# HP 3PAR StoreServ Storage and VMware vSphere 5 best practices

## Table of contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Executive summary</td>
<td>3</td>
</tr>
<tr>
<td>Configuration</td>
<td>4</td>
</tr>
<tr>
<td>Fibre Channel</td>
<td>4</td>
</tr>
<tr>
<td>Multi-pathing considerations</td>
<td>7</td>
</tr>
<tr>
<td>HP 3PAR Persistent Ports</td>
<td>8</td>
</tr>
<tr>
<td>HP 3PAR Peer Persistence</td>
<td>10</td>
</tr>
<tr>
<td>Virtual Connect</td>
<td>11</td>
</tr>
<tr>
<td>Summary</td>
<td>14</td>
</tr>
<tr>
<td>Overview and configuration of VMware vSphere Storage API Integration</td>
<td>14</td>
</tr>
<tr>
<td>VAAI</td>
<td>14</td>
</tr>
<tr>
<td>VASA</td>
<td>15</td>
</tr>
<tr>
<td>Configuring HP VMware vCenter Server integration</td>
<td>16</td>
</tr>
<tr>
<td>Summary</td>
<td>18</td>
</tr>
<tr>
<td>Thin provisioning</td>
<td>18</td>
</tr>
<tr>
<td>HP 3PAR Thin Provisioning vs. vSphere Thin Provisioning</td>
<td>18</td>
</tr>
<tr>
<td>Configuring</td>
<td>18</td>
</tr>
<tr>
<td>HP 3PAR Thin-to-Fat and Fat-to-Thin Conversion</td>
<td>21</td>
</tr>
<tr>
<td>HP 3PAR Thin Persistence Software</td>
<td>21</td>
</tr>
<tr>
<td>HP 3PAR Zero Detect</td>
<td>21</td>
</tr>
<tr>
<td>Summary</td>
<td>22</td>
</tr>
<tr>
<td>HP 3PAR StoreServ Adaptive Optimization</td>
<td>22</td>
</tr>
<tr>
<td>Dynamic and Adaptive Optimization on HP 3PAR StoreServ</td>
<td>22</td>
</tr>
<tr>
<td>VMware Storage DRS</td>
<td>23</td>
</tr>
<tr>
<td>HP 3PAR StoreServ tiered storage features</td>
<td>23</td>
</tr>
<tr>
<td>Best practice recommendations</td>
<td>25</td>
</tr>
<tr>
<td>Summary</td>
<td>26</td>
</tr>
<tr>
<td>Performance tuning</td>
<td>26</td>
</tr>
<tr>
<td>I/O sizing</td>
<td>27</td>
</tr>
<tr>
<td>SPC-1 benchmark results</td>
<td>27</td>
</tr>
<tr>
<td>Alignment considerations</td>
<td>27</td>
</tr>
<tr>
<td>Virtual SCSI adapters and virtual disk types</td>
<td>27</td>
</tr>
</tbody>
</table>
Wide striping ................................................................. 29
Storage I/O Control ......................................................... 29
Adaptive queue depth throttling ......................................... 31
Summary ........................................................................... 32
HP 3PAR Recovery Manager Software for VMware vSphere ...................................................... 32
  Architecture ................................................................. 33
  Benefits ......................................................................... 34
  Usage ............................................................................. 35
  Best practices ................................................................. 35
  Summary ........................................................................... 35
HP 3PAR Integration with VMware vCenter Site Recovery Manager (SRM) ...................................... 36
  Architecture ................................................................. 36
  Best practices ................................................................. 37
  Summary ........................................................................... 38
Summary ........................................................................... 38
For more information ........................................................... 39
Executive summary

When supported with the correct underlying storage platform, server virtualization delivers greater consolidation, administrative efficiency, business continuity and cost savings. As a result, server virtualization is not only transforming the data center, but also the businesses that those data centers fuel. However, these transformative results depend on enterprise class storage to deliver the performance, availability, and flexibility to keep up with the dynamic and consolidated nature of virtualized server environments.

HP 3PAR StoreServ Storage is the next generation of federated Tier 1 storage and was built from the ground up to exceed the economic and operational requirements of virtual data centers and cloud computing environments by providing the SAN performance, scalability, availability and simplified management that clients need. It does this through an innovative system architecture that offers storage federation, secure multi-tenancy, built-in thin processing capabilities, and autonomic management and storage tiering features that are unique in the industry.

When deployed together, VMware vSphere and HP 3PAR StoreServ Storage deliver a compelling virtual data center solution that increases overall resource utilization, provisioning agility, application availability, administrative efficiency, and reduces both capital and operating costs.

Implementing HP 3PAR StoreServ Storage systems with VMware vSphere 5 enables its users the unique ability to:

- Increase consolidation savings by doubling virtual machine density
- Maximize savings through lower storage costs by up to 50%
- Simplify storage provisioning and management time by up to 90%

Figure 1. HP 3PAR StoreServ Storage for VMware vSphere Environments

These benefits in VMware environments are delivered through a combination of HP 3PAR StoreServ advanced features and integration with VMware storage technologies (Figure 1).

Increase Consolidation: Integrating HP 3PAR StoreServ Storage systems with VMware vSphere 5 enables its users to double virtual machine density on physical servers through wide striping, mesh-active clustered architecture, mixed workload support, and hardware assisted support of VMware vSphere Storage APIs for Array Integration (VAAI).

Simplify Administration: Managing storage in VMware environments is simplified through unique HP 3PAR StoreServ capabilities such as Autonomic Groups, Recovery Manager for VMware software, and integrated management through VMware vCenter Server with the HP Insight Control Storage Module for vCenter.

Maximize Savings: HP 3PAR StoreServ thin technologies including Thin Provisioning, Thin Conversion, and Thin Persistence with in-line zero detect capability of the HP 3PAR StoreServ ASIC deliver the ultimate in storage efficiency in VMware environments.

HP 3PAR StoreServ arrays continue to capture the SPC-1 benchmark results for a single storage array using Fast Class disks due to the HP 3PAR StoreServ architecture with multiple storage controller nodes and wide striping over available disk

1 Fast Class (FC) represents the middle tier in an HP 3PAR StoreServ array which could be either Fibre Channel or Serial Attached SCSI drives depending on the model.
drives. Capturing SPC-1 is crucial to VMware’s demand for low latency I/O response and HP 3PAR StoreServ’s ability to double VM density with fewer servers compared to other arrays on the market today.

This white paper outlines best practices on how to set up HP 3PAR StoreServ Storage with VMware vSphere 5.1 as well as how to take advantage of HP 3PAR StoreServ’s unique features such as vSphere integration, HP 3PAR Thin Provisioning technologies, Dynamic and Adaptive Optimization, and Recovery Manager for VMware to create a world class virtualized IT and application infrastructure. The information contained in this document should be used along with the documentation set provided by HP for the HP 3PAR StoreServ Storage system, HP 3PAR Operating System, and the documentation provided by VMware for vCenter, Site Recovery Manager (SRM), and other related products.

**Target audience:** IT Administrators and Solution Architects planning to leverage HP 3PAR StoreServ Storage within a VMware vSphere 5 environment.

This white paper is based on testing performed in November 2012.

**Configuration**

There are several best practices when configuring an HP 3PAR StoreServ array with VMware ESXi 5 as well as in general with any Fibre Channel implementation. This section will describe the best practices when leveraging Fibre Channel networking and an HP 3PAR StoreServ array to an ESXi host, configuring multi-pathing on an ESXi host, describe the benefits of HP 3PAR Persistent Ports, and connectivity when using HP Virtual Connect technologies.

**Fibre Channel**

**Target port limits and specifications**

To ensure an optimal configuration, observe the following limitations on ESXi host server HBA ports and HP 3PAR StoreServ Storage target ports:

- Maximum of 16 host initiators per 2 Gb HP 3PAR StoreServ Storage port
- Maximum of 32 host initiators per 4 Gb HP 3PAR StoreServ Storage port
- Maximum of 32 host initiators per 8 Gb HP 3PAR StoreServ Storage port
- Maximum total of 1,024 host initiators per HP 3PAR StoreServ Storage system

**Note**

Although HP supports 64 host initiator ports per 8 Gb HP 3PAR StoreServ Storage port, HP only recommends and supports 32 for hypervisors.

The I/O queue depth for each HP 3PAR StoreServ Storage system HBA model is shown in Table 1. Note that the I/O queues are shared among the connected host server HBA ports on a first-come, first-served basis. For recommendations on managing I/O queues for optimal performance, please see the Storage I/O Control and Adaptive queue depth throttling sections in this document.

**Table 1. I/O queue depth for HP 3PAR StoreServ Storage HBAs**

<table>
<thead>
<tr>
<th>HP 3PAR StoreServ Storage HBA model</th>
<th>I/O queue depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>QLogic 2Gb</td>
<td>497</td>
</tr>
<tr>
<td>LSI 2Gb</td>
<td>510</td>
</tr>
<tr>
<td>Emulex 4Gb</td>
<td>959</td>
</tr>
<tr>
<td>HP 3PAR HBA 4Gb</td>
<td>1638</td>
</tr>
<tr>
<td>HP 3PAR HBA 8Gb</td>
<td>3276</td>
</tr>
</tbody>
</table>

**Zoning recommendations**

Fabric zoning controls which Fibre Channel end-devices have access to each other on the SAN fabric. You can set up fabric zoning by associating the device World Wide Names (WWNs) or the switch ports with specified zones in the fabric. Although you can use either the WWN method or the port zoning method with HP 3PAR StoreServ Storage, the WWN zoning method is recommended because the zone survives the changes of switch ports when cables are moved around on a fabric.
Employ fabric zoning, using the methods provided by the switch vendor, to create relationships between host server HBA ports and storage server ports before connecting the host server HBA ports or HP 3PAR StoreServ Storage system ports to the fabric(s).

