

PowerPath Foundations

After completing this module, you will be able to:

- Describe EMC PowerPath
- Discuss the features and benefits of PowerPath in storage environments
- Explain how PowerPath achieves transparent recovery
- List the environments that PowerPath supports
- Discuss the management functions available using the GUI and CLI interface
- Discuss recent PowerPath enhancements and storage environmental benefits

These are the objectives for this training. Please take a moment to read them.

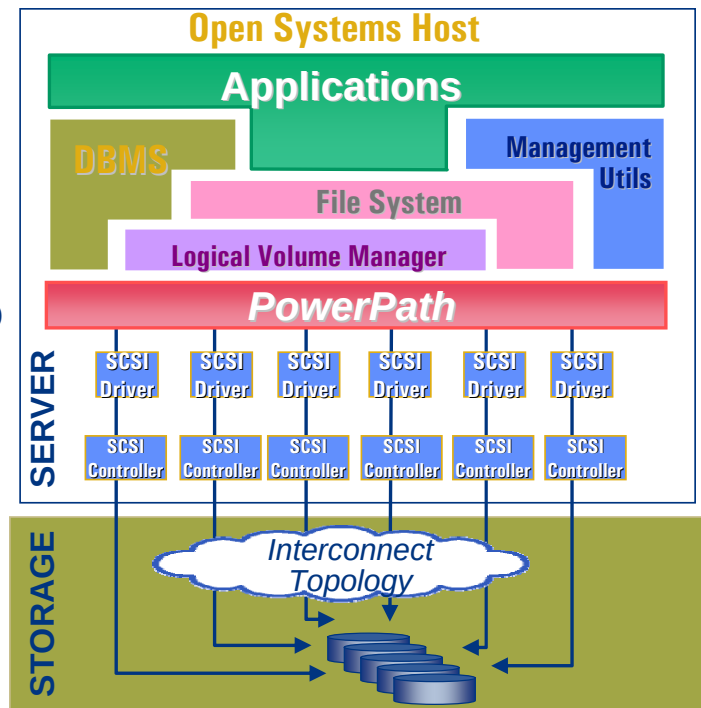
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WHAT IS POWERPATH? – A DEFINITION

In this section, you will learn what PowerPath is and what the software provides.

What is PowerPath

- Host Based Software
- Resides between application and SCSI device driver
- Provides Intelligent I/O path management
- Transparent to the application
- Automatic detection and recovery from host-to-array path failures



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PowerPath is host-based software that resides between the application and the disk device layers. Every I/O from the host to the array must pass through the PowerPath driver software. This allows PowerPath to work in conjunction with the array and connectivity environment to provide intelligent I/O path management. This includes path failover and dynamic load balancing, while remaining transparent to any application I/O requests as it automatically detects and recovers from host-to-array path failures.

Volume groups and filesystems are created using either the PowerPath devices (pseudo devices) or the underlying operating system native devices.

The Value of PowerPath

- Support for Windows, LINUX and UNIX server
- Support for multiple Disk Arrays
- Improves SAN performance
- Maximizes utilization of shared SAN devices and paths
- Reduces connectivity administration overhead and environmental downtime
- Protects against path failures



PowerPath can add value in many ways. Several of the main reasons are listed on the slide.

- PowerPath is supported on many operating system platforms, including Windows, Linux, Solaris, HP-UX, and AIX.
- PowerPath 4.x includes support for all EMC arrays and several non EMC arrays, referred to as 3rd party arrays.
- PowerPath helps maximize SAN performance by using all the I/O processing and bus capacity of all paths to a device. PowerPath load balances I/O on a host-by-host basis and works by equalizing I/O load for all paths. PowerPath intelligently handles each I/O request and checks current load balancing and path failover settings to choose the least-burdened available path.
- PowerPath reduces management time and downtime, because administrators no longer need to configure paths statically across logical devices. With PowerPath, no setup time is required, and paths always are configured for optimum performance.
- If there is a failure in the data path, it fails over the I/O to an alternative path. PowerPath determines the best and optimal way to utilize devices and paths that are shared across the SAN. This capability increases performance within the system.

PowerPath Features

- Multiple paths, for higher availability and performance
- Dynamic multipath load balancing
- Proactive path testing and automatic path recovery
- Automatic path failover
- Online path configuration and management
- High-availability cluster support

PowerPath Delivers:



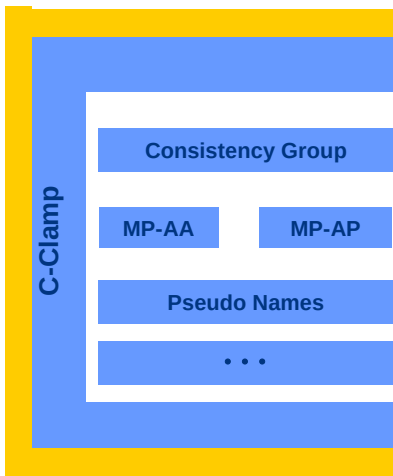
PowerPath maximizes application availability, optimizes performance, and automates online storage management while reducing complexity and cost, all from one powerful data path management solution.

- Multiple path support - PowerPath supports multiple paths between a logical device and a host. Multiple paths enables the host to access a logical device, even if a specific path is unavailable. Also, multiple paths enable sharing of the I/O workload to a given logical device.
- Dynamic load balancing - PowerPath is designed to use all paths at all times. PowerPath distributes I/O requests to a logical device across all available paths, rather than requiring a single path to bear the entire I/O burden.
- Proactive path testing and automatic path recovery - PowerPath uses a path test to ascertain the viability of a path. After a path fails, PowerPath continues testing it periodically to determine if it is fixed. If the path passes the test, PowerPath restores it to service and resumes sending I/O to it.
- Automatic path failover - If a path fails, PowerPath redistributes I/O traffic from that path to functioning paths.
- Online configuration and management - PowerPath management interfaces include a command line interface and a GUI interface on Windows.
- High availability cluster support - PowerPath is particularly beneficial in cluster environments, as it can prevent operational interruptions and costly downtime.



Current PowerPath Product Releases

- PowerPath releases are identified by a three-digit version number:
Major.Minor.Patch
- PowerPath 4.x is built on PowerPath C-Clamp model
- PowerPath 4.x supports
 - Windows
 - UNIX
- PowerPath 3.x is the current version for Novell and Tru64 Unix



PowerPath 4.x C-Clamp

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PowerPath releases are identified by a three-digit version number: *Major.Minor.Patch*. In a full product release, the value of *Patch* is zero (0). An example of a full release is 4.0.0. PowerPath 4.x refers to any version that is released after PowerPath 4.0. These intermediate releases may add minimal functionality, for example support for a new operating system. Other times the new version is a patch that fixes a product defect.

PowerPath 4.x releases are based on a platform-independent base driver known as the C-Clamp. PowerPath 4.x features are implemented as extensions within the C-Clamp.

In the example, the consistency group, multi-path active active, and multipath active passive features of PowerPath are shown in the C-Clamp. PowerPath currently has implemented the C-Clamp model on Windows, Sun Solaris, IBM AIX, HP HP-UX, Red Hat, and SuSe Linux.

On Novell and Tru-64 Unix platforms, the C-Clamp architecture has not been implemented. Therefore none of the new 4.x features, such as multipath active-passive array support are available. PowerPath is currently utilizing 3.x architecture for these two platforms.

PowerPath Licensing Options

License Type	PowerPath Capabilities
Full PowerPath	• Full load balancing and path failover functionality • All load balancing policies available. • Default load balancing policies are • symmetrix optimize (so) - Symmetrix • clariion optimize (co) - CLARiiON • adaptive (ad) – 3rd party arrays
PowerPath Base	• Path failover only
Piranha	• Path failover on CLARiiON arrays • On AX100 arrays full load balancing and path failover functionality
No License	• Path Failover only • No host bus adapter (HBA) failover
Evaluation License	• Same as full for evaluation period

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In the table, the PowerPath licensing options are listed in the left column. The type of license is listed in the first row. The remaining cells list the PowerPath capabilities that are unlocked with each license.

Full PowerPath licenses permit the user to take advantage of the full set of PowerPath load balancing and path failover functionality. The only limitation is that some policies are available for specific arrays only. For example, Symmetrix Optimize can only be used on platforms attached to Symmetrix systems.

PowerPath base licenses permit only failover functionality. The license does not permit load balancing policies to be used.

The piranha license is intended to support a CLARiiON AX100 array. On AX100 arrays, the piranha license authorizes the use of all policies that can be used on CLARiiON arrays. On all other arrays, the piranha license permits failover only, or no load balancing and no failover. On later versions of PowerPath 4.x, full AX100 support is available with or without a PowerPath license.

Finally, an unlicensed PowerPath installation permits only failover on all arrays. Failover is not available across HBA's. Load balancing policies are not available. This is the default policy when a license is not entered during PowerPath installation.

Evaluation licenses enable PowerPath capabilities for a limited period of time.

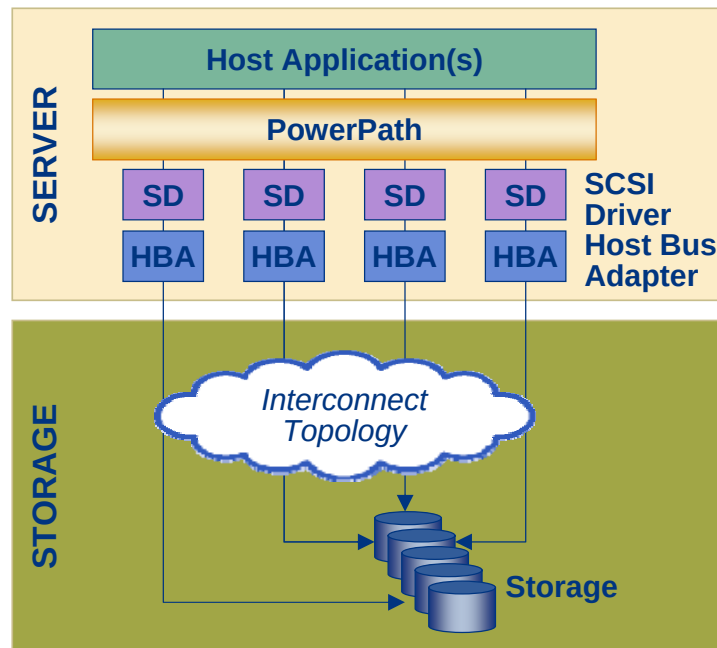
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THEORY OF OPERATION

In this section, we learn the fundamental concepts of how PowerPath works.

