LUN path for ctl2
lunpath   5  0/2/1/0.0x500508b3009097f9.0x4014000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk17
lunpath   4  0/2/1/0.0x500508b3009097f9.0x4015000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk16
lunpath   1  0/2/1/0.0x500508b3009097f9.0x4016000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk13
lunpath   3  0/2/1/0.0x500508b3009097f9.0x4017000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk15
lunpath   2  0/2/1/0.0x500508b3009097f9.0x4018000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk14
lunpath  21  0/4/1/0.0x500508b3009097f1.0x0                 eslpt   CLAIMED     LUN_PATH
LUN path for ctl2
lunpath  22  0/4/1/0.0x500508b3009097f1.0x4014000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk17
```

```
lunpath  23  0/4/1/0.0x500508b3009097f1.0x4015000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk16
lunpath  26  0/4/1/0.0x500508b3009097f1.0x4016000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk13
lunpath  24  0/4/1/0.0x500508b3009097f1.0x4017000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk15
lunpath  25  0/4/1/0.0x500508b3009097f1.0x4018000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk14
lunpath   8  0/4/1/0.0x500508b3009097f9.0x0                 eslpt   CLAIMED     LUN_PATH
LUN path for ctl2
lunpath  13  0/4/1/0.0x500508b3009097f9.0x4014000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk17
lunpath  11  0/4/1/0.0x500508b3009097f9.0x4015000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk16
lunpath  12  0/4/1/0.0x500508b3009097f9.0x4016000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk13
lunpath  10  0/4/1/0.0x500508b3009097f9.0x4017000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk15
lunpath   9  0/4/1/0.0x500508b3009097f9.0x4018000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk14
```

The above shows that five disk LUNs are connected to the target port of world-wide name **`0x500508b3009097f9`** (green outline) and that `ioscan` displays the DSF of the LUN (for example `disk17`) to which each lunpath maps. The LUN corresponding to `/dev/[r]disk/disk17` has four lunpaths.

LUN hardware paths and the corresponding LUN DSFs in the **agile view** look like:

```
# ioscan -kfnNC disk
Class     I  H/W Path  Driver S/W State   H/W Type     Description
===================================================================
disk      13  64000/0xfa00/0x1  esdisk   CLAIMED     DEVICE       COMPAQ  MSA1000 VOLUME
                      /dev/disk/disk13   /dev/rdisk/disk13
disk      14  64000/0xfa00/0x2  esdisk   CLAIMED     DEVICE       COMPAQ  MSA1000 VOLUME
                      /dev/disk/disk14   /dev/rdisk/disk14
disk      15  64000/0xfa00/0x3  esdisk   CLAIMED     DEVICE       COMPAQ  MSA1000 VOLUME
                      /dev/disk/disk15   /dev/rdisk/disk15
disk      16  64000/0xfa00/0x4  esdisk   CLAIMED     DEVICE       COMPAQ  MSA1000 VOLUME
                      /dev/disk/disk16   /dev/rdisk/disk16
disk      17  64000/0xfa00/0x5  esdisk   CLAIMED     DEVICE       COMPAQ  MSA1000 VOLUME
                      /dev/disk/disk17   /dev/rdisk/disk17
...
```

LUN WWID

The **"wwid" attribute** holds the LUN VPD page 83h WWID:

```
# scsimgr get_attr -D /dev/rdisk/disk17 -a wwid

        SCSI ATTRIBUTES FOR LUN : /dev/rdisk/disk1

name = wwid
current = 0x600508b3009097f0421745217a6c0056
default =
saved =
```

LUN-to-lunpaths Mapping

ioscan(1M)

The `ioscan` command is now equipped with a powerful set of new options to query the relationship among various SAN components. The following sections demonstrate the use of these new options in the context of the above example.

`The ioscan command` can query the mapping combinations between LUN and lunpaths using DSF or hardware paths.

- *To which legacy DSF does `/dev/rdisk/disk17` map?*

```
# ioscan -m dsf /dev/rdisk/disk17
Persistent DSF           Legacy DSF(s)
========================================
/dev/rdisk/disk17        /dev/rdsk/c5t2d4
                         /dev/rdsk/c7t2d4
                         /dev/rdsk/c9t2d4
                         /dev/rdsk/c11t2d4
```

- *To which persistent DSF does `/dev/rdsk/c5t2d4` map?*

```
# ioscan -m dsf /dev/rdsk/c5t2d4
Persistent DSF           Legacy DSF(s)
========================================
/dev/rdisk/disk17        /dev/rdsk/c5t2d4
```

- *To which lunpath and legacy hardware paths does LUN hardware path `64000/0xfa00/0x5`map?*