HP 3PAR StoreServ Storage arrays support the following zoning configurations:

- Single initiator to single target per zone (Figure 2).
- Single initiator to multiple targets per zone (zoning by HBA). This zoning configuration is recommended for HP 3PAR StoreServ Storage. Zoning by HBA is required for coexistence with other HP Storage arrays.

**Figure 2.** One initiator (host HBA port) to one HP 3PAR StoreServ target port (one-to-one zoning)

![Figure 2](image)

Figure 3 shows an example where each host HBA port is zoned to two target ports on the HP 3PAR StoreServ array. Note that this provides failover and protection against any single failure in the fabric or array. In addition, it provides the following benefits:

- If one controller node goes offline, both host HBA ports still have one path to the array.
- If the host HBA ports have higher speeds than the array HBA and the array is lightly loaded, this configuration may be able to sustain higher data rates to the array.

**Figure 3.** One initiator (host HBA port) to two HP 3PAR StoreServ target ports (zoning by HBA)

![Figure 3](image)
Note that the storage targets in the zone can be from the same HP 3PAR StoreServ Storage system, multiple HP 3PAR Storage systems, or a mixture of HP 3PAR StoreServ and other HP storage systems.

After configuring zoning and connecting each host server HBA port and HP 3PAR StoreServ Storage port to the fabric(s), verify the switch and zone configurations using the HP 3PAR OS CLI showhost command, to ensure that each initiator is zoned with the correct target(s).

**Creating the host definition**

Before exporting VLUNs from HP 3PAR StoreServ Storage to the ESXi host, you need to create a host definition that specifies a valid host OS for each system that is to be connected to the HP 3PAR StoreServ Storage. The host OS may be specified when creating the host definition, or the host definition may be edited as shown in Figure 4. Set the Host OS field to ESX 4.x/5.x.

**Figure 4. Set Host OS to ESX 4.x/5.x**

Alternatively, the createhost or sethost command may be used to set or change the OS setting from the 3PAR CLI:

```
# createhost –os VMware <hostname> [WWN...]
# sethost –os VMware <hostname>
```
Multi-pathing considerations

To maintain a constant connection between an ESXi host and its storage, ESXi supports multi-pathing. To take advantage of this support, virtual volumes should be exported to multiple paths to the host server. To do this, create a host definition on the HP 3PAR StoreServ Storage system that includes the World Wide Names (WWNs) of multiple HBA ports on the host server and then export the VLUNs to that host definition. For an ESXi cluster, the VLUNs must be exported to all of the host definitions for the cluster nodes, or a host set may be created containing all of the servers and the VLUNs can be exported to the host set.

VMware ESXi 5 includes active/active multipath support to maintain a constant connection between the ESXi host and the HP 3PAR StoreServ Storage array. Three path policies are available, "Fixed", "Most Recently Used" and "Round Robin". For HP 3PAR StoreServ storage, Round Robin is the recommended policy for best performance and load balancing; however, it may not be enabled by default. The path policies can be viewed and modified from the vSphere Web Client on a per datastore basis as follows:

1. In the vSphere Web Client, select the datastore.
2. Select the Manage tab, then the Settings tab, and then click on Connectivity and Multipathing.
3. Select one of the ESXi hosts and then click the Edit Multipathing button (highlighted in red in Figure 5).
4. In the pop-up window, select Round Robin from the Path Selection drop-down menu (as shown in Figure 6).
5. Click the OK button to save the new setting.
6. Repeat steps 3 through 5 for each ESXi host.

Figure 5. Edit multipathing policy
Figure 6 shows an example of an HP 3PAR StoreServ Fast Class VLUN that has the Round Robin path policy. Note that the status for all eight paths to the LUN is “Active (I/O)”

Figure 6. LUN set to Round Robin path policy

HP 3PAR Persistent Ports

New in the HP 3PAR OS 3.1.2, HP 3PAR Persistent Ports allows for an additional layer of redundancy in your HP 3PAR StoreServ solution. HP 3PAR Persistent Ports allows for Online Software Upgrades, non-disruptive HBA Firmware upgrades and node maintenance on HP 3PAR StoreServ arrays all while the normally affected host path remains online. There is no dependency on the software multi-pathing as the host port remains online.

A Host port would be connected and zoned via the fabric via one initiator (host HBA port) to one HP 3PAR StoreServ target port (one-to-one zoning). The pre-designated HP 3PAR StoreServ Backup port must be connected to the same fabric as its partner, however it does not need to be zoned to the Host port as it will assume the WWN of the failed path. It is best practice that a given Host port sees a single I/O path to HP 3PAR StoreServ storage. Optionally, a backup port can be zoned to the same Host port as the Primary port which would result in the Host port seeing two I/O paths to HP 3PAR StoreServ storage. This would also result in the configuration where an HP 3PAR StoreServ port can serve as the Primary port for a given Host port(s) and Backup port for Host port(s) connected to its partner port.
Once the zoning is configured, you can configure the Host ports on the HP 3PAR StoreServ array for persistent port. When configured, the recommended setup should look like Figure 7 below.

**Figure 7.** Logical diagram of a Persistent Ports configuration

![Persistent Ports Configuration Diagram](image)

Each HP 3PAR StoreServ Host-facing port will have a “Native” identity and a “Guest” identity. The “Guest” identity is associated with a pre-designated backup port on another HP 3PAR StoreServ node. The backup port must be on the node’s partner, for example if the primary HP 3PAR StoreServ port is on node 0, the backup HP 3PAR StoreServ port must be on node 1. In a four node system for example, placing the backup on node 2 while the primary HP 3PAR StoreServ port is on node 0 is not supported. Each HP 3PAR StoreServ host-facing port can also only have one Backup port Figure 8.

**Figure 8.** Host ports

<table>
<thead>
<tr>
<th>Position (Node/Slot/Port)</th>
<th>WWNN</th>
<th>State</th>
<th>Node</th>
<th>Topology</th>
<th>Rate (Mbps)</th>
<th>Class</th>
<th>Connected Device Type</th>
<th>Mode Change</th>
<th>Partner</th>
<th>Partner WWN</th>
<th>Failover Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/1:1</td>
<td>20110000A000003E</td>
<td>Ready Target Fabric Attached</td>
<td>8:3</td>
<td>Host Allowed</td>
<td>1/1:1</td>
<td>21100000A000003D</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/1:2</td>
<td>20110000A000003E</td>
<td>Ready Target Fabric Attached</td>
<td>8:3</td>
<td>Host Allowed</td>
<td>1/1:2</td>
<td>21120000A000003D</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/1:3</td>
<td>20110000A000003E</td>
<td>Ready Target Fabric Attached</td>
<td>8:3</td>
<td>Host Allowed</td>
<td>0/1:1</td>
<td>20110000A000003E</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/1:4</td>
<td>20110000A000003E</td>
<td>Ready Target Fabric Attached</td>
<td>8:3</td>
<td>Host Allowed</td>
<td>1/1:2</td>
<td>20110000A000003E</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the event of a failure or a planned activity, the backup port logs into Fabric with Guest identity while the host path from Fabric-to-3PAR switches over from Primary path to Backup path. This switch happens in sub-seconds and is not visible at the SCSI layer. When a failover attempt is executed, the **Failover State** of the host port can be one of the following states:

- **none** – failover not in operation
- **failover_pending** – failover to partner request has been issued but not yet completed (transient state).
- **failed_over** – this port is failed over to its partner.
- **failback_pending** – failback request has been issued but not yet completed (transient state).
- **active** – the partner port is failed over to this port.
- **active_down** – the partner port failed over to this port, but this port is down, e.g. cable missing.
- **active_failed** – the partner port failed over to this port, but the action failed, e.g. Fibre Channel switch did not have NPIV enabled.
For example, with 0:1:1 failing over to 1:1:1, port 0:1:1 has the FailoverState of failover_pending:

```
ACV-P7200-Proto cli% showport 0:1:1 1:1:1
N:S:P    Mode   State   -----Node_WWN-----   -Port_WWN/HW_Addr-   Type  Protocol   Label   Partner   FailoverState
0:1:1    target ready  2FF70002AC0008EB   20110002AC0008EB   host  FC        -      1:1:1     failover_pending
1:1:1    target ready  2FF70002AC0008EB   21110002AC0008EB   host  FC        -      0:1:1     active
```

Once the failover is complete, observe that 0:1:1 has the FailoverState as failed_over and 1:1:1 has the FailoverState of active:

```
ACV-P7200-Proto cli% showport 0:1:1 1:1:1
N:S:P    Mode   State   -----Node_WWN-----   -Port_WWN/HW_Addr-   Type  Protocol   Label   Partner   FailoverState
0:1:1    target ready  2FF70002AC0008EB   20110002AC0008EB   host  FC        -      1:1:1     failed_over
1:1:1    target ready  2FF70002AC0008EB   21110002AC0008EB   host  FC        -      0:1:1     active
```

If the path fails on 1:1:1, observe that 1:1:1 has the FailoverState as active_down:

```
ACV-P7200-Proto cli% showport 0:1:1 1:1:1
N:S:P    Mode   State   -----Node_WWN-----   -Port_WWN/HW_Addr-   Type  Protocol   Label   Partner   FailoverState
0:1:1    target ready  2FF70002AC0008EB   20110002AC0008EB   host  FC        -      1:1:1     failed_over
1:1:1    target ready  2FF70002AC0008EB   21110002AC0008EB   host  FC        -      0:1:1     active_down
```

### HP 3PAR Peer Persistence

HP 3PAR Peer Persistence software enables HP 3PAR StoreServ systems located at metropolitan distances to act as peers to each other, presenting a nearly continuous storage system to hosts and servers connected to them. This capability allows you to configure a high-availability solution between two sites or data centers where failover and failback remains completely transparent to the hosts and applications running on those hosts.