PowerPath Configuration

- All volumes are accessible through all paths
- Maximum 32 paths to a logical volume
- Interconnect support for
 - SCSI
 - SAN
 - ISCSI



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Without PowerPath, if a host needed access to 40 logical volumes, and you had four host bus adapters, you would most likely set it up so that 10 volumes were presented to each host bus adapter. With PowerPath, you would set it up so that all 40 volumes could be “seen” by all four host bus adapters. This would require:

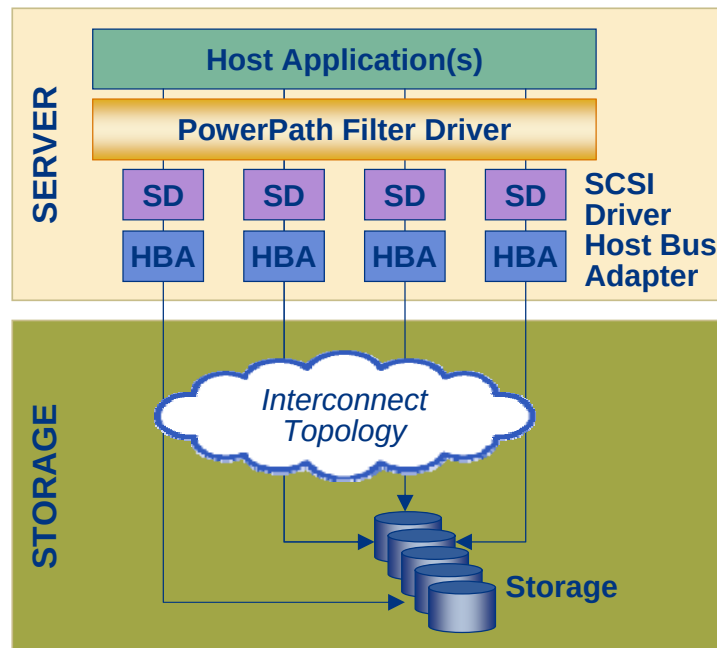
- The storage system be configured to present the volumes to multiple front-end ports
- The SAN fabric is zoned
- Access control through Volume Logix
- HBA binding (if needed)

If set up properly, each Logical volume would be presented multiple times. For example, in a Solaris environment, if SLV 001 is presented to four different front-end directors, and the fabric is zoned properly, that single volume may actually have four different logical device file names, i.e. /dev/dsk/c1t0d0, /dev/dsk/c2t0d0, /dev/dsk/c3t0d0, /dev/dsk/c4t0d0.

PowerPath supports up to 32 paths to a logical volume. The host can be connected to the array using a number of interconnect topologies such as SCSI, ISCSI, and SAN.

The PowerPath Filter Driver

- Platform independent base driver
- Applications direct I/O to PowerPath
- PowerPath directs I/O to optimal path based on current workload and path availability
- When a path fails PowerPath chooses another path in the set



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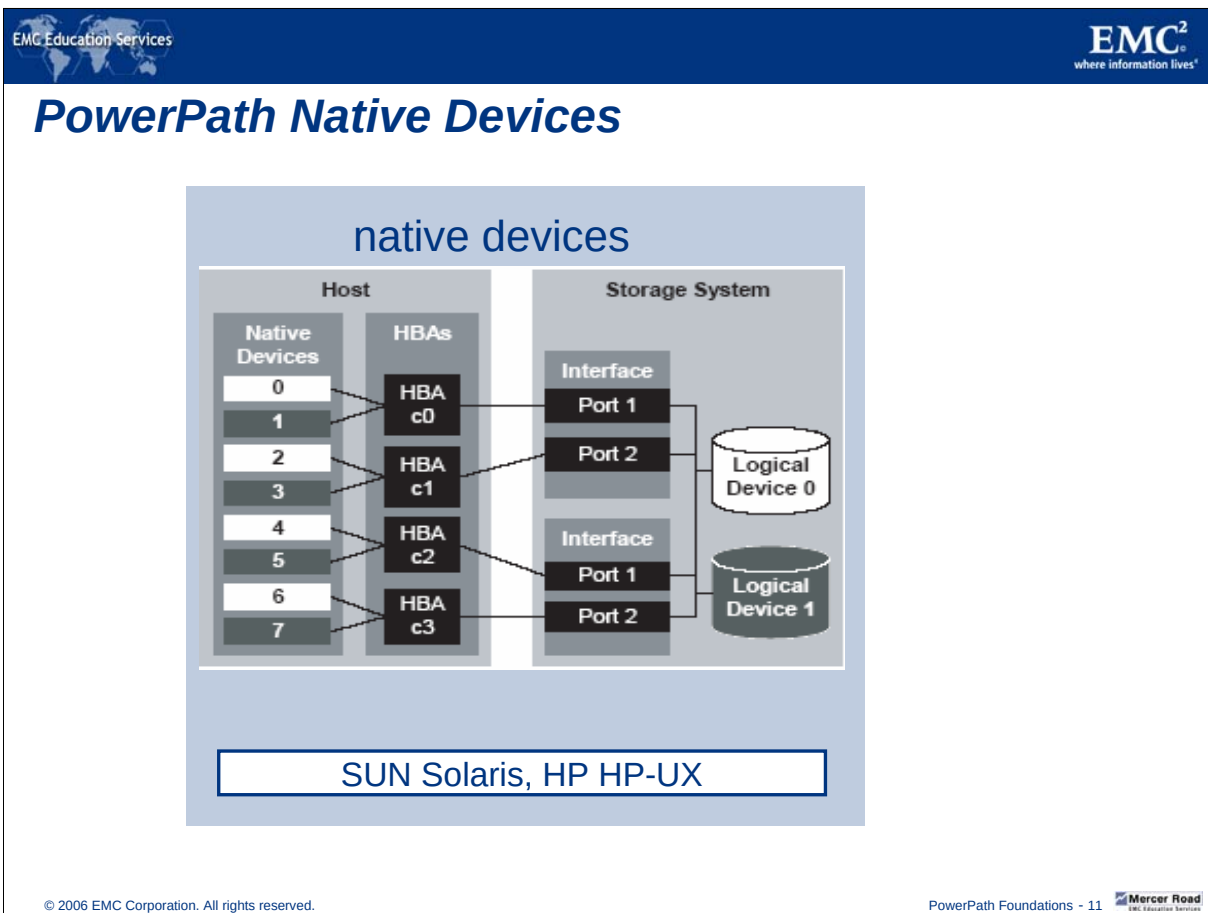
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The PowerPath filter driver is a platform independent driver that resides between the application and HBA driver.

The driver identifies all paths that read and write to the same device and builds a routing table called a volume path set for the device. A volume path set is created for each shared device in the array .

PowerPath can use any path in the set to service an I/O request. If a path fails, PowerPath can redirect an I/O request from that path to any other viable path in the set. This redirection is transparent to the application, which does not receive an error. Occasionally, however, there is a short delay. The delay is caused by the low level disk driver trying to recover from an error or waiting for a request to time out.

PowerPath uses a unique serial number to distinguish between paths to the same volume and paths to a different volume.

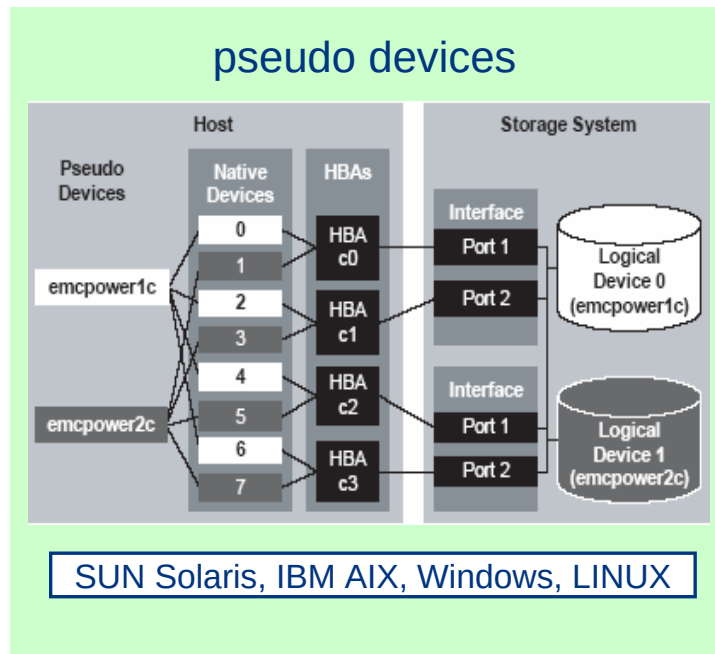


PowerPath supports native devices and pseudo devices. The slide shows an example of a native device. Listed under each illustration is the operating system that the type of device is supported on.

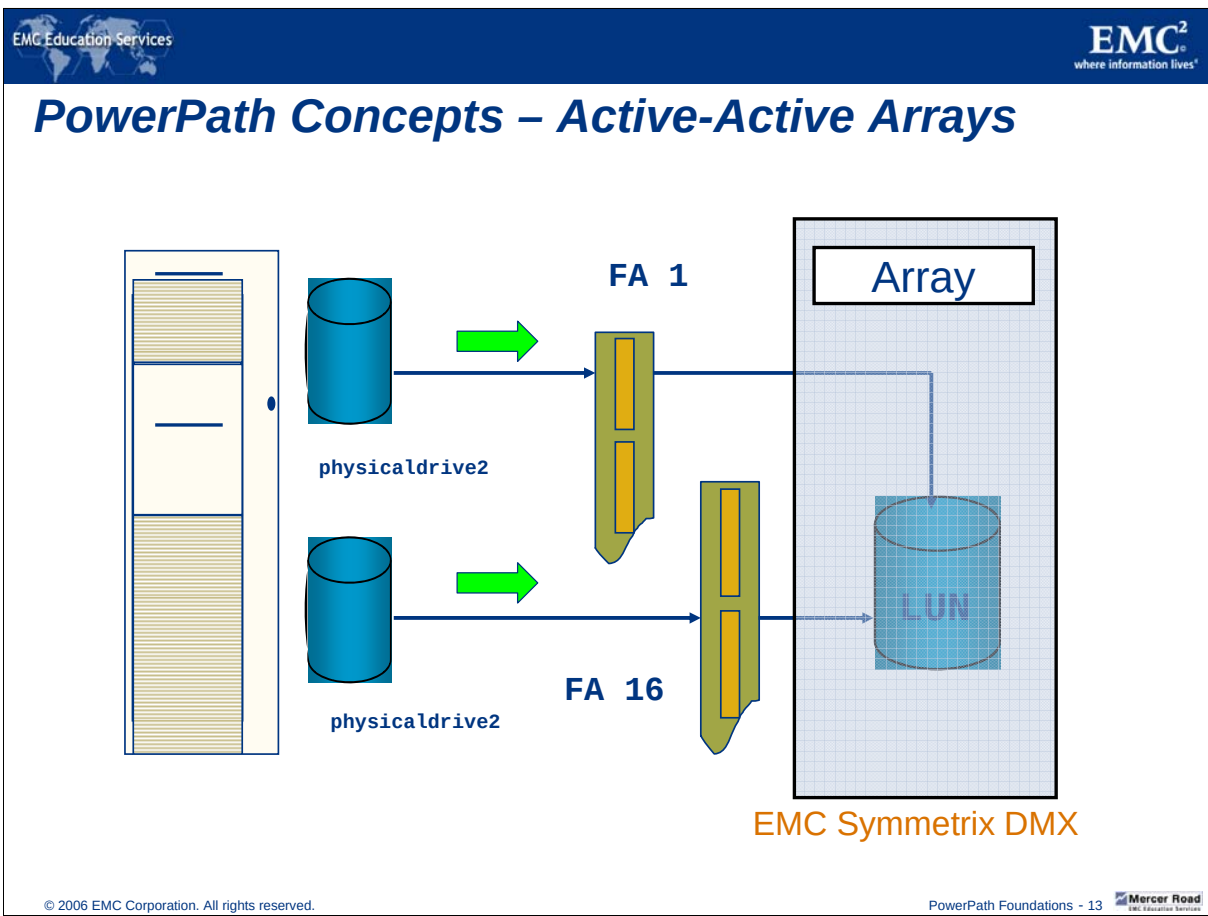
The operating system creates native devices to represent and provide access to logical devices. A native device is path specific and represents a single path to a logical device. The device is native in that it is provided by the operating system for use with applications. In the figure, there is a native device for each path. The storage system in the figure is configured with two shared logical devices, each of which can be accessed by four paths. There are eight native devices, four (in white, numbered 0, 2, 4, and 6) representing a unique path set to logical device 0, and four (in black, numbered 1, 3, 5, and 7) representing a unique path set to logical device 1.