```
# ioscan -m hwpath -H 64000/0xfa00/0x5
Lun H/W Path      Lunpath H/W Path                  Legacy H/W Path
======================================================================
64000/0xfa00/0x5
                  0/2/1/0.0x500508b3009097f9.0x4014000000000000   0/2/1/0.3.8.0.0.2.4
                  0/4/1/0.0x500508b3009097f9.0x4014000000000000   0/4/1/0.3.8.0.0.2.4
                  0/2/1/0.0x500508b3009097f1.0x4014000000000000   0/2/1/0.3.14.0.0.2.4
                  0/4/1/0.0x500508b3009097f1.0x4014000000000000   0/4/1/0.3.14.0.0.2.4
```

- *To which lunpath hardware path and LUN hardware path does legacy lunpath hardware path `0/2/1/0.3.8.0.0.2.4` map?*

```
# ioscan -m hwpath -H 0/2/1/0.3.8.0.0.2.4
Lun H/W Path      Lunpath H/W Path                  Legacy H/W Path
======================================================================
64000/0xfa00/0x5
                  0/2/1/0.0x500508b3009097f9.0x4014000000000000   0/2/1/0.3.8.0.0.2.4
```

- *To which LUN and legacy hardware path does new lunpath hardware path `0/2/1/0.0x500508b3009097f9.0x4014000000000000` map?*

```
# ioscan -m hwpath -H 0/2/1/0.0x500508b3009097f9.0x4014000000000000
Lun H/W Path      Lunpath H/W Path                  Legacy H/W Path
======================================================================
64000/0xfa00/0x5
                  0/2/1/0.0x500508b3009097f9.0x4014000000000000   0/2/1/0.3.8.0.0.2.4
```

Refer to the *HP-UX 11i v3 Mass Storage Device Naming* white paper for more information.

scsimgr(1M)

The `scsimgr` command displays the mapping between LUNs and lunpaths.

```
# scsimgr lun_map -D /dev/rdisk/disk17

        LUN PATH INFORMATION FOR LUN : /dev/rdisk/disk17

Total number of LUN paths     = 4
World Wide Identifier(WWID)    = 0x600508b3009097f0421745217a6c0056

LUN path : lunpath5
Class                         = lunpath
```

```
Instance                      = 5
Hardware path                 = 0/2/1/0.0x500508b3009097f9.0x4014000000000000
SCSI transport protocol       = fibre_channel
State                         = UNOPEN
Last Open or Close state      = ACTIVE

LUN path : lunpath13
Class                         = lunpath
Instance                      = 13
Hardware path                 = 0/4/1/0.0x500508b3009097f9.0x4014000000000000
SCSI transport protocol       = fibre_channel
State                         = UNOPEN
Last Open or Close state      = ACTIVE

LUN path : lunpath16
Class                         = lunpath
Instance                      = 16
Hardware path                 = 0/2/1/0.0x500508b3009097f1.0x4014000000000000
SCSI transport protocol       = fibre_channel
State                         = UNOPEN
Last Open or Close state      = ACTIVE

LUN path : lunpath22
Class                         = lunpath
Instance                      = 22
Hardware path                 = 0/4/1/0.0x500508b3009097f1.0x4014000000000000
SCSI transport protocol       = fibre_channel
State                         = UNOPEN
Last Open or Close state      = ACTIVE
```

The above output shows the lunpath states as `UNOPEN`: it means that the LUN is currently not open. Furthermore, the last open or close state is `ACTIVE`: the LUN is available for I/O traffic.

Statistics

The effects of the distribution of the I/O load across lunpaths can be observed using I/O transfer statistics. Using `scsimgr`, administrators can gather the following I/O transfer statistics on lunpath and LUNs. The `sar` command can also display I/O throughput on LUN and lunpaths (see the Native multi-pathing: an example section below).

In the context of LUN multi-pathing, it is also very useful to be able to monitor the behavior of lunpaths and LUN components. Using error related statistics such as I/O errors and open errors system administrators can readily identify failing components and understand the cause of the failure. For instance, the administrator can gather the following lunpath open failure statistics and I/O errors statistics:

```
# scsimgr get_stat -H 0/4/1/0.0x500508b3009097f9.0x4014000000000000

        STATISTICS FOR LUN path : 0/4/1/0.0x500508b3009097f9.0x4014000000000000

Generic Statistics:
…
Open failures due to inquiry failure             = 0
Open failures due to insufficient inquiry data   = 0
Open failures due to invalid peripheral qualifier= 0
EVPD page 83h inquiries                          = 2757
EVPD page 83h inquiry failures                   = 0
insufficient EVPD page 83h inquiry data          = 0
Mismatches of peripheral qualifiers              = 0
Page 83h ids not associated with the LUN         = 0
Open failures due to no page 83h response        = 0
Open failures due to page 83h code mismatches    = 0
Open failures due page 83h id mismatches         = 0
Open failures due to page 83h length mismatches  = 0
Open failures due to page 83h content mismatches = 0
…
I/O transfer Statistics:
…
```