Compared to the traditional failover models where upon failover, the hosts must be restarted, the Peer Persistence software allows hosts to remain online serving their business applications even when they switch from their original site to the disaster-recovery (DR) site, resulting in a much improved recovery time. The Peer Persistence software achieves this key enhancement by taking advantage of the Asymmetric Logical Unit Access (ALUA) capability that allows paths to a SCSI device to be marked as having different characteristics.

The Peer Persistence software allows you to use both primary and secondary sites in an “active-active mode” thereby putting your secondary site to active use rather than just using it as an expensive insurance policy against disaster. It enables you to move your hosts from one site to another based on your business and performance needs without impacting the applications running on those hosts.

An example would be the use of vMotion within a VMware vSphere Metro Storage Cluster (vMSC). vMSC allows an ESXi cluster to span across data centers (Figure 9). In the figure, a few virtual machines (VMs) are being serviced by an HP 3PAR storage system on site 1 while other VMs are being serviced by another HP 3PAR storage system at site 2 located within metropolitan distance from site 1. vMotion allows customers to move VMs across sites.

As seen in Figure 9 each host is connected to each HP 3PAR StoreServ on both sites via redundant fabric. Additionally, each volume maintains a synchronous copy of itself at the other site. While a primary volume on site 1 is exported in a read/write mode, its corresponding secondary volume on site 2 is exported in a read-only mode.

For example, in the figure, Volume A (primary) and Volume A (secondary) are being exported to hosts on both the sites with a common WWN (LUN A.123). However, volume paths for a given volume are “active” only on the HP 3PAR StoreServ where the “primary” copy of the volume resides. In the figure, for Volume A (primary), the path is active on HP 3PAR StoreServ A on Site 1 whereas for Volume B (primary), the path is active on HP 3PAR StoreServ B on Site 2.

In a managed switchover scenario when hosts from Site 1 failover to Site 2, the paths marked passive for their secondary volumes become active and the hosts continue to access the same volumes (with the same WWN) as they were accessing prior to the failover. This transparent failover capability enabled by the Peer Persistence software protects customers from unplanned host and application outage.
However, under standard storage infrastructure, as the VMs move from site 1 to site 2, it forces presentation of new virtual volumes to those VMs, resulting into a forced reset of the VMs before continuing their operations.

The Peer Persistence software addresses this very limitation by presenting a VM with the "same" virtual volume even when it moves across data centers. In other words, movement of VMs across data centers becomes completely transparent to the applications those VMs are running.

- HP 3PAR Remote Copy is a prerequisite for Peer Persistence. The Peer Persistence software works with HP 3PAR Remote Copy synchronous mode only.
- The Peer Persistence license is required on both primary and secondary HP 3PAR StoreServ systems (just like HP 3PAR Remote Copy).
- For HP 3PAR StoreServ 7000 systems, the Peer Persistence is included in the Replication Suite while also being available as a separate title. For other supported HP 3PAR systems, Peer Persistence is available as a separate software title.

**Virtual Connect**

HP developed Virtual Connect technology to simplify networking configuration for the server administrator using an HP BladeSystem c-Class environment. The baseline Virtual Connect technology virtualizes the connections between the server and the LAN and SAN network infrastructure. It adds a hardware abstraction layer that removes the direct coupling between them. Server administrators can physically wire the uplinks from the enclosure to its network connections once, and then manage the network addresses and uplink paths through Virtual Connect software. Using Virtual Connect interconnect modules provides the following capabilities:

- Reduces the number of cables required for an enclosure, compared to using pass-through modules.
- Reduces the number of edge switches that LAN and SAN administrators must manage.
- Allows pre-provisioning of the network—so server administrators can add, replace, or upgrade servers without requiring immediate involvement from the LAN or SAN administrators.
- Enables a flatter, less hierarchical network, reducing equipment and administration costs, reducing latency and improving performance.
- Delivers direct server-to-server connectivity within the BladeSystem enclosure. This is an ideal way to optimize for East/West traffic flow, which is becoming more prevalent at the server edge with the growth of server virtualization, cloud computing, and distributed applications.
Without Virtual Connect abstraction, changes to server hardware (for example, replacing the system board during a service event) often result in changes to the MAC addresses and WWNs. The server administrator must then contact the LAN/SAN administrators, give them updated addresses, and wait for them to make the appropriate updates to their infrastructure. With Virtual Connect, a server profile holds the MAC addresses and WWNs constant, so the server administrator can apply the same networking profile to new hardware. This can significantly reduce the time for a service event.

The HP Virtual Connect 8Gb 20-port and HP Virtual Connect 8Gb 24-Port Fibre Channel modules offer enhanced Virtual Connect capabilities, allowing up to 128 virtual machines (20-port) and 255 virtual machines (24-port) running on the same physical server to access separate storage resources. The provisioned storage resource is associated directly to a specific virtual machine, even if the virtual server is re-allocated within the BladeSystem. Storage management of virtual machines is no longer limited by the single physical HBA on a server blade; SAN administrators can now manage virtual HBAs with the same methods and viewpoint of physical HBAs. The HP Virtual Connect Fibre Channel Modules simplify server connections by cleanly separating the server enclosure from SAN, simplify SAN fabrics by reducing cables without adding switches to the domain, and allow you to change servers in just minutes, not days.

Virtual Connect Flex-10 technology further simplifies network interconnects. Flex-10 technology lets you split a 10 GbE port into four physical function NICs (called FlexNICs). This lets you replace multiple, lower-bandwidth NICs with a single 10 GbE adapter. Prior to Flex-10, a typical server blade enclosure required up to 40 pieces of hardware (32 mezzanine adapters and 8 modules) for a full enclosure of 16 virtualized servers. Use of HP FlexNICs with Virtual Connect interconnect modules reduces the required hardware up to 50% by consolidating all the NIC connections onto two 10 GbE ports.

Virtual Connect FlexFabric adapters, broadened the Flex-10 capabilities by providing a way to converge network and storage protocols on a 10 GbE port. Virtual Connect FlexFabric modules and FlexFabric adapters can (1) converge Ethernet, Fibre Channel, or accelerated iSCSI traffic into a single 10 Gb data stream, (2) partition a 10 Gb adapter port into four physical functions with adjustable bandwidth per physical function, and (3) preserve routing information for all data types. Flex-10 technology and FlexFabric adapters reduce management complexity: the number of NICs, HBAs, and interconnect modules needed, and associated power and operational costs. Using FlexFabric technology lets you reduce the hardware requirements by 95% for a full enclosure of 16 virtualized servers—from 40 components to two FlexFabric modules.

The most recent Virtual Connect innovation is the ability to connect directly to HP 3PAR StoreServ Storage systems. You can either eliminate the intermediate SAN infrastructure or have both direct-attached storage and storage attached to the SAN fabric. Server administrators can manage storage device connectivity and LAN network connectivity using Virtual Connect Manager. The direct-attach Fibre Channel storage capability has the potential to reduce SAN acquisition and operational costs significantly while reducing the time it takes to provision storage connectivity.

**HP Fibre Channel Virtual Connect and HP 3PAR StoreServ Storage**

When using HP Fibre Channel Virtual Connect with HP 3PAR StoreServ Storage, the SAN fabric must be wired similar to Figure 10, with a minimum of two SAN cables per module and Virtual Connect SAN Profile, and up to eight (HP Virtual Connect 8Gb 24-Port Fibre Channel module) per module and Virtual Connect SAN profile.

**Figure 10.** Example of wiring from Virtual Connect to HP 3PAR StoreServ 7200 with SAN switches

In Figure 10 the connections from one interconnect, in this example bays 3 and 4, are all in the same SAN fabric and go to one SAN switch, and the other interconnect goes to the other SAN switch. It is not supported to have connections in the same Virtual Connect SAN fabric go to multiple fabrics, and doing so results in an error in Virtual Connect and your SAN definition in your server profiles will not function. A proper configuration looks similar to Figure 11 below, displaying both ports are healthy and connected to the same SAN fabric in each Virtual Connect SAN Fabric profile.
**Figure 11.** Example of proper SAN Fabric definitions in HP virtual Connect

**HP FlexFabric Virtual Connect and HP 3PAR StoreServ Storage**

When using HP FlexFabric Virtual Connect with HP 3PAR StoreServ Storage, the SAN fabric can be wired in several different ways. To get the best SAN and Network performance, a configuration similar to Figure 12 is recommended, with a minimum of two SAN cables per module and Virtual Connect SAN Profile. It is also possible with HP FlexFabric Virtual Connect to converge both SAN and network using only the LAN on motherboard (LOM). In this scenario, Figure 13, it is recommended that a minimum of two SAN cables per module and Virtual Connect SAN Profile, four maximum, be used.

**Figure 12.** Example of wiring using four HP FlexFabric Virtual Connect modules to an HP 3PAR StoreServ 7200 with SAN switches

![Wiring Diagram](image1)

**Figure 13.** Example of wiring using two HP FlexFabric Virtual Connect modules to an HP 3PAR StoreServ 7200 with SAN switches

![Wiring Diagram](image2)

It is also possible to directly connect HP 3PAR StoreServ to HP FlexFabric Virtual Connect modules and not need the added cost of SAN switches. It is still recommended that a minimum of two SAN cables per module and Virtual Connect SAN Profile, four maximum, be used. However, you can run connections from the same HP FlexFabric Virtual Connect module to separate controllers (Figure 14).
Summary

When configuring an HP 3PAR StoreServ Storage for use in a VMware vSphere environment, it is important to follow the recommendations for the maximum number of host server HBA ports per HP 3PAR StoreServ Storage target ports, 32 host initiators per 8Gb port, and zoning by HBA to allow coexistence with other HP Storage arrays. Creating a resilient and easy to manage VMware vSphere cluster is simple by leveraging 3PAR Persistent Ports for additional redundancy for non-disruptive maintenance and upgrades as well as utilizing Virtual Connect for ease of server, storage and network administration.