Applications do not need to be reconfigured to use native devices. The idea is to use the existing disk devices created by the operating system. The access to the device is transparent in that PowerPath maintains the correspondence between an individual native device and the path set to which it belongs.

PowerPath Pseudo Devices

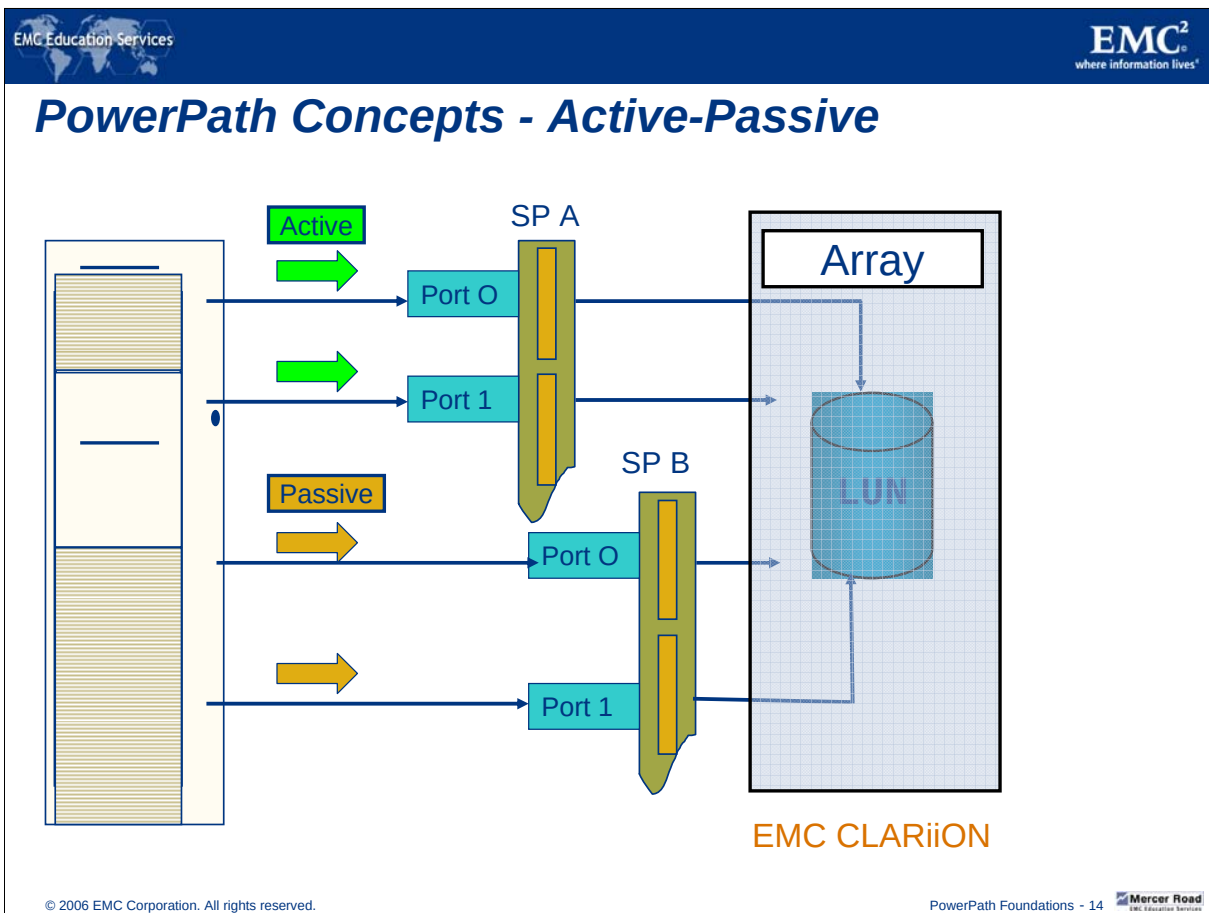


The slide shows an example of a pseudo device. A PowerPath **pseudo device** represents a single logical device and the path set leading to it. There is one pseudo device per path set. In the example, logical devices 0 and 1 are referred to by pseudo device names `emcpower1c` and `emcpower2c`, respectively. Each pseudo device represents the set of paths connected to its respective logical device: `emcpower1c` represents the set of paths connected to logical device 0, and `emcpower2c` represents the set of paths connected to logical device 1. In most cases, the application must be reconfigured to use pseudo devices, otherwise PowerPath load balancing and path failover functionality will not be available. The PowerPath product guide provides instruction on when to reconfigure an application when using pseudo devices.



The illustration shows an example of multi-pathing on a Symmetrix DMX. In an **active-active** storage array, if multiple interfaces exist to a LUN, they all provide equal access to the logical device. Active-active means all interfaces to a device are active simultaneously.

In a configuration that includes an active-active array, PowerPath can spread the work load across both paths. In addition, PowerPath can failover across both paths to the LUN.



In this example of CLARiiON connectivity, a LUN is assigned to port 0 and port 1 on storage processor, or SP A. In an active-passive system, SP A is designated as the primary or **active** route to the device, and therefore all I/O is directed down the paths through SP A to the device. PowerPath will load balance I/O across these active paths as shown by the green arrows.

The LUN can also be accessed through SP B but only after the device has been re-assigned (trespassed) to storage processor B. This path is referred to as a passive path. PowerPath will not send I/O down the passive paths. These paths are shown by the orange arrows.

With all active paths to the LUN unavailable, the active paths to an interface card logical device must be moved to another storage processor. This reassignment is initiated by the other, functioning interface. When PowerPath is installed on the host, the reassignment is initiated by PowerPath, which instructs the storage system to make the reassignment. On a CLARiiON array, these reassignments are known as **trespassing**. Trespassing can take several seconds to complete; however, I/Os do not fail during it. After devices are trespassed, PowerPath detects the changes and seamlessly routes data via the new route. After a trespass, logical devices can be trespassed back to their original paths once the error is corrected.

In order to take advantage of all array interfaces, the devices should be assigned equally among interface cards. This insures that the full capacity of the array interfaces are being used.

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PowerPath and Solutions Enabler Interoperability

- **SRDF Consistency Protection**
 - Guarantees a consistent restartable copy of data is available on the remote Symmetrix when a SRDF link failure occurs

- **TimeFinder Consistent Splits**
 - Enables split of consistent, DBMS restartable copy of a database without any interruption to the application

The diagram is divided into two parts. The top part, 'SRDF Consistency Protection', shows a 'Host' connected to 'PowerPath', which in turn connects to two Symmetrix storage systems: 'Symmetrix A' and 'Symmetrix B'. Symmetrix A contains 'R1 Devices' and Symmetrix B contains 'R1 Devices'. Both are connected via 'SRDF Links' to 'Symmetrix A'' and 'Symmetrix B'' respectively. Symmetrix A' contains 'R2' and is labeled 'Prior Point-in-Time Remote Coherency'. Symmetrix B' contains 'R2'. The bottom part, 'TimeFinder Consistent Splits', shows a 'Production Host' with a 'SYMAPI DBMS Instance' connected to 'PowerPath'. PowerPath connects to a 'Symmetrix' storage system. The Symmetrix system has a 'Standard' volume and a 'BCV' (Backup Copy Volume). A 'Split' operation is shown, moving data from the 'Standard' volume to the 'BCV' volume. A 'Secondary Host' with a 'SYMAPI DBMS Instance' is also connected to the 'BCV' volume. Arrows indicate 'Suspend' and 'Resume' operations between the host and the Symmetrix system.

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PowerPath works in conjunction with Solutions Enabler to support two application critical solutions.

SRDF consistency protection helps maintain data coherency across an SRDF-based configuration by managing data propagation from the source volumes to their corresponding target volumes to ensure data consistency and restartability. When consistency protection is enabled, the PowerPath-connected SRDF consistency group will suspend all data propagation from the source R1 devices if one or more source devices cannot transmit data to their corresponding target devices. This action instantly and completely halts data flow to the consistency group's target side ensuring that a consistent, up to the point-in-time of data propagation failure database exists on the remote side of the configuration, and preserving the integrity of the remote database.

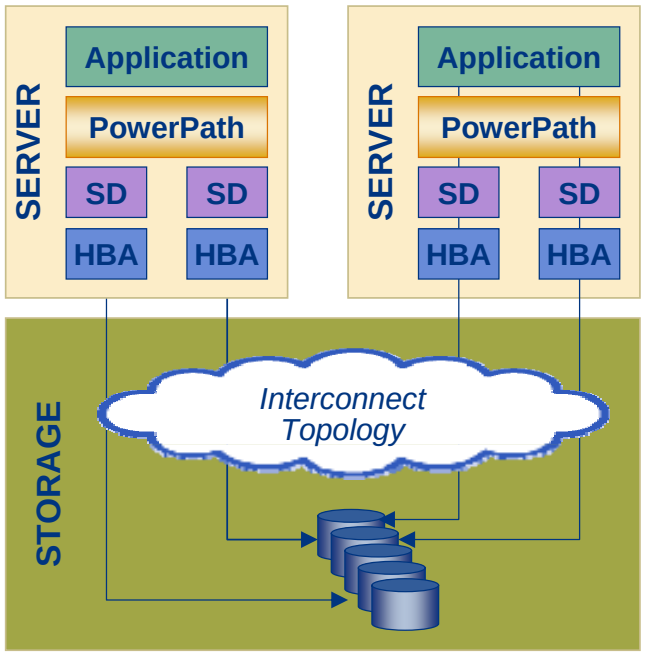
PowerPath also works with the Solutions Enabler TimeFinder component to support consistent split of BCV's. PowerPath will suspend database device writes at the host level for a very short time until the split is complete. Consistent split is useful when database management system (DBMS) restartable copies of a large database is needed. There is no interruption to the application. After the split, the BCV copy of the database can be used for backups, decision support, or restore.

The latest releases of Symmetrix Enginuity code includes a new Enginuity consistency assist (ECA) feature which replaces the need to use PowerPath to support consistent splits. The Multi Session Consistency (MSC) feature of Solutions Enabler 6.x replaces the need to use PowerPath for consistency group protection.



PowerPath and HA Clusters

- PowerPath enhances High Availability Cluster environments
- Increases application availability by eliminating the need to failover when a path failure occurs
- Tested with leading HA cluster products
 - HACMP for AIX
 - HP MC ServiceGuard
 - Veritas FirstWatch
 - Sun Cluster
 - Qualix HA
 - NT MSCS



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Open Systems clustering technology manages application availability by detecting failures, and restarts high availability applications on a surviving cluster node.