```
Check condition status                          = 43
Busy status                                     = 0
Queue full status                               = 0
Reservation conflicts                           = 0
Invalid Request status                          = 0
Select Timeout status                           = 0
Incomplete status                               = 0
No Resource status                              = 0
Target Path Offline status                      = 0
IO Timeout status                               = 0
IO Aborted status                               = 0
Reset Occured status                            = 0
Unrecognized CDB status                         = 0
Bad Sense data status                           = 0
Deferred errors                                 = 0
Recovered errors                                = 0
NOT READY sense status                          = 0
Medium errors                                   = 0
Hardware errors                                 = 0
Illegal request sense status                    = 42
Unit Attentions                                 = 1
```

Lunpath and LUN Health

The "health" property of an I/O node is new in HP-UX 11i v3. It can be displayed with "`ioscan -P health`" (see the *"Next Gen Mass storage stack white-paper"* white paper).

The table below explains the "health" property values of a disk LUN I/O node.

online	The LUN is accessible through one or more lunpaths
offline	All the lunpaths to the LUN have gone offline. As a result, the LUN is not accessible
limited	Not all paths to the LUN are active : some paths are failing
unusable	Not Applicable
disabled	The LUN has been suspended as a result of one of the following errors: • LUN disabled due to unrecoverable deferred error. • SIOC_DISABLE I/O control operation issued by a kernel component or an application. For instance, a disk LUN can be disabled using the `scsimgr` command with the disable option: scsimgr disable –D <disk lun DSF> • Change in block size (for disk only) As a result of being disabled, all pending I/O requests to the LUN are aborted and are returned with an error to upper layers and applications. No further I/O operation can be issued to the LUN.
standby	Not Applicable

The table below explains the "health" property values of a lunpath I/O node.

online	The lunpath is active

offline	The lunpath is reported offline as a result of the following conditions:
	• The underlying target path becoming offline (see target path offline)
	• The lunpath open failed for some of the following reasons:
	  o INQUIRY command failure
	  o WWID authentication failure

limited	Not Applicable
unusable	Lunpath authentication failed
disable	The lunpath has been suspended as a result of one of the following errors: • SIOC_DISABLE I/O control operation issued by a kernel component or an application. For instance, a lunpath can be disabled using the `scsimgr`

	command with the disable option: scsimgr disable –H <lunpath hw path> • The corresponding LUN has been disabled
standby	For active/passive devices, the path is a standby path

See Native Multi-Pathing: A Concrete Example section for an example on how the health attribute changes when a target port becomes unavailable.

LUN and Lunpaths Attributes

The `scsimgr` command reads and sets the multi-pathing related attributes of LUN components. All the LUN and lunpath attributes are described in details in the *scsimgr SCSI Management and Diagnostics Utility* white paper. The following table summarizes LUN and lunpath attributes of interest for multi-pathing:

Component	Attributes
LUN	Generic: hw_path, wwid, serial_number, vid, pid, total_path_cnt, transient_secs, leg_mpath_enable, lpt_lockdown, uniq_name, Disk LUNs: path_fail_secs, load_bal_policy, infinite_retries_enable, preferred_path
lunpath	Generic: Lunid, hw_path

Setting I/O Load Balancing for Disk Devices

Disk LUN Load Balancing Selection

The default load balancing policy for disk devices is "round_robin":

```
# scsimgr get_attr -D /dev/rdisk/disk17 -a load_bal_policy

        SCSI ATTRIBUTES FOR LUN : /dev/rdisk/disk17

name = load_bal_policy
current = round_robin
default = round_robin
```

This can be changed to "cell locality based round robin":

```
# scsimgr set_attr -D /dev/rdisk/disk17 -a load_bal_policy=cl_round_robin
# scsimgr get_attr -D /dev/rdisk/disk17 -a load_bal_policy

        SCSI ATTRIBUTES FOR LUN : /dev/rdisk/disk17

name = load_bal_policy
current = cl_round_robin
default = round_robin
saved =
```

To change the "load_bal_policy" attribute to "preferred_path", the "preferred_path" attribute must be updated along with the hardware path of the preferred lunpath. The following commands show how to find the lunpaths hardware paths mapping to /dev/rdisk/disk17 and how to select one of them as the preferred path:

```
# ioscan -m hwpath -H 64000/0xfa00/0x5
```

```
Lun H/W Path      Lunpath H/W Path                 Legacy H/W Path
================================================================
64000/0xfa00/0x5
                  0/2/1/0.0x500508b3009097f9.0x4014000000000000   0/2/1/0.3.8.0.0.2.4
                  0/4/1/0.0x500508b3009097f9.0x4014000000000000   0/4/1/0.3.8.0.0.2.4
                  0/2/1/0.0x500508b3009097f1.0x4014000000000000   0/2/1/0.3.14.0.0.2.4
                  0/4/1/0.0x500508b3009097f1.0x4014000000000000   0/4/1/0.3.14.0.0.2.4