Overview and configuration of VMware vSphere Storage API Integration

HP and VMware deliver advanced integration between HP 3PAR StoreServ Storage and VMware vSphere 5 with vSphere Storage APIs for Storage Awareness (VASA) and vSphere Storage APIs for Array Integration (VAAI). This section will provide an overview of the APIs as well as how to configure and leverage them.

VAAI

The vSphere Storage APIs are a set of technologies and interfaces that enable vSphere to leverage storage resources to deliver the efficiency, control, and ease of customization that clients demand of their virtual environment. The vSphere Storage APIs for Array Integration (VAAI) is one of these technologies. Under the VAAI initiative, APIs have been introduced to improve performance, resource utilization, and scalability by leveraging more efficient array-based operations.

HP developed the HP 3PAR Management Software Plug-In for VMware VAAI to deliver enhanced performance, agility, and scalability using vSphere commands first introduced in vSphere 4.1. Initial support of the SCSI (T10) standard was introduced in vSphere 4.1 through the use of block level commands. These standard commands were enabled by a standard VMware plug-in which enabled Hardware Assisted Locking, Fast Copy, and Block Zeroing.

vSphere 5 provides enhanced support for the T10 standards without the need to install a plug-in, enabling vSphere to directly utilize more advanced features of the storage array. With other storage arrays, including HP 3PAR StoreServ Storage before the release of HP 3PAR OS version 3.1.1, that do not natively support the T10 SCSI standard, a VAAI plug-in is needed to use the VAAI capabilities VMware offers. To manage a VAAI capable device, your host attaches the VAAI filter and vendor-specific VAAI plug-in to the device. Because of the native T10 support built into HP 3PAR OS 3.1.1 and greater, this is not needed and as a result your ESXi host can communicate directly to HP 3PAR StoreServ Storage and does not require the VAAI plug-ins.

Some of the important hardware primitives that VAAI enables are documented below:

**Hardware Assisted Locking** eliminates SCSI reservation contention by providing a fast, fine-grained locking mechanism. The ATS ("Atomic Test and Set") command verifies that a block of metadata is what is expected (test) and then replaces it with an updated block (set) in a single, atomic operation. Using this command, the ESXi host can lock a portion of a LUN related to a single VM instead of locking the whole LUN as seen in Figure 15, thereby allowing other VMs on the same LUN to continue operating normally. The implementation of ATS on HP 3PAR StoreServ Storage arrays uses the HP 3PAR StoreServ ASIC to further improve performance. The combination of ATS and the HP 3PAR StoreServ ASIC allows an increase in VM density per LUN and greater scalability for vSphere deployments.
Figure 15. Diagram representing old method before VAAI on the left and hardware-assisted locking method available with VAAI on the right.

Fast Copy uses the XCOPY command to improve the performance of common storage operations like VM cloning and Storage vMotion by performing large data movement operations directly within the storage array. By not requiring each block to make a round-trip to the host, the time required for these operations is significantly reduced and storage network traffic minimized. When combined with HP 3PAR Thin Persistence Software, drive I/O and storage capacity can also be reduced since blocks of zeros are not written due to the array’s Zero Detect capability, which is integrated into the HP 3PAR StoreServ ASIC.

Block Zeroing uses the standard SCSI command WRITE_SAME to offload large, block-level write operations of zeros from the host to the storage array. Block zeroing improves host performance and efficiency when allocating or extending Eager Zeroed Thick (EZT) virtual disks, or on initial access to a block on a non-EZT virtual disk. When combined with built-in Zero Detect and EZT virtual disks, storage array bandwidth, disk I/O bandwidth, and disk consumption is minimized. Initializing EZT virtual disks in seconds rather than minutes eliminates the tradeoff between fast VM creation and more predictable run-time performance.

For more information on VMware vSphere VAAI and HP 3PAR storage, please see the VMware vSphere VAAI for HP 3PAR Storage performance benefits technical paper for more information:


VASA

The vSphere Storage APIs for Storage Awareness (VASA) is a set of APIs introduced with vSphere 5 that enables VMware vCenter Server to detect the capabilities of the storage array LUNs and their datastores. This visibility into the array’s configuration of its datastores and their capabilities, simplifies vSphere administration with HP 3PAR StoreServ Storage. Capabilities such as RAID level, thin or thick provisioned, device type (SSD, Fast Class, or Nearline) and replication state can now be made visible from within vCenter Server’s disk management interface. This allows vSphere administrators to select the appropriate disk for virtual machine placement based on its needs. VASA eliminates the need for maintaining complex spreadsheets detailing the storage capabilities of each LUN previously required to guarantee the correct Service Level Agreement (SLA).

The concept of a storage profile, introduced in vSphere 5, extends the base VASA functionality. These profiles are used in conjunction with the capabilities of the LUN to determine which LUNs meet the needs of a VM. vSphere 5 can use this information to migrate virtual machines between LUNs for load balancing using Storage Distributed Resource Scheduler (DRS) while maintaining the storage performance and availability needs (RAID level, etc.) of the virtual machine. These profiles also allow vSphere to make placement decisions automatically based on the needs of the VM and the available datastores, further reducing the administration impact.

Beginning with vSphere 5, the HP 3PAR Management Software Plug-In for VMware vCenter also includes a vSphere Storage APIs for Storage Awareness (VASA) plug-in which allows vSphere to display detailed (device type, RAID level, etc.) information on the 3PAR LUNs directly from within the vSphere Client. You can read more about the HP 3PAR Management Software Plug-In for VMware vCenter which leverages VMware’s VASA capabilities in the HP 3PAR Management Software Plug-In for VMware vCenter section below.
Configuring HP VMware vCenter Server integration

HP 3PAR Management Software Plug-In for VMware vCenter

The HP 3PAR Management Software Plug-in for VMware vCenter is a plug-in that allows easy identification of HP 3PAR StoreServ virtual volumes used by VMs and datastores. It provides an integrated view of the VMs and associated storage resources. Properties such as volume type (Thick or Thin Provisioned Virtual Volume (TPVV)), device type (FC disk, NL disk, or SSD), RAID level, etc. are displayed via the 3PAR tab in the vSphere Client.

The HP 3PAR Management Software Plug-In for VMware vCenter provides the VMware administrator a view into the HP 3PAR StoreServ Storage via a single pane (Figure 16). There is no need to login to the storage array to identify space consumption or determine how a volume maps to a datastore. This information is easily visible via the plug-in, as is capacity usage, allocation limits, and other data. This information can then be used to define storage profiles ensuring the storage meets the needs of the virtual machine.

Figure 16. Viewing virtual volume mapping information via the HP 3PAR plug-in

HP 3PAR Recovery Manager Software for VMware vSphere

HP 3PAR Recovery Manager Software for VMware vSphere enables the protection and rapid recovery of VMs and datastores. It provides virtual copy management and allows the administrator to take LUN-level snapshots of VMs and datastores via the vSphere Client. HP 3PAR Recovery Manager Software provides array-based snapshots that are fast, space-efficient, and VM-aware. This plug-in solves the issues associated with traditional, agent-based backup schemes that are typically slow, complex, and fail to offer the flexibility and granularity that array-based snapshots can provide.

HP 3PAR Recovery Manager Software makes it possible to create hundreds of virtual copies. The number of virtual copies to retain and the retention period for each virtual copy can easily be specified. Once a virtual copy has been created, this plug-in allows the flexibility of granular restores at the VMFS layer, the VM layer, or the individual file level.

For more detailed information on the HP 3PAR Management Software Plug-In for VMware vCenter see http://h18006.www1.hp.com/storage/software/3par/mpvs/index.html and for HP 3PAR Recovery Manager Software for VMware vSphere, see http://h18006.www1.hp.com/storage/software/3par/rms-vsphere/index.html.

HP 3PAR Replication Adapter Software for VMware vCenter SRM

VMware vCenter Site Recovery Manager (SRM) provides end-to-end management of array-based replication, virtual machine failover, and automated disaster recovery management for environments that use VMware vCenter Server. HP 3PAR Replication Adapter Software for VMware vCenter SRM was developed to provide integration between VMware vCenter Site Recovery Manager (SRM) and HP 3PAR Remote Copy Software.
HP 3PAR Storage Replication Adapter (SRA) Software for VMware vCenter Site Recovery Manager (SRM) integrates VMware SRM with HP 3PAR Storage and replication software to provide a complete and integrated Business Continuity solution. The solution offers centralized management of recovery plans, non-disruptive testing, and automated site recovery, failback and migration processes. The HP 3PAR SRA software combines HP 3PAR Remote Copy Software and HP 3PAR Virtual Copy Software with VMware SRM to ensure the highest performing and most reliable disaster protection for all virtualized applications.

**HP Insight Control Storage Module for vCenter**

The HP Insight Control Storage Module for vCenter is an HP-developed plug-in to VMware’s vCenter management console. It enables VMware administrators to view the relationships between VMs, datastores and the storage arrays, and manage them directly from the vSphere Client or the new vSphere Web Client. It supports active management for HP 3PAR StoreServ arrays, including the ability to perform storage provisioning operations such as adding a new datastore, deleting or expanding an existing datastore, creating new VMs from a template, and cloning existing VMs. Figure 17 shows the storage details displayed by the Storage Module for one of the VMware datastores.

**Figure 17.** HP Insight Management storage details for datastore

<table>
<thead>
<tr>
<th>Summary</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issues</td>
<td>Performance</td>
</tr>
<tr>
<td>Datastore/MDR</td>
<td>Tasks...</td>
</tr>
</tbody>
</table>

**Figure 18.** Expand datastore using HP Insight Management Storage Module

HP Insight Management Storage Module allows a VMware administrator to create, delete or expand a datastore from the vSphere Web Client. Figure 18 shows an example of expanding a datastore by right clicking on the datastore, selecting All HP Insight Management Actions and then selecting HP Expand Datastore.