The deployment of PowerPath in the cluster eliminates the application downtime due to a channel failure. PowerPath will detect the channel failure and use alternate channels so that the cluster software does not have to reconfigure the cluster to keep the applications running.

PowerPath improves the availability of the applications running in the cluster.

Many clusters are deployed to provide performance scalability (i.e., Oracle Parallel Server). PowerPath's load balancing can help the customer maximize performance and get the greatest value from their cluster investment.

PowerPath must work cooperatively with the cluster software. This does not require special code in the cluster, but does require PowerPath to work with the storage management component of the cluster software. Validating PowerPath with the cluster software systems requires extensive knowledge and testing of the cluster software with PowerPath.

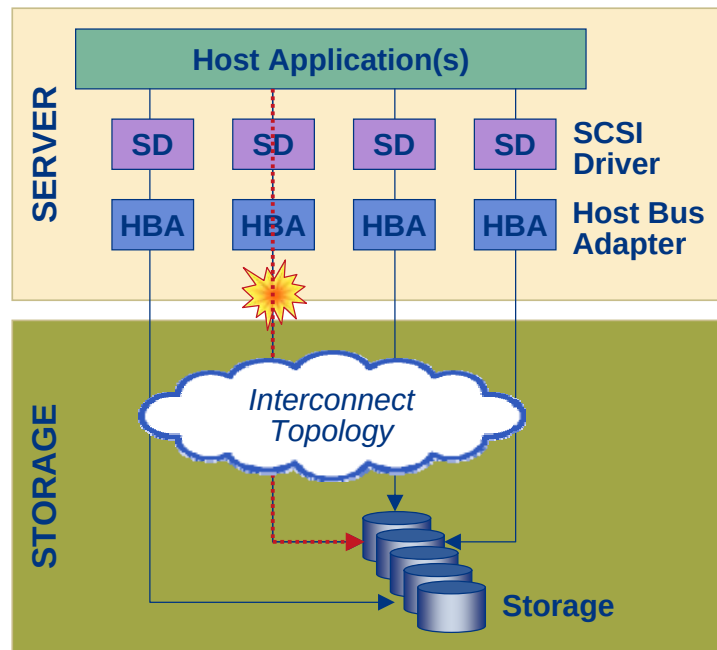
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FEATURES AND FUNCTIONALITY

In this section, you will learn the features and functionality of PowerPath.

Path Fault without PowerPath

- In most environments, a host will have multiple paths to the Storage System
- Volumes are spread across all available paths
- Each volume has a single path
- Host adapter and cable connections are single points of failure
- Work load not balanced among all paths



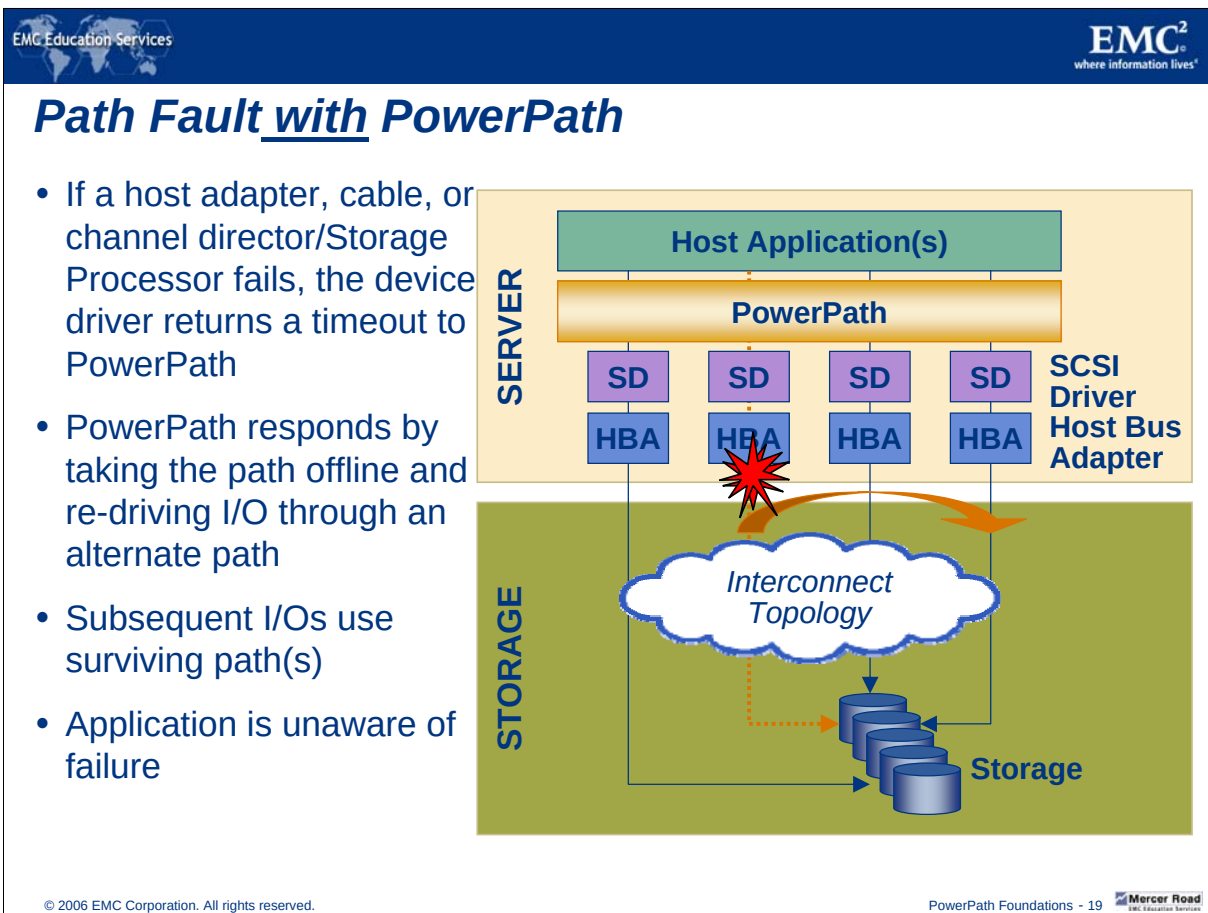
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On the slide, an application running on a server has 4 paths to the storage, but only one path is used because the volume manager native to the operating system running on the server only allows for one path to be defined. This is expressly done when the administrator chooses a device name on which to build the volume group and filesystem on.

Without PowerPath or another path failover software package, the loss of a channel (red dotted line) means one or more applications may stop functioning. This can be caused by the loss of a Host Bus Adapter, Symmetrix Channel Director, CLARiiON Storage Processor, FC-AL hub, or a failed cable. In a standard non-PowerPath environment, these are all single points of failure. In this case, all I/O that was heading down the path highlighted in red is now lost, resulting in an application failure and the potential for data loss or corruption.



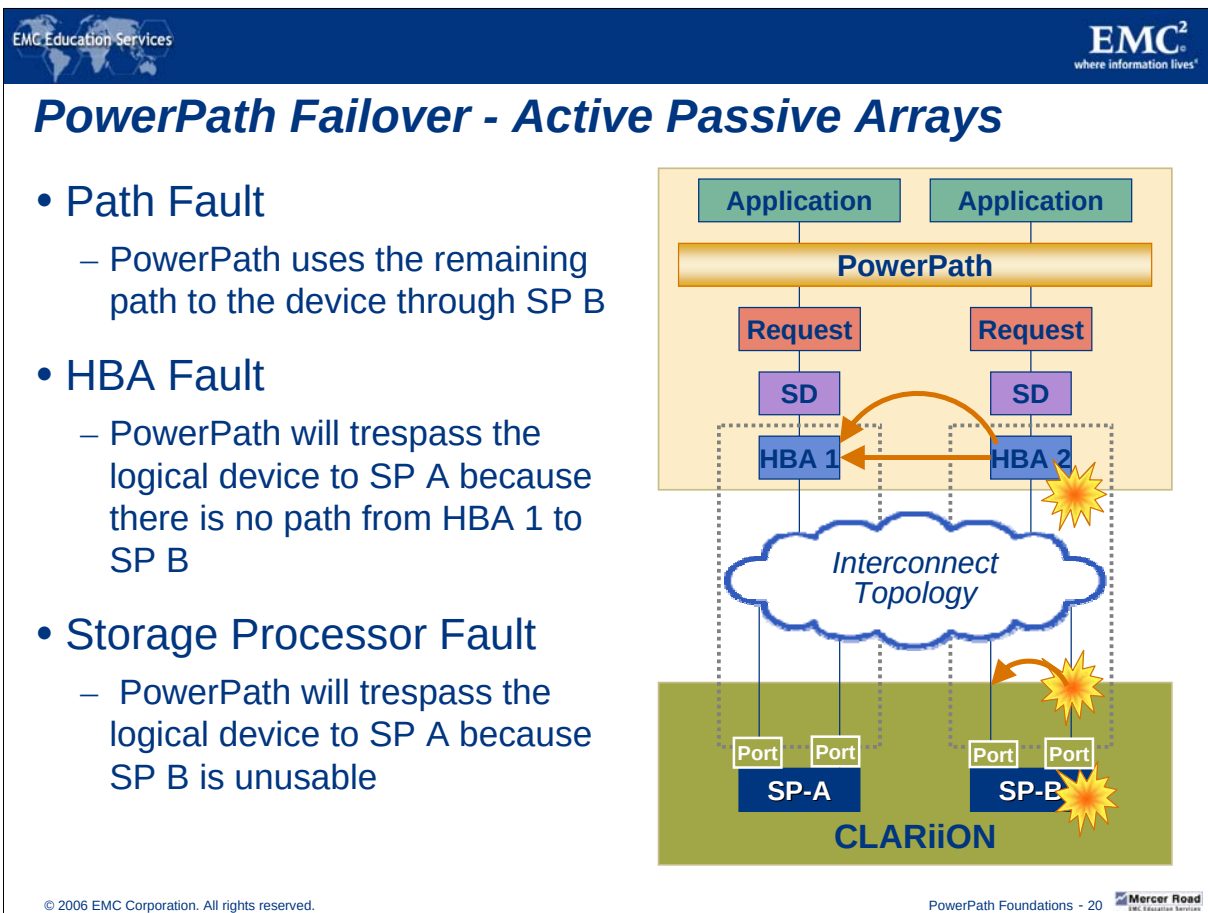
The illustration depicts how PowerPath failover works on a host attached to an active-active array, e.g. Symmetrix.

When a failure occurs, PowerPath transparently redirects the I/O down the most suitable alternate path. The PowerPath filter driver looks at the volume path set for the device, considers current workload, load balancing, and device priority settings, and chooses the best path to send the I/O down. This functionality represents a more intelligent handling of path failures than other path management products. The other products often failover all I/O to the next available path, therefore causing the path to be overburdening.

In the example, PowerPath has three remaining paths to redirect the failed I/O and to load balance across.

Because PowerPath spreads the additional load across the remaining channels, the system will continue to operate, however, in a “degraded” mode. This takes the pressure off the administrative staff to make corrections immediately and do planned outage maintenance since some servers do not support hot plugging of boards, which may require bringing the server down. PowerPath allows the IT staff to schedule the repair at a convenient time.

To test the effect of degraded mode behavior, the PowerPath GUI provides the ability to disable and re-enable channels on the fly, so you can test the performance sensitivity of your configuration to manage environmental configuration.