# scsimgr set_attr -D /dev/rdisk/disk17 -a load_bal_policy=preferred_path -a
preferred_path=0/2/1/0.0x500508b3009097f9.0x4014000000000000
  value of attribute load_bal_policy set successfully
  Value of attribute preferred_path set successfully

# scsimgr get_attr -D /dev/rdisk/disk17
...
name = load_bal_policy
current = preferred_path
default = round_robin
saved =
…
name = preferred_path
current = 0/2/1/0.0x500508b3009097f9.0x4014000000000000
default =
saved =
...
```

The “preferred_path” attribute is only valid when the “load_bal_policy” is set to “preferred_path”.

To change the “load_bal_policy” attribute to “least_cmd_load”, the administrator runs `scsimgr` as follows:

```
# scsimgr set_attr -D /dev/rdisk/disk17 -a load_bal_policy=least_cmd_load
# scsimgr get_attr -D /dev/rdisk/disk17
…
name = load_bal_policy
current = least_cmd_load
default = round_robin
saved
…
```

Pass-Through LUN Load Balancing

The pass-through device driver (`esctl`) only supports the “path lock down” multi-pathing policy. The SCSI stack internally selects the path on which I/O operations will be sent and sets the LUN “lpt_lockdown” attribute with the hardware path of the locked down path. Run `scsimgr` to see the “lpt_lockdown” attribute value:

```
# scsimgr get_attr -D /dev/pt/pt2 –a lpt_lockdown
…
name = lpt_lockdown
current = 0/4/1/0.0x500508b3009097f9.0x0
default =
saved =
```

This shows that for device `/dev/pt/pt2`, the OS internally selected the lunpath of hardware path `0/4/1/0.0x500508b3009097f9.0x0`.

Setting Lunpath Failure Detection Tunables

The mass storage subsystem monitors the I/O error statistics on lunpaths to detect failing lunpaths to LUNs.

If the lunpath continues to see I/O errors with no successful completions for a certain time interval, the SCSI stack takes the broken lunpath offline. This time interval value is defined by the "path_fail_secs" LUN attribute:

```
# scsimgr get_attr -D /dev/rdisk/disk17 -a path_fail_secs
...
name = path_fail_secs
current = 120
default = 120
saved =
```

This attribute can be set to a different value:

```
# scsimgr set_attr -D /dev/rdisk/disk17 -a path_fail_secs=100
Value of attribute path_fail_secs set successfully
```

Setting Native Multi-Pathing Support on Legacy DSFs

How to turn off multi-pathing on legacy DSFs?

To turn multi-pathing off on legacy lunpath DSFs, system administrators can use `scsimgr` to set the LUN "leg_mpath_enable" attribute to false. For instance:

```
# scsimgr set_attr -D /dev/rdisk/disk17 -a leg_mpath_enable=false
Value of attribute leg_mpath_enable set successfully
```

When legacy multi-pathing is turned off, the mass storage subsystem sends an I/O issued on a legacy DSF onto the corresponding lunpath. This behavior is consistent with pre-HP-UX 11i v3.

Note: Users can also set this attribute globally, if no DSF name is specified. Refer to `scsimgr(1M)` man page for details.

How multi-pathing works on legacy DSFs?

A command using legacy DSF can succeed when multi-pathing is enabled on legacy DSFs even if the path corresponding to legacy DSF is not available. This is an example of how applications using legacy DSFs can take advantage of multi-pathing lunpath failover.

For instance, there are four paths to disk17. One of them is not available: it shows as `NO_HW` in the `ioscan` output:

```
# ioscan -kfnNC lunpath
Class     I  H/W Path  Driver S/W State   H/W Type     Description
===================================================================
…
lunpath  16  0/2/1/0.0x500508b3009097f1.0x4014000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk17
lunpath   5  0/2/1/0.0x500508b3009097f9.0x4014000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk17
lunpath  22  0/4/1/0.0x500508b3009097f1.0x4014000000000000  eslpt   NO_HW       LUN_PATH
LUN path for disk17
lunpath  13  0/4/1/0.0x500508b3009097f9.0x4014000000000000  eslpt   NO_HW        LUN_PATH
LUN path for disk17
```

The lunpath with NO_HW state maps to legacy lunpath DSF `/dev/[r]dsk/c11t2d4` :