The latest version of the HP Insight Control Storage Module for vCenter may be downloaded from: https://h20392.www2.hp.com/portal/swdepot/displayProductInfo.do?productNumber=HPVPR
Summary

With the advanced integration that exists between HP 3PAR StoreServ Storage and VMware vSphere 5's VASA and VAAI technologies, HP 3PAR StoreServ storage can be managed from a single pane of glass with the HP 3PAR Management Software Plug-In for VMware vCenter and HP 3PAR Recovery Manager Software for VMware vSphere. In addition to managing the HP 3PAR array itself, an administrator can also get insight into how virtual machines are mapped to datastores and individual disk volumes, as well as create and manage both datastores and virtual machines with HP Insight Control Storage Module for vCenter. Lastly, the combination of HP 3PAR Remote Copy and VMware vCenter Site Recovery Manager lets customers build resilient utility computing infrastructures, protect applications at a lower cost, and recover data more quickly and efficiently compared to traditional disaster recovery offerings.

Thin provisioning

HP 3PAR Thin Provisioning allows for creating Thinly-Provisioned Virtual Volumes (TPVVs) as an alternative to fully-provisioned volumes. A TPVV uses logical disks (LD) that belong to a logical disk pool, or the Common Provisioning Group (CPG).

All TPVVs associated with the same CPG draw user space from a shared LD pool as needed and are allocated on demand in one chunklet increments, either 256 MB for HP 3PAR F-Class and T-Class, or 1 GB for HP 3PAR StoreServ 10000 and 7000, per controller node. As the volumes that draw space from the CPG require additional storage, the system automatically creates additional logical disks and adds them to the pool until the CPG reaches the user-defined growth limit that restricts the CPG's maximum size. The maximum TPVV volume size limit is 16 TB. These allocations are adaptive since subsequent allocations are based on the rate of consumption for previously allocated space. For example, if a TPVV is initially allocated 256 MB per node but then consumes that space in less than sixty seconds, the next allocation becomes 512 MB per node. However, if the initial 256 MB per node is consumed more slowly, the next allocation increment remains at 256 MB per node. Under this provisioning scheme, the maximum allocation increment is 1 GB per controller node supporting the TPVV.

As the TPVV reaches either its exported size or its user-defined allocation limit, the system allows for allocation of an additional 128 MB per node beyond these limits in order to ensure that the exported TPVV address space is usable. With VMware vSphere 5, HP 3PAR Thin Provisioning simplifies management by allowing creation of large VMFS datastores without impacting VM performance, while also increasing ROI by not having to pay for more storage than actually used. For more information on performance enhancements with HP 3PAR StoreServ, refer to the VAAI section in this document. For more information on using HP 3PAR Thin Provisioning and/or VMware Thin Provisioning, refer to the HP 3PAR Thin Provisioning vs. vSphere Thin Provisioning section in this document.

HP 3PAR Thin Provisioning vs. vSphere Thin Provisioning

When implementing HP 3PAR StoreServ TPVVs, administrators often ask whether implementing vSphere Thin Provisioning for VMDK files makes any sense. In general, Thin Provisioning with HP 3PAR StoreServ and vSphere accomplish the same end-result, albeit at different logical layers. With VMware vSphere Thin Provisioning, administrators realize greater VM density at the VMFS layer, at the cost of some CPU and disk I/O overhead as the volume is incrementally grown on the ESXi hosts. By implementing HP 3PAR StoreServ TPVVs, the same VM density levels are achieved, however the thin provisioning CPU work is offloaded to the HP 3PAR StoreServ ASIC. If the goal is to reduce storage costs, maximize storage utilization, and maintain performance, then use HP 3PAR Thin Provisioning Software to provision VMFS volumes. If performance is not a concern but over-provisioning VMs at the VMFS layer is important, then administrators can consider implementing both Thin Provisioning solutions. However, administrators should realize that there are no additional storage savings realized by using VMware Thin Provisioning on top of 3PAR TPVVs and in fact, implementing both solutions adds more management complexity to the environment. For a better understanding of the performance tradeoffs implementing both Thin Provisioning solutions, see the Virtual SCSI adapters and virtual disk types topic in the Performance tuning section of this document.

Configuring

As previously discussed, when implementing HP 3PAR Thin Provisioning, LDs are added on demand to a CPG allowing storage allocation as required to all the TPVVs associated with the CPG. CPGs provide the dynamic framework to balance storage utilization and performance with Thin Provisioning. However, it is imperative that growth increments be adaptive to the CPG characteristics and monitored to meet workload demand. To accomplish this, define and use different CPGs for differing service qualities. For example when using RAID 1 or RAID 6 VVs leveraging Nearline (NL), Fast Class (FC) and Solid State Disk (SSD), use different CPGs for VVs for where it is desirable to use different disks to minimize interaction with each other for performance or availability reasons, for example to separate databases and their transaction logs. It is also imperative that you continue to define, set, and monitor CPG growth warnings and growth limits over time to ensure you do not over allocate your physical resources or run out of space in your CPGs.
Note
Proper planning and monitoring is required when using TPVV as it is possible to set the growth warnings or limits to exceed the amount of available storage on a system. If a TPVV associated with a CPG consumes all available system space, new writes will fail and/or snapshot volumes associated with the CPG may become invalid or stale. Under these conditions, some host applications will not handle write failures gracefully and may produce unexpected failures.

When creating a CPG, whether using thin or thick provisioning, the growth increment should be as small as possible to minimize the amount of growth space. For optimal performance, the CPG's growth increment needs to be tuned to evenly distribute LDs across all HP 3PAR StoreServ Storage System Physical Disks (PDs) per CPG policy.

For a better understanding of CPG growth increments and the benefits of properly sizing them, take note of Figure 19 and note the following:
- The default CPG has 8 LDs compared to 4 for the tuned CPG.
- The default CPG's LDs are unevenly allocated to PDs (size MB) when compared with the tuned CPG's evenly sized LDs.
- The default CPG row size (RowSz) is smaller/not balanced when compared to the tuned CPG; keeping in mind larger row sizes are a best practice in themselves.

Figure 19. Default vs. Tuned LD distribution on disk

Please see Table 2 for an illustration of the impact on physical disks in both test scenarios.

Table 2. StatPd Comparison – Default vs. Tuned Auto Growth

<table>
<thead>
<tr>
<th>StatPd (write service time)</th>
<th>RAID5 TPVV Default</th>
<th>RAID5 TPVV Tuned</th>
<th>StatPd (PD Max)</th>
<th>RAID5 TPVV Default</th>
<th>RAID5 TPVV Tuned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milliseconds (95\textsuperscript{th} pct)</td>
<td>SSZ4 Default</td>
<td>SSZ4 Tuned</td>
<td>Milliseconds</td>
<td>SSZ4 Default</td>
<td>SSZ4 Tuned</td>
</tr>
<tr>
<td>5ms</td>
<td>0</td>
<td>1</td>
<td>&gt;20 &lt;50ms</td>
<td>31</td>
<td>14</td>
</tr>
<tr>
<td>6ms</td>
<td>68</td>
<td>107</td>
<td>&gt;50 &lt;100ms</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>7ms</td>
<td>113</td>
<td>115</td>
<td>&gt;100 &lt;200ms</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>8ms</td>
<td>49</td>
<td>21</td>
<td>&gt;200ms</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>9ms</td>
<td>15</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10ms</td>
<td>6</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11ms</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>12ms</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
The tuned RAID 5 TPVV achieves usage of approximately 87% of all PDs with less than 7ms write service time. However, the PDs in the untuned TPVV are only capable of using 70% of the available PDs with less than 7ms write service time. More dramatic is the number of ‘hot disks’ in the default CPG, with over 10% recording over 50ms write service times (3.5% >200ms) compared with 6% (0% >200ms) in the tuned CPG. See Table 3 for both default and minimum CPG growth increments.

Table 3. CPG Growth Increments

<table>
<thead>
<tr>
<th>Number of Nodes</th>
<th>Default</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>32G</td>
<td>8G</td>
</tr>
<tr>
<td>3-4</td>
<td>64G</td>
<td>16G</td>
</tr>
<tr>
<td>5-6</td>
<td>96G</td>
<td>24G</td>
</tr>
<tr>
<td>7-8</td>
<td>128G</td>
<td>32G</td>
</tr>
</tbody>
</table>

The optimal CPG growth increment depends on several factors, including but not limited to the following:

- Total physical drives per node pair
- Number of system nodes
- RAID type
- Drive type (FC, NL, SSD)

Growth Increment explained: A 64 GB growth increment using RAID1 (set size = 2) on a 4 node system will distribute 16 chunklets per node, or 32 mirrored chunklets per node. This assumes all PDs are evenly distributed across all nodes. For a 4 node system with 128 PDs, this CPG growth increment would be optimal, resulting in allocation of LDs across all available PDs (32 mirrored chunklets per node x 4 nodes = 128 chunklets on disk). The same 64GB growth increment using RAID5 (set size = 3) would use the same 16 chunklets per node, but instead would require an additional 8 parity chunklets for 24 in total per node. In this scenario, the newly allocated LD would be striped across 96 PDs (24 chunklets x 4 nodes = 96 chunklets on PD), leaving 32 PDs unused. Ideally, this RAID5 CPG should be created with a growth increment of 87380MB which with parity overhead (2D+1P or 87380MB + 43690MB = 131070MB/1024MB = 128), which would allocate LDs across all 128 PDs.