In comparison, failover on a active passive array is controlled by PowerPath in conjunction with the array technology. The illustration shows failover on a active-passive array. The logical device is assigned to storage processor B (SP B). PowerPath is load balancing the application I/O across the two ports on SP B. The paths to the device through SP A are considered passive and therefore are not supporting I/O.

Lets consider what happens when a failure occurs on any of the components that make up the path to the logical device.

Path fault — If a path or a cable is accidentally bumped or pulled, PowerPath will automatically failover the path to an alternate path. The logical device is not trespassed because one path to the logical device through the primary storage processor, SP B, is remaining. Once the path has been restored, PowerPath automatically recognizes this and resumes sending I/O down that path.

HBA fault — If an HBA is lost at the front end, PowerPath will failover the entire path to an alternate HBA. In this case, a trespass will occur because there is no path from the alternate HBA to the primary SP, SP B. The trespass could be avoided if the HBA is zoned to SP B. In fact, EMC recommends the zone be implemented. Once the HBA is brought back online, PowerPath recognizes this and resumes sending I/O through the HBA.

Storage Processor fault — If SP-B fails (see diagram), PowerPath will stop all I/O that was currently headed from the server to SP-B and trespasses it over to SP-A. Once SP-B is brought back online, PowerPath recognizes that SP-B is now available and resumes sending I/O down to SP-B. In the event of any of the above scenarios taking place, PowerPath ensures that applications remain continuously available.

Active Passive Failover Redefined with PowerPath

- Use all active paths before doing a trespass
- When all active paths are exhausted, trespass on a LUN by LUN basis
- Scope of LUNs failing over depends upon component
 - If there is a failure to an HBA or cable connecting the HBA to a Storage Processor, hub, or switch, just the affected host's LUNs failover
 - If there is a failure to a Storage Processor, all LUNs assigned to that Storage Processor will failover if they are accessed

Failover occurs on a LUN-by-LUN basis. This helps avoid any unnecessary trespassing of devices that can cause possible performance issues and degradation.

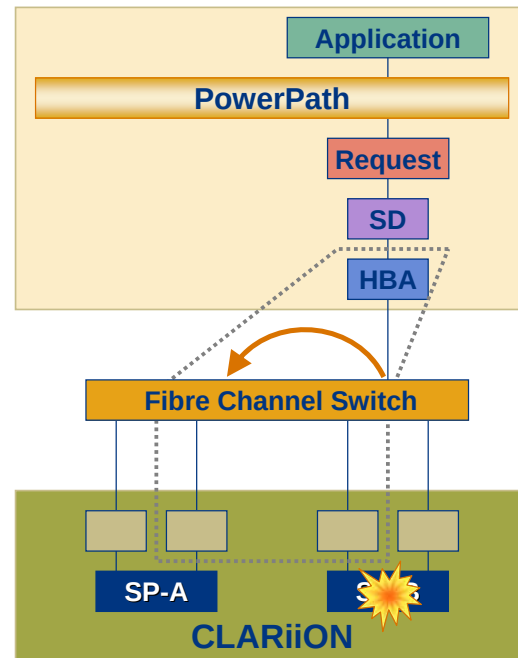
A multi-path failover will re-route the I/O through an alternate path to the LUN through the Storage Processor that is the primary owner. If the LUN is still inaccessible after going through all possible paths, a LUN trespass will occur. Trespass means that LUN ownership has been transferred to the alternate Storage Processor.

The manner in which logical units fail will also depend upon the mode of failure within the data path. If there is a failure of the HBA, or anywhere between the server and the array, just the affected host's devices would trespass over to the other Storage Processor, so they are accessible to the server through the alternate data path.

If there is a Storage Processor failure, all devices assigned to that Storage Processor that received I/O from the requesting host will failover to the surviving Storage Processor.

PowerPath Fabric Failover Functionality

- Available for both CLARiiON and Symmetrix
- Provides back-end failover, non-disruptive upgrades, and single HBA configuration support for single-attach hosts
- Replaces CLARiiON CDE Functionality
- Included in CLARiiON Utility Kit
- Access Logix is required
- Non-HA environment
- No multi-pathing capabilities



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As a special case for non-high availability environments, PowerPath Fabric Failover replaces CDE (CLARiiON Driver Extensions) functionality. It is provided on all CLARiiON arrays. It provides single HBA configuration support, back-end failover support and non-disruptive upgrade support.

This does not have any multi-pathing or load balancing capabilities and should not be used in a high availability environment.

PowerPath Fabric Failover is a version of PowerPath without a license key that provides only Basic Failover functionality. It protects against CLARiiON SP failures, Symmetrix FA port failures, back-end storage-system failures and supports non-disruptive upgrade, or NDU, of storage system software. While a server is running normally, PowerPath Fabric Failover takes no action.

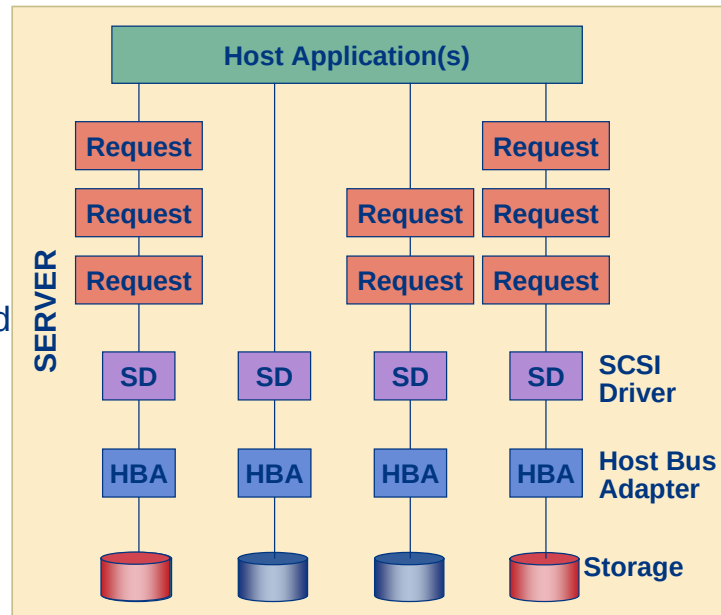
If a failure occurs in an SP or an FA port, PowerPath Fabric Failover attempts to fail over (transfer) the I/Os to a different SP or FA port. PowerPath Fabric Failover does not protect against HBA, Switch, or Switch port failures. To protect against such failures in storage systems with multiple HBAs connected to a storage system, you must order PowerPath and an accompanying license.

In the example, PowerPath sends an I/O down the path to SP B. A failure occurs on the backend. PowerPath receives the error and resends the I/O down the path to SP A.

PowerPath Fabric Failover is called Utility Kit PowerPath in CLARiiON documentation.

I/O without PowerPath Queues Out of Balance

- I/O performance is partially based on queue length
- Optimal performance cannot be achieved unless work is balanced
- I/O workload across HBAs is seldom balanced
- At any point in time, some paths may be idle while other paths have multiple I/O operations queued



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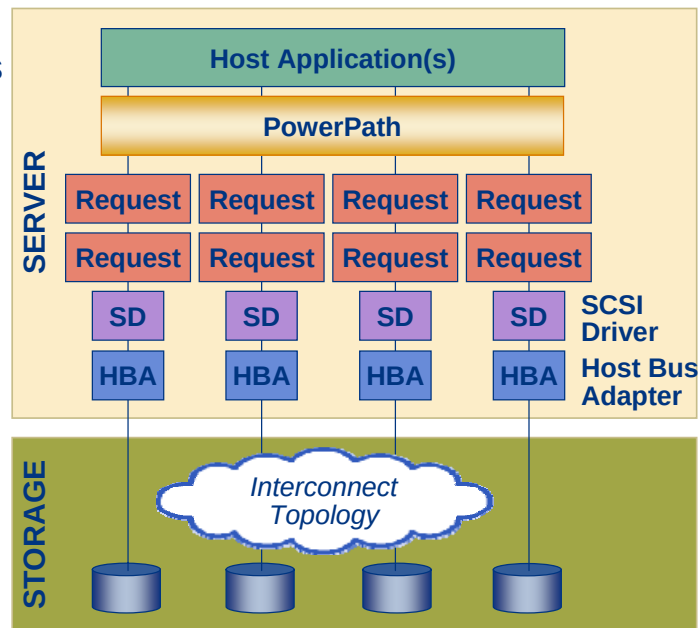
The server views each disk resource to be on a single path. EMC technical personnel set up the configuration of the storage system to spread I/O load across the paths. Each application is set up with its own storage. The storage is allocated to Channel Directors or Storage Processors based on expected data requirements of the applications. This setup is done based on snapshot measurements, guesstimates of average loading, predictive loads and the experience of the EMC experts.

This diagram depicts a snapshot of the system at a moment in time. The depth of the I/O queues is very unbalanced. Host applications sitting on top of deep queues are not getting the data they need. If this was the average loading, the System Administrator would reconfigure the system to balance the load better. In any system, there will be points in time when the load is unbalanced due to one application receiving heavy I/O requirements.

In this instance, two of the applications are currently causing high I/O traffic. At this point, two channels are overloaded (depicted by the red disks on the outside and the pending request stack), while two other channels are lightly loaded. In a while, the requests will have been handled and the system will return to a more balanced load. In the meantime, the applications are being “data starved” and the users or applications are experiencing less than optimal performance.

I/O with PowerPath Queues in Balance

- PowerPath dynamically balances workload across all available paths
- PowerPath will provide greatest performance improvement in environments where the workload is not balanced
 - Workloads are seldom balanced
 - Workloads dynamically change



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When PowerPath is installed, applications transparently access PowerPath instead of the SD (SCSI driver) devices. PowerPath allocates the requests across all available channels, reducing bottlenecks and improving performance. This diagram shows a similar snapshot with PowerPath using multiple channels to minimize the queue depth on all channels.

Since the Channel Directors or Storage Processors are writing to cache and not to disks, any Channel Director/Storage Processor can handle any request. This allows PowerPath to constantly tune the server to adjust to changing loads from the applications running on the server, which in turn improves the performance of the server by enabling it to make better use of the storage. This results in better application performance and less operational resources spent on the care and feeding of the system, with more (financial) value from your server investment.

PowerPath does not manage the I/O queues; it manages the placement of I/O requests in the queue.



PowerPath Load Balancing Policies

- **Symm_opt / CLAR_opt / Adaptive (default)**
 - I/O requests are balanced across multiple paths based on composition of reads, writes, and user-assigned device / application priorities
- **Round_Robin**
 - I/O requests are distributed to each available path in turn
- **Least_I/Os**
 - I/O requests are assigned to the path with the fewest number of requests in the queue
- **Least_Blocks**
 - I/O requests are assigned to the path with the fewest total blocks in the queue
- **Request**
 - Path failover only
- **No Redirect**
 - Disable path failover and load balancing (same as Transparent=on)
 - Default for Symmetrix when there is no license key
 - not supported on CLARiiON
- **Basic Failover**
 - PowerPath SE functionality (SPA-SPB failover)
 - Default for CLARiiON when there is no license key; not supported on Symmetrix

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The slide lists the load balancing policies that are available.