```
# ioscan -m hwpath -H 0/4/1/0.0x500508b3009097f1.0x4014000000000000
Lun H/W Path      Lunpath H/W Path                 Legacy H/W Path
==========================================================================
64000/0xfa00/0x5
                  0/4/1/0.0x500508b3009097f1.0x4014000000000000   0/4/1/0.3.14.0.0.2.4
# ioscan -kfnH 0/4/1/0.3.14.0.0.2.4
Class     I  H/W Path  Driver S/W State   H/W Type     Description
==========================================================================
disk     26  0/4/1/0.3.14.0.0.2.4  sdisk   NO_HW       DEVICE       COMPAQ  MSA1000 VOLUME
                     /dev/dsk/c11t2d4   /dev/rdsk/c11t2d4
```

Although the path corresponding to `/dev/rdsk/c11t2d4` is unavailable, it is still possible to access the legacy DSF `/dev/rdsk/c11t2d4`:

```
# dd if=/dev/rdsk/c11t2d4 of=/dev/null count=1
1+0 records in
1+0 records out
```

The mass storage subsystem accesses the LUN corresponding to `/dev/rdsk/c11t2d4` via the two remaining active paths and it dynamically balances the I/O operations issued on the `/dev/rdsk/c11t2d4` DSF across the remaining two paths.

However, path bound I/O operations or path bound ioctls fail since the path corresponding to `/dev/rdsk/c11t2d4` is offline. For instance, the SIOC_INQUIRY ioctl issues a path bound INQUIRY command to get the inquiry data. Since the `diskinfo` command gets the inquiry data via the SIOC_INQUIRY ioctl, it will fail:

```
# diskinfo /dev/rdsk/c11t2d4
diskinfo: can't SIOC_INQUIRY /dev/rdsk/c5t2d4: No such device or address
```

Native Multi-Pathing: A Concrete Example

This example illustrates what happens when a target port is disconnected and reconnected while I/O operations are flowing. This example will illustrate:

- Error reporting
- Asynchronous target port offline notification
- `ioscan` and `scsimgr` use cases to display multi-pathing information
- Lunpath failover
- Lunpath recovery

First, initiate some I/O traffic:

```
# dd if=/dev/rdisk/disk15 of=/dev/rdisk/disk16 &
```

Then, the target port of world wide name `0x500508b3009097f9` is physically disconnected.

The administrator is **notified** via a message in `/var/adm/syslog/syslog`:

```
Jan 31 02:08:50 hpfcs835 vmunix: class : tgtpath, instance 3
Jan 31 02:08:50 hpfcs835 vmunix: Target path (class=tgtpath, instance=3) has gone offline.
The target path h/w path is 0/2/1/0.0x500508b3009097f9
Jan 31 02:08:50 hpfcs835 vmunix:
Jan 31 02:08:50 hpfcs835 vmunix: class : tgtpath, instance 6
Jan 31 02:08:50 hpfcs835 vmunix: Target path (class=tgtpath, instance=6) has gone offline.
The target path h/w path is 0/4/1/0.0x500508b3009097f9
```

Since the target port SAN element is involved in the definition of two target paths, both target paths went offline.

The `ioscan` command shows that two target paths have gone to `NO_HW` state:

```
# ioscan -fnNC tgtpath
Class     I  H/W Path       Driver S/W State   H/W Type     Description

…

tgtpath   7  0/2/1/0.0x500508b3009097f1  estp   CLAIMED     TGT_PATH
fibre_channel target served by td driver

tgtpath   3  0/2/1/0.0x500508b3009097f9  estp   NO_HW       TGT_PATH
fibre_channel target served by td driver

tgtpath   8  0/4/1/0.0x500508b3009097f1  estp   CLAIMED     TGT_PATH
fibre_channel target served by td driver

tgtpath   6  0/4/1/0.0x500508b3009097f9  estp   NO_HW       TGT_PATH
fibre_channel target served by td driver
```

Using `scsimgr`, the administrator gathers statistics for offline events on the target path:

```
# scsimgr get_stat -H 0/4/1/0.0x500508b3009097f9
...
Target path offline events from I/F driver       = 1
```

As a result of the target port `0x500508b3009097f9` being disconnected, all the lunpaths using this SAN component become unavailable. The `ioscan` command shows these lunpaths with a NO_HW state:

```
# ioscan -kfnNC lunpath
Class     I  H/W Path  Driver S/W State   H/W Type     Description
====================================================================
lunpath  14  0/0/2/0.0.0x0.0x0                              eslpt   CLAIMED     LUN_PATH
LUN path for disk20
lunpath   7  0/1/1/0.0x0.0x0                                eslpt   CLAIMED     LUN_PATH
LUN path for disk19
lunpath   6  0/1/1/0.0x1.0x0                                eslpt   CLAIMED     LUN_PATH
LUN path for disk18
lunpath  15  0/2/1/0.0x500508b3009097f1.0x0                  eslpt   CLAIMED     LUN_PATH
LUN path for ctl2
lunpath  16  0/2/1/0.0x500508b3009097f1.0x4014000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk17
lunpath  19  0/2/1/0.0x500508b3009097f1.0x4015000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk16
lunpath  17  0/2/1/0.0x500508b3009097f1.0x4016000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk13
lunpath  18  0/2/1/0.0x500508b3009097f1.0x4017000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk15
lunpath  20  0/2/1/0.0x500508b3009097f1.0x4018000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk14
lunpath   0  0/2/1/0.0x500508b3009097f9.0x0                  eslpt   NO_HW       LUN_PATH
LUN path for ctl2
lunpath   5  0/2/1/0.0x500508b3009097f9.0x4014000000000000  eslpt   NO_HW       LUN_PATH
LUN path for disk17
lunpath   4  0/2/1/0.0x500508b3009097f9.0x4015000000000000  eslpt   NO_HW       LUN_PATH
LUN path for disk16
lunpath   1  0/2/1/0.0x500508b3009097f9.0x4016000000000000  eslpt   NO_HW       LUN_PATH
LUN path for disk13
lunpath   3  0/2/1/0.0x500508b3009097f9.0x4017000000000000  eslpt   NO_HW       LUN_PATH
LUN path for disk15
lunpath   2  0/2/1/0.0x500508b3009097f9.0x4018000000000000  eslpt   NO_HW       LUN_PATH
LUN path for disk14
lunpath  21  0/4/1/0.0x500508b3009097f1.0x0                  eslpt   CLAIMED     LUN_PATH
LUN path for ctl2
lunpath  22  0/4/1/0.0x500508b3009097f1.0x4014000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk17
lunpath  23  0/4/1/0.0x500508b3009097f1.0x4015000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk16
```

```
lunpath  26  0/4/1/0.0x500508b3009097f1.0x4016000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk13
lunpath  24  0/4/1/0.0x500508b3009097f1.0x4017000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk15
lunpath  25  0/4/1/0.0x500508b3009097f1.0x4018000000000000  eslpt   CLAIMED     LUN_PATH
LUN path for disk14
lunpath   8  0/4/1/0.0x500508b3009097f9.0x0                 eslpt   NO_HW       LUN_PATH
LUN path for ctl2
lunpath  13  0/4/1/0.0x500508b3009097f9.0x4014000000000000  eslpt   NO_HW       LUN_PATH
LUN path for disk17
lunpath  11  0/4/1/0.0x500508b3009097f9.0x4015000000000000  eslpt   NO_HW       LUN_PATH
LUN path for disk16
lunpath  12  0/4/1/0.0x500508b3009097f9.0x4016000000000000  eslpt   NO_HW       LUN_PATH
LUN path for disk13
lunpath  10  0/4/1/0.0x500508b3009097f9.0x4017000000000000  eslpt   NO_HW       LUN_PATH
LUN path for disk15
lunpath   9  0/4/1/0.0x500508b3009097f9.0x4018000000000000  eslpt   NO_HW       LUN_PATH
LUN path for disk14
```

The health of the affected lunpaths and LUNs changes too. The affected lunpaths health becomes "offline" and affected LUNs health becomes "limited" (see section Lunpath and LUN Health for more information on health)

```
# ioscan -P health
Class       I  H/W Path       health
================================================
…
tgtpath     7  0/2/1/0.0x500508b3009097f1                   online
lunpath    15  0/2/1/0.0x500508b3009097f1.0x0                online
lunpath    16  0/2/1/0.0x500508b3009097f1.0x4014000000000000  online
lunpath    19  0/2/1/0.0x500508b3009097f1.0x4015000000000000  online
lunpath    17  0/2/1/0.0x500508b3009097f1.0x4016000000000000  online
lunpath    18  0/2/1/0.0x500508b3009097f1.0x4017000000000000  online
lunpath    20  0/2/1/0.0x500508b3009097f1.0x4018000000000000  online
tgtpath     3  0/2/1/0.0x500508b3009097f9                   offline
lunpath     0  0/2/1/0.0x500508b3009097f9.0x0                offline
lunpath     5  0/2/1/0.0x500508b3009097f9.0x4014000000000000  offline
lunpath     4  0/2/1/0.0x500508b3009097f9.0x4015000000000000  offline
lunpath     1  0/2/1/0.0x500508b3009097f9.0x4016000000000000  offline
lunpath     3  0/2/1/0.0x500508b3009097f9.0x4017000000000000  offline
lunpath     2  0/2/1/0.0x500508b3009097f9.0x4018000000000000  offline
ba          3  0/3            N/A
slot        1  0/3/1          N/A
fc          1  0/3/1/0        online
fc          2  0/3/1/1        online
ba          4  0/4            N/A
slot        2  0/4/1          N/A
fc          3  0/4/1/0        online
tgtpath     8  0/4/1/0.0x500508b3009097f1                   online
lunpath    21  0/4/1/0.0x500508b3009097f1.0x0                online
lunpath    22  0/4/1/0.0x500508b3009097f1.0x4014000000000000  online
lunpath    23  0/4/1/0.0x500508b3009097f1.0x4015000000000000  online
lunpath    26  0/4/1/0.0x500508b3009097f1.0x4016000000000000  online
lunpath    24  0/4/1/0.0x500508b3009097f1.0x4017000000000000  online
lunpath    25  0/4/1/0.0x500508b3009097f1.0x4018000000000000  online
tgtpath     6  0/4/1/0.0x500508b3009097f9                   offline
lunpath     8  0/4/1/0.0x500508b3009097f9.0x0                offline
lunpath    13  0/4/1/0.0x500508b3009097f9.0x4014000000000000  offline
lunpath    11  0/4/1/0.0x500508b3009097f9.0x4015000000000000  offline
lunpath    12  0/4/1/0.0x500508b3009097f9.0x4016000000000000  offline
lunpath    10  0/4/1/0.0x500508b3009097f9.0x4017000000000000  offline
lunpath     9  0/4/1/0.0x500508b3009097f9.0x4018000000000000  offline
…
disk       13  64000/0xfa00/0x1                             limited
disk       14  64000/0xfa00/0x2                             limited
disk       15  64000/0xfa00/0x3                             limited
disk       16  64000/0xfa00/0x4                             limited
disk       17  64000/0xfa00/0x5                             limited
```

Using the `scsimgr` command, the administrator gathers statistics for offline events and I/O errors on the lunpath path:

```
# scsimgr get_stat -H 0/2/1/0.0x500508b3009097f9.0x4014000000000000
...
Offline events                                = 1
```

```
Online events                                   = 0
...
I/O transfer Statistics:

Bytes read                                      = 1426794
Bytes written                                   = 0
Total I/Os processed                            = 12215
I/O failures                                    = 1
Retried I/Os                                    = 2
Retried I/O failures                            = 0
...
```

Some I/O operation errors are expected since I/O operations may have been pending on the lunpaths that were taken offline when the target port was disconnected. However, **it is critical to observe that the transfer of data is uninterrupted due to lunpath failover**. This can be verified running the `sar` command which shows I/O activity on the remaining two active lunpaths for disk15 and disk16:

```
# sar -R -L -d 1 5

HP-UX hpfcs835 B.11.31 U ia64    02/01/07

03:38:16        lunpath   %busy   avque     r/s     w/s  blks/s  avwait  avserv
                           %age     num     num     num     num    msec    msec
                  device   %busy   avque     r/s     w/s  blks/s  avwait  avserv
        disk15_lunpath18   27.00    0.50     534       0     534    0.00    0.51
        disk16_lunpath19   17.00    0.50       0     533     533    0.00    0.33
        disk16_lunpath23   18.00    0.50       0     534     534    0.00    0.32
        disk15_lunpath24   27.00    0.50     533       0     533    0.00    0.51
                  disk15   55.00    0.50    1066       0    1066    0.00    0.51
                  disk16   35.00    0.50       0    1067    1067    0.00    0.33
```

Now, the target port of world wide name `0x500508b3009097f9` is reconnected.

The following messages are immediately logged in `/var/adm/syslog/syslog.log`:

```
Jan 31 02:41:48 hpfcs835 vmunix: class : tgtpath, instance 3
Jan 31 02:41:48 hpfcs835 vmunix: Target path (class=tgtpath, instance=3) has gone online.
The target path h/w path is 0/2/1/0.0x500508b3009097f9
Jan 31 02:41:48 hpfcs835 vmunix: class : tgtpath, instance 6
Jan 31 02:41:48 hpfcs835 vmunix: Target path (class=tgtpath, instance=6) has gone online.
The target path h/w path is 0/4/1/0.0x500508b3009097f9
~
```

As a result of the target port `0x500508b3009097f9` coming back online, all the lunpaths using this SAN component become available again. The `ioscan` command shows these lunpaths with a CLAIMED state. Using `scsimgr`, the administrator gathers some statistics for online events on the target path and lunpath path:

```
# scsimgr get_stat -H 0/4/1/0.0x500508b3009097f9.0x4014000000000000

        STATISTICS FOR LUN path : 0/4/1/0.0x500508b3009097f9.0x4014000000000000

Generic Statistics:
…
Offline events                                  = 1
Online events                                   = 1
…
```

Using `sar`, the system administrator observes that I/O operations are still going from disk15 to disk16 on all lunpaths:

```
# sar -L 1 5

HP-UX hpfcs835 B.11.31 U 9000/800    02/01/07

16:41:10       lunpath   %busy   avque     r/s     w/s  blks/s  avwait  avser
                          %age     num     num     num     num    msec    msec
       disk15_lunpath18    7.92    0.50     122       0     122    0.00     0.6
```

```
        disk15_lunpath3    5.94    0.50       0     122     122    0.00    0.4
       disk15_lunpath24   23.76    0.50       0     121     121    0.00    1.9
       disk15_lunpath10    9.90    0.50     122       0     122    0.00    0.8
       disk16_lunpath19    5.94    0.50     122       0     122    0.00    0.4
        disk16_lunpath4   15.84    0.50     121       0     121    0.00    1.2
       disk16_lunpath23   21.78    0.50       0     122     122    0.00    1.7
       disk16_lunpath11    7.92    0.50       0     122     122    0.00    0.6
…
```

The `ioscan` command shows that LUN and lunpath health is set back to online automatically.