CGP Auto-Grow Calculation

\[ \text{CGP Auto-Grow Calculation} \]

\[
\frac{(\text{PDs} - (\text{Node\_PDs}/\text{SSZ}*\text{Nodes}))/(\text{Nodes}*\text{Chunklet\_Size})}{\text{Nodes}}
\]

For best storage performance, HP recommends that CPGs be tuned based upon number of physical drives, RAID type, and drive type for well-balanced and efficient disk utilization and system performance.

Beyond aligning growth increments with available PDs and RAID type, for best performance, scheduling regular CPG compactions is recommended. CPG compaction allows for capacity allocated to a CPG not currently in use to be returned to the pool of free chunklets. This activity should be scheduled during low activity periods to minimize the performance impact of chunklet initialization (zeroing) which happens automatically when chunklets are freed.

**Tech tip**

You can schedule regular compaction of CPGs with the `createsched` command

```
% createsched compactcpg <CPG_name> <taskschedule> <schedname>
```

The following example will perform a compactcpg every Saturday at 2:00 A.M.

```
% createsched compactcpg CPG_FC_15K_RAID5 "0 2 * * 6"
```

For more information refer to the HP 3PAR OS Command Line Interface Reference guide or run “help createsched” from the CLI.
To ensure maximum performance and optimal reliability in the volumes supported by the logical disks created from a CPG, CPGs should use cage availability, which is the default if available. If cage availability is not available, then magazine availability should be used. Leveraging cage or magazine availability ensures that chunklets in the same row, RAID set or set size, are from different physical disks. This ensures that a physical disk failure, in magazine availability, or a single cage full of disks in cage availability, does not cause loss of data. The system should use as many physical disks as possible and the load on all physical disks should be balanced. Lastly, provision a virtual volume’s user space and snapshot space from different CPGs. If the virtual volume’s user and snapshot space are on different CPGs, the user space remains available to the host if the CPG containing the snapshot space becomes full.

When creating VMs, there are a number of options that are available for the VMDK files. VMware vSphere creates VMs using the “Lazy Zeroed Thick” option by default. With this option, when a new VM is created, the full size of the VMDK is not immediately zeroed. Instead, zeros are returned upon reads from unwritten areas, but not actually backed by physical storage until actual write operations. For performance-intensive environments and security concerns, VMware recommends using “Eager Zeroed Thick” (EZT) virtual disks. EZT disks have the smallest overhead but require zeros to be written across all of the capacity of the VMDK at the time of creation. Unlike many other storage vendors, HP 3PAR Thin Persistence Software and HP 3PAR Zero Detect enabled virtual volumes allow clients to retain the thin provisioning benefits when using Eager Zeroed Thick VMDKs without sacrificing any of the performance benefits offered by this VMDK option. Please see the Virtual SCSI adapters and virtual disk types section of this document for a comparison of the available disk types with VMware vSphere 5.

**HP 3PAR Thin-to-Fat and Fat-to-Thin Conversion**

In previous releases of the HP 3PAR OS, customers had to perform an offline transition in order to change the provisioning attributes of a volume. This used the legacy physical copy technology where upon completion of the copy, all the VLUNs and applications had to be manually moved from the old VV to the new one. With HP 3PAR OS 3.1.2 you now have the ability with HP 3PAR Thin-to-Fat and Fat-to-Thin Conversion to convert from a thin-provisioned volume to a fully-provisioned volume (or vice versa) without requiring an offline transition. Fat-to-thin saves space for volumes that are sparsely consumed VMware datastores while thin-to-fat saves on thin provisioning license usage for data stores that are currently thin provisioned volumes and mostly or completely allocated.

**HP 3PAR Thin Persistence Software**

HP 3PAR Thin Persistence Software is an optional feature that keeps TPVVs and read/write snapshots of TPVVs small by detecting pages of zeros during data transfers and not allocating space for those pages. This feature works in real-time and analyzes the data before it is written to the source TPVV or read/write snapshot of the TPVV. Freed blocks of 16 KB of contiguous space are returned to the source volume and freed blocks of 128 MB of contiguous space are returned to the CPG for use by other volumes.

Thin Copy Reclamation Software, which is included with every HP 3PAR StoreServ Storage system, reclaims space when snapshots are deleted from a system. As snapshots are deleted, the snapshot space is reclaimed from a Thinly-Provisioned Virtual Volume (TPVV) or fully-provisioned virtual volume and returned to the CPG for reuse by other volumes. Deleted snapshot space can be reclaimed from virtual copies, physical copies, or remote copies. The HP 3PAR OS automatically reclaims snapshot space if the Virtual Copy, Remote Copy, or Thin Provisioning license is enabled.

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**Note**

Reclaiming space when snapshots are deleted with the Thin Copy Reclamation feature requires the Virtual Copy, Remote Copy, or Thin Provisioning license.

---

**HP 3PAR Zero Detect**

Zero Detect is currently enabled by default in HP 3PAR OS 3.1.2. In previous versions of the HP 3PAR OS, it was disabled by default. It is a best practice to enable zero detect on TPVVs and thus why it is enabled by default. Zero Detect can be disabled by using the “Advanced options” checkbox of the 3PAR Management Console when creating a TPV. Zero Detect enables Thin Persistence and achieves space reclamation. For example, when an administrator deletes a VMDK file on an HP 3PAR TPVV the HP 3PAR StoreServ ASIC detects those zeros as the same pattern (SCSI write_same). Those blocks having been earlier utilized triggers HP 3PAR Thin Persistence reclamation of those blocks and releases them back to the CPG. Thin persistence can reclaim space in chunks of 128MB of contiguous unused or zero-filled space on the LD. Please see Figure 20 below and take note of approximately 80GB total space reclaimed.
Summary

HP 3PAR Thin Provisioning Software increases storage system efficiency and optimizes capacity utilization. It does this by addressing the problem of capacity over-allocation through eliminating the need to dedicate storage capacity up-front. HP 3PAR Thin-to-Fat and Fat-to-Thin Conversion allows conversion from a thin-provisioned volume to a fully-provisioned volume (or vice versa) without requiring an offline transition and enabling the Storage Administrator to properly manage space and thin provision licensing usage. HP 3PAR Thin Persistence Software and HP 3PAR Zero Detect ensure that thin volumes on HP 3PAR StoreServ Storage systems stay as lean and efficient as possible by reclaiming unused space associated with deleted data.

HP 3PAR StoreServ Adaptive Optimization

Tiered storage is a data storage environment consisting of two or more kinds of storage, typically identified by the following characteristics:

- Tier 0 – Low capacity / High IOPS tier (Usually Solid State Drives (SSD) drives)
- Tier 1 – Mid-capacity / Mid IOPS tier (Usually Fast Class (FC) drives)
- Tier 2 – High capacity / Low IOPS tier (Usually Nearline (NL) drives)

With tiered storage, administrators can assign different classes of storage to different workloads in their environments based on protection levels, performance requirements, and frequency of access. With both HP 3PAR StoreServ and VMware vSphere storage assignments can be both manual and automated functions and based upon company defined storage policies. The benefit of tiered storage for storage consumers are reduced costs, by moving idle storage to lower cost tiers, and greater performance by rapidly migrating frequently accessed data to the higher performing storage tiers. The following sections will provide an overview of the options available in an HP 3PAR StoreServ and VMware vSphere 5.0 environment.

Dynamic and Adaptive Optimization on HP 3PAR StoreServ

HP 3PAR StoreServ Dynamic Optimization and Adaptive Optimization software are optional features that allow storage administrators to seamlessly migrate data between storage tiers in their environment without interrupting data access. With HP 3PAR StoreServ Dynamic Optimization, users can manually and non-disruptively alter service levels associated with a storage volume by RAID level, subsystem failure protection level, drive type, stripe width, and/or radial placement to take greater advantage of storage resources. For example, when a system is upgraded by adding nodes, cages, or physical disks, the initial volume and logical disk layouts may no longer be optimal for the new system configuration. Updating the system layout with Dynamic Optimization optimizes the use of all physical resources in the system at a given time.

HP 3PAR StoreServ Adaptive Optimization Software takes the capabilities of HP 3PAR StoreServ Dynamic Optimization to another level by taking an autonomic, fine-grained, and highly automated approach to service level optimization. HP 3PAR StoreServ Adaptive Optimization uses policy-driven, granular data movement, providing highly reliable, non-disruptive, cost-optimized storage tiering at the sub-volume level to deliver the right Quality of Service to the right data at the right time on a large scale. Figure 21 shows how HP 3PAR StoreServ Adaptive Optimization uses chunks of every tier in an HP 3PAR StoreServ array to ensure the best performance and cost effectiveness of the array.
For further details on Adaptive Optimization, please see the following:

**VMware Storage DRS**

VMware Storage DRS is a new Datastore Cluster object in vSphere 5.0 giving users the capability to automate provisioning and maintenance of virtual machines on tiered storage resources. Users of VMware have grown accustomed to the many benefits of host clusters. With VMware Storage DRS, users can now aggregate storage resources yielding similar high availability and performance functionality. VMware Storage DRS provides both initial and ongoing placement recommendations of virtual machine and virtual disk drives based on capacity and I/O workloads.

For further details on Storage DRS, please see the following:
http://www.vmware.com/technical-resources/virtualization-topics/virtual-storage/storage-drs.html

For an implementation overview of Storage DRS, please see the following:
http://www.vmware.com/resources/techresources/10286

**HP 3PAR StoreServ tiered storage features**

**HP 3PAR StoreServ Dynamic Optimization**

HP 3PAR StoreServ Dynamic Optimization is an optional and licensed feature that analyzes the entire storage system and automatically analyzes and corrects virtual volume and physical disk capacity imbalances for optimal performance. HP 3PAR StoreServ Dynamic Optimization is part of HP 3PAR OS and does not require separate installation. Once initiated, Dynamic Optimization's automated tuning process has three phases:

1. Analyze the system and detect virtual volumes which are not correctly balanced between nodes. If virtual volumes are not balanced correctly, the volumes are tuned to correct the imbalance.
2. Analyze the system and detect any chunklet imbalance between physical disks associated with the same node. After the analysis, chunklets are moved from overused physical disks to under used physical disks associated with the same node.
3. Analyze the system and verify that logical disks associated with a CPG have the same characteristics as the CPG. If the logical disk characteristics do not match the CPG, the logical disk is modified to match the CPG characteristics.