Symm_opt / CLAR_opt / Adaptive — Choose paths based on path load and logical device priority. Device priority is host-based priority and not Symmetrix/CLARiiON level priority. Adaptive is the default priority on non-EMC arrays and performs similarly to Symm_opt and CLAR_opt.

Round Robin — I/O requests are assigned to each available path in rotation.

Least I/Os — Load balance is based on the number of pending I/Os. I/O requests are routed to the path with the fewest queued requests, regardless of total block volume.

Least Blocks — Load balance is based on the number of blocks in pending I/Os. I/O requests are routed to the path with the fewest queued blocks, regardless of the number of requests involved.

Request — For native devices, this policy uses the path that would have been used if PowerPath were not installed. For pseudo devices, it uses one arbitrary path for all I/O. For all devices, path failover is in effect, but load balancing is not.

No Redirect — Neither load balancing or failover is in effect. If this algorithm is set on a failed path and a native device is used, I/O errors will occur when I/O is directed to that path. This policy is valid **only** on Symmetrix arrays.

Basic failover — Load balancing is not in effect. I/O routing on failure is limited to one host bus and one port on each Storage Processor. This policy is required for a nondisruptive upgrade. It protects against Storage Processor and back-end failures, but not against HBA or host loop failures

You can change the policies from the powermt set policy command, or within the GUI on Windows.

PowerPath Load Balancing Policies Array Support

Symmetrix Policies	CLARiiON Policies	3 rd Party Array Policies
Symmetrix Optimize (so)	CLARiiON Optimize (co)	Adaptive (ad)
Round Robin (rr)	Round Robin (rr)	Round Robin (rr)
Least Blocks (lb)	Least Blocks (lb)	Least Blocks (lb)
Least I/O (li)	Least I/O (li)	Least I/O (li)
	Request (re)	
No Redirect (nr)		No Redirect (nr)
Basic Failover (bf)	Basic Failover (bf)	

The table lists the PowerPath policies that can be used on each array. The column 3rd party refers to IBM, Hitachi, HP XP, and HP StorageWorks array.

In the first row are the default policies for each array. Note that all policies except basic failover, request, and the default policy can be applied to all arrays.

Load balancing policies are assigned per device. An administrator can assign a load balancing policy to all devices, a subset of devices, or one device.

A PowerPath license is required to set all policies, except No Redirect and Basic Failover. PowerPath licensing is covered in more detail elsewhere in this training.

PowerPath supports attachment of multiple arrays to a host. In this situation, PowerPath will not set load balancing policies that are applicable for LUNs belonging to one type of array on LUNs that belong to an array type that the load balancing policy does not apply to.

PowerPath Foundations

POWERPATH MANAGEMENT TOOLS

In this section, we illustrate the PowerPath management tools that are currently available.

PowerPath Management Tools

- Windows based GUI
- Unix based CLI software

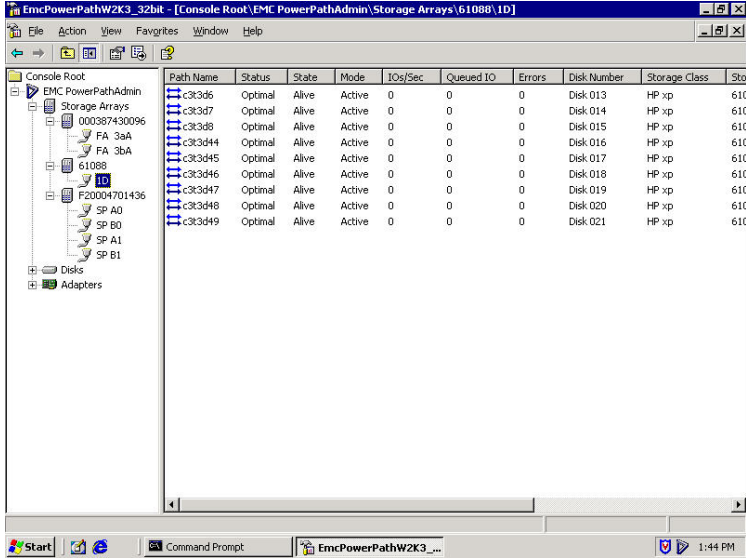


PowerPath may be managed by either a Windows-based GUI or a Unix-based CLI.

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Management Tools

- PowerPath provides GUI and CLI interface for online management
 - Performance and status monitoring
 - Configuration
 - Channel director and path maintenance
 - Restoring path after repair
 - Testing



The screenshot shows the EMC PowerPathW2K3_32bit GUI. The left pane displays a tree view of the console root, including EMC PowerPathAdmin, Storage Arrays, and various disks and adapters. The right pane shows a table of storage paths with the following columns: Path Name, Status, State, Mode, IOs/Sec, Queued IO, Errors, Disk Number, Storage Class, and Size. The table lists paths c3k3d6 through c3k3d9, all with an 'Optimal' status and 'Alive' state, connected to HP xp disks.

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When PowerPath is installed, maintenance, configuration, and tuning can be performed online without interrupting the applications. When a path failure occurs, PowerPath disables the path. When a Storage Administrator repairs the fault, a simple command line entry will enable I/O through the path. The applications will not be affected when re-establishing the path.

With PowerPath, the Storage Administrator can disable a channel causing I/O to use the remaining channels. Maintenance can also be performed on the channel director without taking the application down, and the channel can be re-establish using PowerPath.

PowerPath provides tools to look at the behavior of the SCSI I/Os, which allows monitoring of the amount of traffic on each queue and to each device. On installation of PowerPath, all configuration and maintenance is performed online, keeping the server available to do productive, revenue-generating work.

When a channel is lost, the server will continue to operate in a degraded state. How degraded it really is can be easily determined by taking a channel offline. If it causes a serious problem, you can return it to service in a few seconds. Additionally, suppose you have run out of slots on the Symmetrix. You want to add SRDF for disaster recovery and you need to add Remote Link Adapters (RLDs). You can see how the server will respond to having fewer SCSI channels available.

PowerPath CLI Interface

```

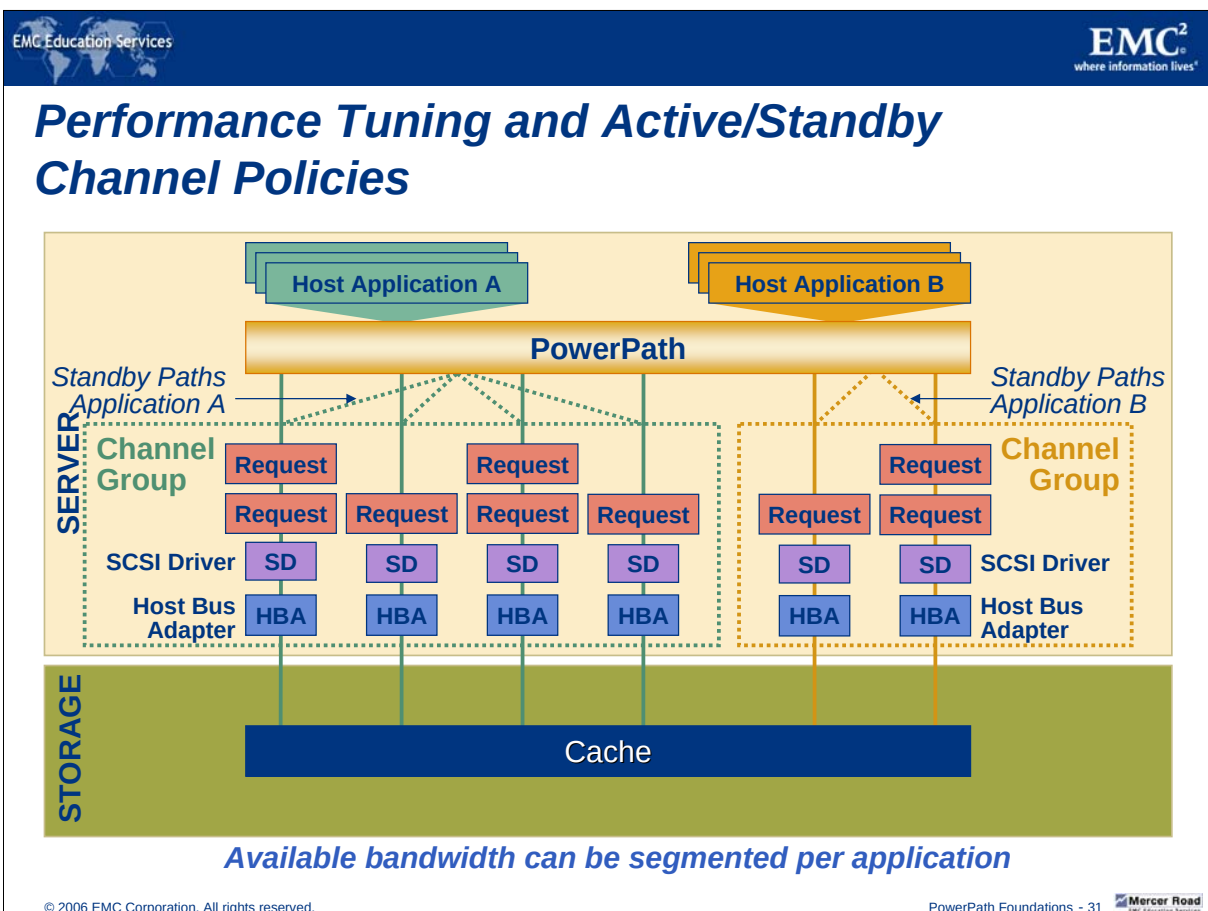
powermt check [force] [hba=<hba#>|all] [dev=<device>|all]
powermt check_registration
powermt config
powermt display [ports] [dev=<device>|all] [every=<#seconds>]
powermt display options
powermt display paths [every=<#seconds>]
powermt display unmanaged
powermt manage {dev=<device> | class={hitachi | hp xp | ess | hpsx}}
powermt unmanage {dev=<device> | class={hitachi | hp xp | ess | hpsx}}
powermt load [file=<filename>]
powermt remove [force] [hba=<hba#>|all] [dev=<device>|all]
powermt restore [hba=<hba#>|all] [dev=<device>|all]
       [force [hba=<hba#>|all] [dev=<device>|all]]
powermt save [file=<filename>]
powermt set mode=active|standby [hba=<hba#>|all] [dev=<device>|all]
powermt set periodic_autorestore=on|off
powermt set policy={ad|bf|co|lb|li|nr|re|rr|so} [dev=<device>|all]
powermt set priority=<priority> [dev=<device>|all]
powermt set write_throttle={on|off} [dev=<device>|all]
powermt set write_throttle_queue=<queue_depth> [dev=<device>|all]
powermt update lun_names
powermt version

sobo-mf01 / powermt help_

```

The CLI interface is available on all hosts. The commands are used to view or change the PowerPath options for the HBA port, the Path of the device.

The illustration above is a help menu for the different options, the help menu is invoked with the command "**powermt help.**"



PowerPath provides configuration flexibility that allows you to define some paths as “active” and some as “standby” (indicated by the dotted lines in the graphic). This means that the standby paths will only be used if the active paths fail. You can dynamically add and remove paths. For example, if you had eight paths partitioned into four for one application and four for another, and one application needed more bandwidth (as during batch) through scripts, you can add more paths during the batch run and take them away when you're done.