```
# ioscan -P health
Class       I  H/W Path       health
…
tgtpath     7  0/2/1/0.0x500508b3009097f1                    online
lunpath    15  0/2/1/0.0x500508b3009097f1.0x0                online
lunpath    16  0/2/1/0.0x500508b3009097f1.0x4014000000000000 online
lunpath    19  0/2/1/0.0x500508b3009097f1.0x4015000000000000 online
lunpath    17  0/2/1/0.0x500508b3009097f1.0x4016000000000000 online
lunpath    18  0/2/1/0.0x500508b3009097f1.0x4017000000000000 online
lunpath    20  0/2/1/0.0x500508b3009097f1.0x4018000000000000 online
tgtpath     3  0/2/1/0.0x500508b3009097f9                    online
lunpath     0  0/2/1/0.0x500508b3009097f9.0x0                online
lunpath     5  0/2/1/0.0x500508b3009097f9.0x4014000000000000 online
lunpath     4  0/2/1/0.0x500508b3009097f9.0x4015000000000000 online
lunpath     1  0/2/1/0.0x500508b3009097f9.0x4016000000000000 online
lunpath     3  0/2/1/0.0x500508b3009097f9.0x4017000000000000 online
lunpath     2  0/2/1/0.0x500508b3009097f9.0x4018000000000000 online
ba          3  0/3            N/A
slot        1  0/3/1          N/A
fc          1  0/3/1/0        online
fc          2  0/3/1/1        online
ba          4  0/4            N/A
slot        2  0/4/1          N/A
fc          3  0/4/1/0        online
tgtpath     8  0/4/1/0.0x500508b3009097f1                    online
lunpath    21  0/4/1/0.0x500508b3009097f1.0x0                online
lunpath    22  0/4/1/0.0x500508b3009097f1.0x4014000000000000 online
lunpath    23  0/4/1/0.0x500508b3009097f1.0x4015000000000000 online
lunpath    26  0/4/1/0.0x500508b3009097f1.0x4016000000000000 online
lunpath    24  0/4/1/0.0x500508b3009097f1.0x4017000000000000 online
lunpath    25  0/4/1/0.0x500508b3009097f1.0x4018000000000000 online
tgtpath     6  0/4/1/0.0x500508b3009097f9                    online
lunpath     8  0/4/1/0.0x500508b3009097f9.0x0                online
lunpath    13  0/4/1/0.0x500508b3009097f9.0x4014000000000000 online
lunpath    11  0/4/1/0.0x500508b3009097f9.0x4015000000000000 online
lunpath    12  0/4/1/0.0x500508b3009097f9.0x4016000000000000 online
lunpath    10  0/4/1/0.0x500508b3009097f9.0x4017000000000000 online
lunpath     9  0/4/1/0.0x500508b3009097f9.0x4018000000000000 online
…
disk       13  64000/0xfa00/0x1                              online
disk       14  64000/0xfa00/0x2                              online
disk       15  64000/0xfa00/0x3                              online
disk       16  64000/0xfa00/0x4                              online
disk       17  64000/0xfa00/0x5                              online
```

This illustrates the fact that as the target port comes back online, the related lunpaths automatically become active. As a result, they are automatically used again for I/O traffic.

For More Information

To learn more about mass storage on HP-UX 11i v3 see the following documents on the HP documentation websites (http://docs.hp.com and http://docs.hp.com/en/netsys.html#Storage%20Area%20Management):

- The Next Generation Mass Storage Stack
- HP-UX 11i v3 Mass Storage Device Naming
- HP-UX 11i v3 Native Multi-Pathing for Mass Storage
- HP-UX 11i v3 Mass Storage I/O Performance Improvements
- scsimgr SCSI Management and Diagnostics Utility
- HP-UX 11i v3 Persistent DSF Migration Guide
- HP-UX 11i v3 Writing Active/Passive Switch Plug-Ins
- LVM Online Disk Replacement (LVM OLR)
- When Good Disks Go Bad: Dealing with Disk Failures under LVM
- Migrating from HP Storage Works Secure Path for Active-Active Disk Arrays to Native Multi-pathing in HP-UX 11i v3

Call to Action

HP welcomes your input. Please give us comments about this white paper, or suggestions for mass storage or related documentation, through our technical documentation feedback website: http://docs.hp.com/en/feedback.html

02/20/2007