Dynamic Optimization tasks can be performed with both the HP 3PAR StoreServ Command Line Interface and the HP 3PAR StoreServ Management Console. Users can reference the HP 3PAR StoreServ CLI Administrator’s Manual and the HP 3PAR StoreServ Management Console Online Help for instructions on how to administer Dynamic Optimization tasks.
HP 3PAR StoreServ Adaptive Optimization

Beginning with HP 3PAR OS version 3.1.2, a new On-Node HP 3PAR StoreServ Adaptive Optimization implementation has been released that runs entirely on the HP 3PAR StoreServ system. This enhanced design replaces the previous implementation whereby a separate HP 3PAR StoreServ System Reporter installation was required for data collection used by HP 3PAR StoreServ Adaptive Optimization processes. This data collection provides historical statistical data characterizing the HP 3PAR StoreServ workloads, which is then analyzed to determine optimal placement of data regions between tiered storage on the system. Also with the new implementation it is now possible to reduce licensing cost by eliminating the separate database requirement and Microsoft Windows Server for System Reporter if the only use for it was for Adaptive Optimization.

Note

In the HP 3PAR OS 3.1.2 release only the data needed for HP 3PAR StoreServ Adaptive Optimization has been moved from HP 3PAR System Reporter and moved onto the HP 3PAR StoreServ system nodes. HP 3PAR StoreServ System Reporter is still needed to view historical performance and utilization data.

It is also no longer possible to use and configure HP 3PAR StoreServ System Reporter for Adaptive Optimization. The only place that Adaptive Optimization can be configured with an HP 3PAR OS 3.1.2 based array is via the HP 3PAR StoreServ Management Console or CLI.

On-Node Adaptive Optimization provides several customer benefits over previous HP 3PAR StoreServ Adaptive Optimization implementations. First, Adaptive Optimization configuration is now managed directly via the HP 3PAR CLI and/or Management Console interfaces eliminating the need for a separate HP 3PAR StoreServ System Reporter for Adaptive Optimization use. The region movement data of System Reporter is now embedded into the HP 3PAR StoreServ system. Due to this implementation, Adaptive Optimization functionality now has built-in clustered node redundancy which was never possible before with the separate HP 3PAR StoreServ System Reporter implementation.

There are also several enhanced algorithms provided with HP 3PAR StoreServ Adaptive Optimization:

- Ability to define measurement/sampling intervals used to determine region movements
- Ability to define maximum Adaptive Optimization run time (minimum=1 hour)
- Ability for a single Adaptive Optimization run to iterate through successive region move passes
- Finer user control over CPG compaction (trim (remove unused logical disk space), auto (trim and region moves), or none)
- More efficient sample analysis consuming less time and system overhead
- No Adaptive Optimization configuration size limit

With on-node Adaptive Optimization, active configurations can be either scheduled or manually initiated to analyze statistical data gathered by the on-board System Reporter data collector processes. As with previous implementations of HP 3PAR StoreServ Adaptive Optimization, all virtual volumes in each defined CPG are automatically included in Adaptive Optimization analysis for region movement. If space and IOPS on the destination CPG permit, heavily used (high I/O) regions will be moved to a higher tier, and lightly or not used regions will be moved to a lower tier.

Region movement can be biased using one of 3 settings:

- Performance – move as much data as possible to higher tiers
- Cost – move as much data as possible to lower tiers
- Balanced – do not aggressively move between tiers

Adaptive Optimization can be configured with four easy steps:

1. Ensure the HP 3PAR StoreServ array has the proper licensing for Adaptive Optimization.
2. Define a minimum of two CPG tiers per Adaptive Optimization configuration specification.
3. Create an AO Configuration via the HP 3PAR StoreServ Management Console or CLI.
4. Schedule Adaptive Optimization to perform the analysis and tier movement.

Note

Adaptive Optimization requires a minimum of 3 hours data collection before effectively moving data regions between tiers
Adaptive Optimization tasks can be performed with both the HP 3PAR OS Command Line Interface and the HP 3PAR Management Console. Users can reference the HP 3PAR OS CLI Administrator’s Manual and the HP 3PAR StoreServ Management Console Online Help for instructions on how to administer Adaptive Optimization tasks.

**Best practice recommendations**

Any of the following physical disk combinations in Table 4 within the same Adaptive Optimization configuration policy are acceptable. However, 3-tier disk performance offers the best storage utilization, performance, and management benefits.

**Table 4. Examples of acceptable Adaptive Optimization configurations**

<table>
<thead>
<tr>
<th>Tier 1</th>
<th>Tier 2</th>
<th>Tier 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSD</td>
<td>FC</td>
<td>NL</td>
</tr>
<tr>
<td>SSD</td>
<td>FC</td>
<td></td>
</tr>
<tr>
<td>FC</td>
<td>NL</td>
<td></td>
</tr>
<tr>
<td>SSD</td>
<td>FC 15K RAID 1</td>
<td>FC 10K RAID 6</td>
</tr>
<tr>
<td>FC 15K RAID 1</td>
<td>FC 10K RAID 6</td>
<td>NL</td>
</tr>
</tbody>
</table>

As a general rule, the following Disk/RAID/Volume/CPG configuration recommendations should be observed with HP 3PAR StoreServ Adaptive Optimization:

- Plan and test Adaptive Optimization policies if using different RAID levels per configuration so that anticipated data movement between tiers is achieved. The maximum service times value (maxScvtms) helps determine if a tier can tolerate additional workload and is one of several factors used in determining region movement between tiers. For example, if Adaptive Optimization algorithms calculate that Tier-1 below is exceeding its set service maximums of 40msec during the preset measurement interval, no regions will migrated from either tiers 0 or 2 during that scheduled optimization run.
  - Tier-0, R1_SSD (15 msec)
  - Tier-1, R1_FC (40 msec)
  - Tier-2, R1_NL (60 msec)

**Note**

Use maxScvtms(disk_type) * raidSvctFactor(raid) to calculate max service time algorithm triggering data movements between tiers:

```
maxScvtms(SSD) 15; maxScvtms(FC) 40; maxScvtms(NL) 60
raidSvctFactor(0&1) 1.0; raidSvctFactor(5) 1.5; raidSvctFactor(6) 2.0
```

- When using Thin Provisioning volumes with Adaptive Optimization, select a single CPG user space from which to provision volumes.
- Ensure the default tier has enough capacity and performance to accommodate the requirements of new applications until data is migrated to other tiers.
- All CPGs used in an Adaptive Optimization configuration should have the same level of availability (Magazine/Port/Cage). Using a CPG with “Magazine level” availability in an Adaptive Optimization configuration with CPGs at “Cage level” availability renders all virtual volumes effective availability equivalent to “Magazine level”.
- It is recommended not to set any capacity limits on the Adaptive Optimization configuration level, or on the CPG (no allocation warning or limit). This will allow Adaptive Optimization to make the best use of the different tiers available in the system.
- Do not create Thin Provisioned volumes on SSD CPGs; this will guarantee all SSD capacity is consumed by Adaptive Optimization and allow capacity to be safely used to 95%.
- For SSDs, the CPG grow size should be set to as small as the system will allow allowing for maximum disk utilization.
For all but the most latency sensitive workloads, configure SSD CPGs of RAID5 type with a “Set size” of 3+1 for the best performance/capacity ratio.

Scheduling CPG compaction with Adaptive Optimization is not required. CPG compaction is part of the Adaptive Optimization process.

When defining Adaptive Optimization schedules follow these recommendations:

- Allow a minimum of 3 hours data sampling before running or scheduling Adaptive Optimization moves.
- Start and schedule sampling periods with peak data usage in mind. The more accurate the sample window, the better the optimization achieved.
- Do not allow overlapping measurement intervals for the same Adaptive Optimization configuration to avoid generating errors as the same region moves are attempted to be moved by another task.
- For most applications, use the pre-defined “balanced” Adaptive Optimization configuration. In doing so, Adaptive Optimization will leverage all available tiers, run during the work week once a day during lower disk activity periods and use a measurement sample of 24 hours.
- For applications requiring optimal performance, use the pre-defined “performance” Adaptive Optimization configuration. In doing so, Adaptive Optimization will leverage all available tiers, execute once a day immediately following high disk activity periods and uses a measurement sample defined by the preceding heavy workload period.
- Do not mix Adaptive Optimization with any other application or processes that move data on or between volumes based on I/O load balancing. VMware Storage DRS for initial and ongoing virtual machine and VMDK placement based on capacity measures is acceptable and recommended to prevent downtime due to out of storage scenarios.

Summary

HP 3PAR Adaptive Optimization is a powerful feature offering greater return on storage investments by realizing untapped and hidden storage potential. In addition, Adaptive Optimization offers tremendous flexibility and ease of management by allowing administrators to provision storage resources once and offering peace of mind that their application workloads will be continually and automatically tuned for best performance. In the case of Exchange 2010, workloads are often imbalanced across volumes and databases. In fact, these workloads are constantly shifting based on many factors including time of day, week, and changing user profiles. Typically, administrators must manage workload imbalances by defining, assigning, and managing user profiles to match specific service level resources; those resources that best match changing user profiles. This can be and often is a never ending task, with administrators constantly managing the environment, ensuring that no one storage resource is either under or over utilized. HP 3PAR Adaptive Optimization offers administrators a different approach to service level optimization; offering an intelligent, fine-grained, and a highly automated approach for managing changing I/O and capacity demands in the data center. These are substantial and significant benefits that impact both end-user satisfaction and an organizations bottom line. HP 3PAR StoreServ with Adaptive Optimization is the ideal platform for virtually any workload, adapting seamlessly and intelligently to changing workloads, providing unsurpassed flexibility to model changing demands in an organization’s IT environment while mining typically untapped physical disk performance in competitors storage systems. Additionally, with the improvements in 3PAR OS 3.1.2’s on-node Adaptive Optimization, implementing, managing, and maintaining an organizations tiered storage solution is practically a turn-key implementation.