The actual command is **`powermt set mode=standby/active adapter=adapter# dev=integer/all`**

Here are examples of two practical applications of this:

- If you have two applications on a server that are both very busy, but you don't want the activity of one application to impact the performance of the other application, set up the two applications to have their own sets of channels. I/O for those two channels would be balanced among the channel groups only, and if one application was very busy, the other application would not be impacted from an I/O standpoint. In the event of all the defined channels for one Channel Group failing, I/O would be re-routed to the other Channel Group's channels.
- If a host has two types of channels, for example, Fibre Channel and SCSI, segregate channels by channel type. It is not possible for PowerPath to load balance an application across both Fibre Channel and SCSI together, but by using channel segregation, a user can set up the environment so that PowerPath would load balance across the SCSI channels for one set of devices and Fibre Channel for the other set of devices. Then, in the event of a failure, all the devices defined to the failed paths would use the other available paths for I/O because they were standby paths for those devices.

PowerPath Storage Classes

```
# powermt display options
```

```
Default storage system class: all
Show CLARiiON LUN names:      true
```

Storage System Class	Attributes
-----	-----
Symmetrix	periodic autorestore = on status = managed
CLARiiON	periodic autorestore = on status = managed
Ess	periodic autorestore = on status = managed
Hitachi	periodic autorestore = on status = managed
HP xp	periodic autorestore = on status = managed

PowerPath refers to a supported storage array as a **storage class** (this referencing began with version 4.1). When the logical devices belonging to a storage class are under PowerPath control, the storage class is considered to be **managed**. When PowerPath is installed, a storage class is managed by default.

The ***powermt display options*** command reports the managed status of each class of storage arrays that PowerPath 4.x supports.

By grouping logical devices by storage classes, a user can operate on all the devices belonging to the class. For example, the ***powermt display class=hpxp*** command reports information about HBAs and/or the devices under PowerPath control that are connected to an HP StorageWorks XP array.

Using *powermt* Command in PowerPath V4.x

Command	Description
powermt manage class=<storage class>	Places all devices of the storage class specified in <storage class> under PowerPath control.
powermt unmanage class=<storage class>	Removes all devices of the storage class specified in <storage class> from PowerPath control.
powermt manage dev=<device>	Places the individual device identified in <device> under PowerPath control.
powermt unmanage dev=<device>	Removes the individual device identified in <device> from PowerPath control.
powermt display unmanaged	Displays all unmanaged devices under PowerPath control.
powermt display options	Displays the management status of each class under PowerPath control.

Use the **powermt** command to manage and unmanage a storage class, or a device within a storage class. The **manage** and **unmanage** commands are supported for third-party storage systems only.

PowerPath Foundations

BUSINESS JUSTIFICATION AND SOFTWARE IMPLEMENTATION OF POWERPATH

In this section, we will discuss the business justification and software implementation of PowerPath.

Business Challenges

- **Application availability**
 - Businesses require 24x7 access to data
- **Storage manageability**
 - Optimize information access
 - Maximize server, storage, and data path utilization
- **Quality of service (QoS)**
 - Diverse requirements
 - Competing applications
 - Need to tune the infrastructure performance by application
 - Need to protect application availability

PowerPath addresses the main business challenges facing IT professionals:

- **Availability:** Customers want their businesses up 24x7. Application availability is critical to protect revenue streams, support new product development efforts, and increase customer satisfaction.
- **Manageability:** Businesses always need the manageability to maximize their technology investments. IT professionals are searching for new and more-efficient ways to manage and hide the complexity of their environment. Today, the search is on for policy-based, automated management tools that optimize and simplify information access.
- **Quality of Service:** EMC is sensitive to competing requirements of different applications and must respond to changes in your business environment. Management tools must have the ability to quickly respond to various and changing business requirements to provide continuous protection to your data.

PowerPath Advantages

- **Automatic**
 - Dynamic intelligent load management
 - Manages multiple I/O data paths to maximize performance and high availability
 - Utilizes multiple data paths to provide greatest efficiency
- **Nondisruptive**
 - Path failover keeps your business in business
 - Continuous access to information
 - Online management and configuration
- **Optimized**
 - Optimizes server and data path utilization by eliminating downtime
 - Prioritizes bandwidth utilization
 - Maximizes existing server investment

PowerPath path management provides information access optimization. How do you optimize your information infrastructure for all your diverse applications?

PowerPath needs to be:

- **Automatic**
 - Intelligent I/O path management
 - Manage multiple I/O paths to optimize performance and application availability
- **Nondisruptive**
 - High availability access to information
 - Access to your data when you need it, how you need it, at the service level you need
 - Needs to be dynamic and configurable
- **Optimized**
 - Consistent service levels; less setup and maintenance times
 - Ensures optimal application performance
 - Leverage existing investments better across heterogeneous server and storage environments

PowerPath Interoperability

Operating System Support	Storage Platform Support	Number of Paths (maximum)	High-availability Cluster Software
Solaris	Symmetrix CLARiiON Hitachi Data Systems (HDS) Lightning HP XP (Hitachi OEM) IBM ESS (Shark) HPQ HSG80 HPQ StorageWorks EVA	32 (16 for CLARiiON)	Sun Cluster (Path Management only) Veritas Cluster Server EMC Legato AAM Cluster
Windows Linux	Symmetrix CLARiiON Hitachi Data Systems (HDS) Lightning HP XP (Hitachi OEM) HPQ HSG80 HPQ StorageWorks EVA IBM ESS (Shark)	32 (16 for CLARiiON)	Microsoft Cluster Server (Path management only)
HP-UX Tru64 UNIX (Symmetrix only)	Symmetrix CLARiiON Hitachi Data Systems (HDS) Lightning HPQ HSG80 HPQ StorageWorks EVA HP XP (Hitachi OEM) IBM ESS (Shark)	32 (16 for CLARiiON)	MC/ServiceGuard (Path Management only) TruCluster Server (Symmetrix only)
AIX	Symmetrix CLARiiON Hitachi Data Systems (HDS) Lightning HPQ HSG80 HPQ StorageWorks EVA HP XP (Hitachi OEM) IBM ESS (Shark)	32 (16 for CLARiiON)	HACMP (Path Management only)
Novell	Symmetrix CLARiiON	32 (16 for CLARiiON)	Novell Cluster Services

The table shows the storage arrays and high availability cluster support for each operating system that PowerPath supports.

Check the PowerPath Support Matrix for details on which operating system versions and patches are supported by PowerPath.

PowerPath Operating System Support

Solaris	AIX	HP-UX Tru64	Windows	Linux	Netware
Solaris 6, 7, 8, 9, 10	AIX 5.1, 5.2, 5.3	HP-UX 11.0, 11.11, 11.23 Tru64 4.0 and 5.1	Windows 2000 Advanced server, Datacenter, Server Windows 2003 Enterprise and Standard Edition 32 and 64 bit Windows 2003 Enterprise, Standard, and Datacenter Edition IA64	Miracle Linux 32 and 64 bit Miracle Linux Ia64 Red Hat 32 bit, AMD-64, EM64T, IA64 SuSe 32 bit, AMD-64, EM64T	Novell 5.0, 5.1 and 6.0

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The table lists the current operating system platforms that PowerPath supports. PowerPath 4.x is the most recent release of PowerPath for all platforms except Novell and Tru64. PowerPath version 3.0.6 is the current version for Novell Netware. PowerPath 2.1 is the current version for Tru64 UNIX.

Check the PowerPath Support Matrix for details on which operating system versions and patches are supported by PowerPath.

 			
PowerPath Array Support			
Array Vendor	Model	Array Type	Comments
	Symmetrix, DMX-2, DMX-3	Active-active	
	CLARiiON FC, CX series	Active-passive	
	AX Series Arrays	Active-passive	
	Invista	Active-active	PowerPath 4.5 on Solaris, Red Hat, HP-UX. Windows requires an RPQ.
	Lightning 9970V/9980V	Active-active	
	Lightning 9910/9960	Active-active	
	XP 48/512	Active-active	HP OEM version of HDS Lightning 99x0
	XP 128/1024	Active-active	HP OEM version of HDS Lightning 99x0V
	MA 8000, EMA 12000/16000	Active-passive	Not supported on Linux,
	EVA 3000/5000	Active-active	Linux Support for SuSE SP3 ONLY
	F10/F20	Active-active	
	800/800T	Active-active	

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The table lists the storage arrays by vendor that PowerPath currently supports.

PowerPath version 4.x and later adds non EMC array, aka third-party array support. The level of support varies slightly from other operating systems. Check the EMC Support Matrix for details on which arrays are supported by PowerPath.



PowerPath Volume Manager/Filesystem Support

PowerPath supports most volume managers and file systems

<u>Volume Managers</u>	<u>File systems</u>
– HPQ HP LVM – IBM AIX LVM – Microsoft Disk Admin – Linux Native LVM – SUN ➤ UFS, ➤ Sun Solstice DiskSuite – Veritas VxVM	– HPQ ➤ HFS and JFS – IBM ➤ JFS and JFS2 – Microsoft NTFS – Red Hat/SuSe ➤ EXT2 and EXT3 ➤ EXT3 – Sun UFS – Veritas VxFS

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PowerPath supports most of the more commonly used volume managers and filesystems. The slide lists several examples. Check the EMC Support Matrix for details on which arrays are supported by PowerPath.

PowerPath 4.x Support Highlights

- Windows
 - 3rd party (non EMC) array support
 - CLARiiON AX100SC and AX100
 - CLARiiON Nice Names (LUN names)
 - Non-interactive (Silent) Install via Command Line Interface
 - Automatic configuration of logical devices
 - Dell PowerEdge™ 3250 64-bit Itanium 2 processor
- UNIX and Linux
 - CLARiiON Nice Names
 - 3rd party (non EMC) array support
 - Invista Array Support
 - HP-UX 11i on IA64 and PA-RISC
- 5671 Symmetrix Enginuity Code Support
 - Supports Symmetrix device numbers that are greater than 8k
 - PowerPath Utility Kit for Symmetrix

Shown is an itemized list of the major new features and functionality included in the current 4.x releases of PowerPath.

PowerPath for Windows adds support for CLARiiON Nice Names, or LUN Names. As part of that functionality, the *powermt* update lun_names command is available for CLARiiON arrays only. Use this command to retrieve the latest user-specified CLARiiON LUN names.

Administrators can now install PowerPath for Windows using a non-interactive (Silent), unattended installation on a local or remote server. This release also supports the automatic configuration of new logical devices. PowerPath for Windows also includes support for the new Dell PowerEdge 3250 server with the Itanium 64-bit processor running Windows 2003 OS only.

On UNIX and Linux platforms, new PowerPath features include support for CLARiiON “Nice Names.” Nice names is PowerPath terminology for CLARiiON LUN Names, which are assigned through Navisphere Manager.

On both Windows and Unix, PowerPath supports non EMC arrays such as the HDS Lightning and HDS/HPQ variant Storage Works XP array. Check the PowerPath Support Matrix for details on which 3rd party arrays are supported by PowerPath.

Symmetrix 5x71 microcode. With Symmetrix 5x71 microcode, PowerPath supports Symmetrix devices that have device numbers greater than 8k.

The Symmetrix utility kit protects against FA port failures and back-end storage-system failures, and supports non-disruptive upgrade (NDU) of storage system software. It does not protect for HBA failures.

PowerPath Verses Other Products

- Veritas DMP
 - Provides failover and limited load balancing capability
- SUN Alternate Pathing
 - Failover only
- HP PVlinks
 - Failover only
- Windows MPIO
 - Failover only

The slide lists some of the more popular software products that provide similar functionality to PowerPath.

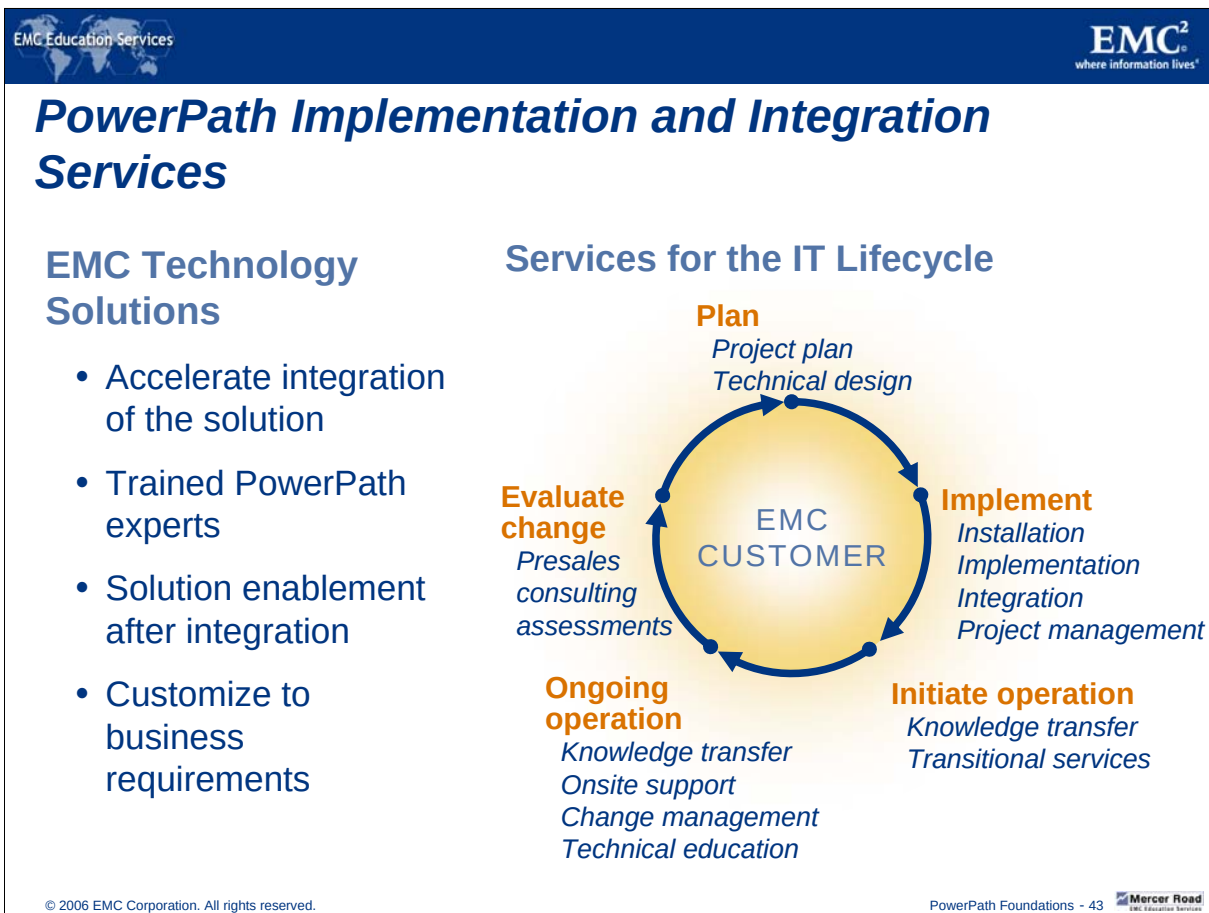
Veritas Volume Manager (VxVM) is available on Solaris, HP-UX, AIX, and Windows platforms. When VxVM is installed, Veritas dynamic multi-pathing devices, called DMP devices, are automatically created. Administrators must place application data on a DMP device name (/dev/vx/rmp/...) to benefit from DMP functionality. When PowerPath is installed on all platforms except AIX, administrators do not need to specify a special device file in order for PowerPath functionality to be available.

Both products dynamically redirect I/O requests from a failed path to an operational path. However, while PowerPath redistributes all the I/O requests over all the remaining operational paths, DMP redirects all the I/Os from the failed path to the one “next” to it, resulting in unbalanced I/O distribution. Both DMP and PowerPath are managed by command.

Sun Alternative Path (AP) product provides failover capability on the host. It does not load balance. AP cannot co-exist with PowerPath.

HP Pvlins is another failover product that is distributed by Hewlett Packard. Pvlins also is used for failover. Pvlins and PowerPath can co-exist. PowerPath handles load balancing and failover.

Windows MPIO is another product that delivers path failover capability only. MPIO and PowerPath can not co-exist on the same system.

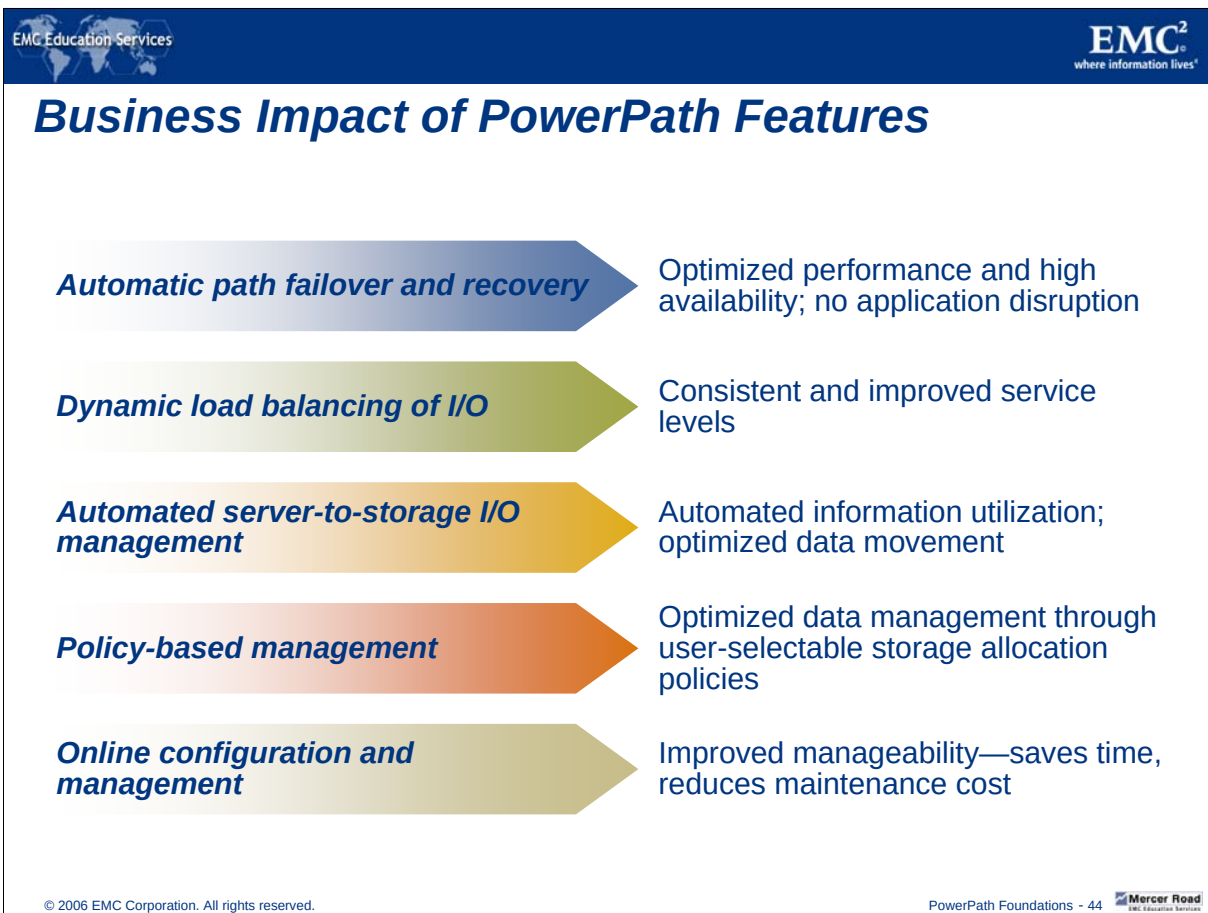


EMC Technology Solutions speeds the time to value of the PowerPath solution through quick and flawless implementation. Trained PowerPath experts leverage their product knowledge and experience to minimize business disruption during the implementation and reduce the risk from implementation of new technology.

Technology Solutions' implementation provides test and acceptance, functional overview, and product demonstrations to insure that customers are ready to operate in the PowerPath-enabled environment. Technology Solutions provides a production-ready environment so you can quickly realize value.

For customers with integration requirements beyond the scope of the basic implementation services, Technology Solutions provides custom services to meet all their software integration needs.

EMC Services provides services to help customers at every stage of their IT lifecycle—from consulting, assessment, and solution conceptualization, through solution design and implementation, to ongoing support.



Automatic path failover and recovery - By taking advantage of all available paths, PowerPath increases the ability of the server to access data on the Symmetrix, CLARiiON, and non-EMC storage arrays. If a path is lost, PowerPath automatically fails over the I/O to another path and alerts the system there is a problem with the path. If there is a failure anywhere in the data path, PowerPath will automatically send I/O down another path, thereby maintaining data availability. All this occurs without the application being interrupted. Once the path has been repaired, PowerPath automatically restores the path to service.

Dynamic load balancing of I/O - PowerPath has the ability to balance the I/O load that is being asked for by the servers. For instance, there are four paths, and if the I/O queues are unbalanced across these four paths (say there are four requests on Path 1; two on Path 2; and one each on Path 3 and 4), PowerPath detects that there is a better way to manage the I/O load on the paths and distributes the I/O across the four paths evenly. Now there are two requests going down each path. This leads to faster and quicker response time to the server.

Online configuration and management - After the initial installation, all maintenance, monitoring, and configuration work can be done with the system fully functional. PowerPath provides queue monitoring functions so that the user can see how the paths are being used. PowerPath also allows the user to idle a path for maintenance, such as a SCSI Adapter upgrade or replacement.

Module Summary

Key points covered in this module:

- PowerPath is server based software that provides multiple paths between the host bus adapter and the Storage Subsystem
 - Redundant paths eliminate host adapter, cable connection, and channel adapters as single points of failures and increase availability
 - Improves performance by dynamically balancing the workload across all available paths
 - Application transparent
- Enhances data availability in SAN environment
- Close integration with most UNIX and NT hosts
- GUI and CLI interface for management functions

PowerPath is at the device driver layer. Basically, “you set it and forget it!” However, there is an easy to use GUI that allows you to setup and monitor PowerPath operations.

From the manageability standpoint, automatic load balancing reduces the amount of time a system administrator has to spend fine-tuning the server’s performance. Operationally, this will free-up the system administrator for other tasks. In addition, the system administrator can make any adjustments online, without disrupting the application. This is provided for ease-of-use for those environments where one may need to address modified configurations or anomalies.