Performance tuning

While virtual environments certainly increase server consolidation, simplify administration, and maximize ROI, these environments also present unique performance challenges for storage administrators. After consolidation, typically most environments will find memory over utilization a significant factor. In fact, VMware vSphere utilizes several sophisticated techniques for handling memory over-commitment including page sharing, ballooning, compression and swapping. These techniques enable effective memory management which in turn enables more virtual machines to be hosted on a single host. However, several of these memory handling processes place a greater load on the backend storage system. Namely, ballooning and swapping often will page to disk and it is here where high speed and low latency I/O is critical for optimum performance in a VMware vSphere environment. Compounding the reliance on storage resources is the random nature of virtualized workloads, which typically do not find data in storage read cache but must fetch it on disk. There is some benefit to enabling read cache in virtualized environments, but primarily, the ability for storage systems to deliver IOPS is going to achieve best performance.
I/O sizing

Traditional storage systems have administrators working through various storage sizing exercises seeking to define volume I/O per any given workload. With a traditional disk based array, administrators must identify storage performance requirements for given workloads using some of the following guidelines:

- Different RAID groups (think physical drives) tailored to specific I/O performance, capacity, and redundancy with volumes assigned to these different groups
- When RAID groups do not meet I/O requirements, additional, dedicated groups must be created for newly provisioned volumes
- Manually balancing/distributing the RAID groups and volumes across the available storage processors for best performance

These management considerations are time consuming, and can be expensive and complex to implement, especially when adding additional storage to meet I/O requirements. With HP 3PAR StoreServ Storage systems, there is no separation of underlying physical drives and logical RAID groups and all of the planning and spreadsheets to keep track of. Instead an HP 3PAR StoreServ system will leverage its built in Wide striping capabilities to use every defined physical disk (FC, NL, SSD) on the array. Because of this, I/O sizing is significantly simplified with HP 3PAR StoreServ Storage, and storage administrators should consider the I/O requirements of their environment and then align the HP 3PAR StoreServ Storage configuration (SPC-1 benchmark results) to meet those specific requirements.

SPC-1 benchmark results

The Storage Performance Council (SPC) defines and administers industry standard benchmarks to characterize storage products. The SPC-1 benchmark was designed to demonstrate the performance of a storage subsystem while performing the typical functions of business critical applications. Those applications are characterized by predominately random I/O operations and require both queries as well as update operations. In October 2011, HP announced that the HP 3PAR StoreServ 10000 Storage system delivered record SPC-1 results, yielding over 450,000 IOPS:

storageperformance.org/results/benchmark_results_spc1

At the time of the publication of this paper, this was the number one SPC-1 result for a single storage array using Fast Class disks.

Alignment considerations

The improper alignment of VMFS file system partitions may impact performance. The recommended practice is to add VMFS storage to ESXi hosts using the vSphere Client, as it automatically aligns VMFS partitions when it creates them. For ESXi 5, VMFS3 and VMFS5 file systems that are created using the vSphere Client are automatically aligned on a 1 MB boundary. VMFS3 file systems created with a previous version of ESX/ESXi used 64 KB alignment.

Partitions that are created using vmkfstools may be aligned manually using the partedUtil tool from the command line. For detailed instructions on using partedUtil, refer to the VMware Knowledge Base entry: http://kb.vmware.com/kb/1036609. Note that when using partedUtil, alignment is determined by the start sector parameter. Specifying a start sector at offset 128 will result in 64 KB alignment, and a start sector at offset 2048 will provide 1 MB alignment.

Virtual SCSI adapters and virtual disk types

ESXi 5 provides several virtual storage adapters, with the default depending upon the guest operating system and virtual hardware version. The paravirtualized SCSI storage adapter (PVSCSI), also called VMware Paravirtual, is recommended for optimal performance, especially for environments with I/O intensive applications. The PVSCSI adapter provides a significant reduction in CPU utilization with potential for increased throughput as compared to the default storage adapters. Note that virtual machines must be using virtual hardware version 7 or later in order to take advantage of PVSCSI. For details on configuring the PVSCSI adapter and a list of guest operating systems that support it for the boot disk, reference VMware Knowledge Base entry http://kb.vmware.com/kb/1010398.

The virtual disk options available to administrators include thick virtual disks which have all space allocated at time of creation and thin virtual disks which have their space allocated but written to upon first write operation. Additionally, two thick virtual disks options are available to choose from, eager-zeroed and lazy-zeroed. Eager-zeroed allocates all the space requested by writing zeros for the entire virtual disk at creation, while lazy-zeroed only zeros at first write. Administrators also have the option of provisioning raw device mapped (RDM) volumes which allow for management access of raw SCSI LUNs as VMDK files. In terms of performance, each virtual disk type has unique characteristics as noted in Table 5 below.
Table 5. Performance comparison - virtual disk types

<table>
<thead>
<tr>
<th>StatLun (Hosts) Counters</th>
<th>Lazy Zero Thick (first-write) on TPVV</th>
<th>Lazy Zero Thick (after block zero) on TPVV</th>
<th>vSphere TP and TPVV</th>
<th>RDM on TPVV</th>
<th>Eager Zeroed Thick on TPVV</th>
<th>Fully Provisioned (3PAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write I/O per sec</td>
<td>95th pctl</td>
<td>663</td>
<td>715</td>
<td>758</td>
<td>723</td>
<td>717</td>
</tr>
<tr>
<td></td>
<td>Avg</td>
<td>631</td>
<td>674</td>
<td>729</td>
<td>689</td>
<td>690</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>672</td>
<td>742</td>
<td>779</td>
<td>752</td>
<td>740</td>
</tr>
<tr>
<td>Write KB per sec</td>
<td>95th pctl</td>
<td>130948</td>
<td>379988</td>
<td>132791</td>
<td>384151</td>
<td>382198</td>
</tr>
<tr>
<td></td>
<td>Avg</td>
<td>124912</td>
<td>358678</td>
<td>127505</td>
<td>366625</td>
<td>366866</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>133740</td>
<td>394937</td>
<td>135316</td>
<td>401146</td>
<td>394267</td>
</tr>
<tr>
<td>Write Svt ms</td>
<td>95th pctl</td>
<td>2</td>
<td>37</td>
<td>2</td>
<td>31</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Avg</td>
<td>2</td>
<td>32</td>
<td>2</td>
<td>28</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>3</td>
<td>39</td>
<td>2</td>
<td>34</td>
<td>39</td>
</tr>
</tbody>
</table>

Table 5 is limited to large block file transfers only and thus records write operations on disk. Most notably, lazy-zeroed and host thin provisioned volumes (1st and 3rd column results) perform very similarly with first write penalties recorded in both test cases. Subsequent writes to both types of volumes does show a notable increase in performance as seen and recorded in the second column (Lazy Zeroed Thick (after block zero) on TPVV). In all cases, utilizing host-side thin provisioning reduces the underlying volume performance while at the same time incurring additional ESXi host overhead.

See Table 6 below for a comparison of host thin provisioned versus eager zeroed thick I/O characteristics. This comparison illustrates that host-side thin provisioned volumes are not pre-allocated upon creation and must be read from prior to write operations; thus, the read I/O penalty seen below.

Table 6. Read I/O penalty for host-side thin provisioned volumes

<table>
<thead>
<tr>
<th>StatPort (Host) Counters</th>
<th>vSphere TP and TPVV</th>
<th>Eager Zeroed Thick on TPVV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read I/O per sec</td>
<td>95th pctl</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Avg</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>4.0</td>
</tr>
<tr>
<td>Read IOSz KB</td>
<td>95th pctl</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Avg</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>280</td>
</tr>
<tr>
<td>Read KBytes per sec</td>
<td>95th pctl</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Avg</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>1119</td>
</tr>
<tr>
<td>Read Svt ms</td>
<td>95th pctl</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Avg</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>7.8</td>
</tr>
</tbody>
</table>
In terms of performance and overhead, RDM, eager-zeroed, and fully provisioned 3PAR VMDKs compared favorably with each other. However, 3PAR fully provisioned volumes experienced the shortest disk service times and least amount of storage CPU cycles. Overall, all three virtual disk types perform remarkably similar and the choice of virtual disk type should be based on specific application requirements.

**Wide striping**

The unique HP 3PAR StoreServ architecture stripes volumes widely across all drives to deliver maximum I/O throughput and minimum latencies, which mitigates server memory bottlenecks and traditional storage constraints. Increased array performance cannot only boost VM-based application performance, but when paired with the superior reliability of the HP 3PAR StoreServ Storage system and advanced support of VMware’s vSphere Storage APIs for Array Integration (VAAI) capabilities, result in higher VM density. This benefit enables organizations to double virtual machine density on physical servers by placing twice as many VMs on physical servers as compared with traditional storage platforms.

**Storage I/O Control**

**Note**

vSphere Storage I/O Control (SIOC) is a vSphere feature which manages ESXi device-queue depths, while AO is an HP 3PAR feature which moves data between storage tiers at scheduled intervals depending upon usage patterns. The two features operate at different layers, so there is no conflict between them.

SIOC provides finer-grained control than Adaptive queue depth throttling, and the latter is not needed if SIOC is enabled.

The vSphere Storage I/O Control (SIOC) feature manages shared storage resources across ESXi hosts to provide more predictable performance during periods of congestion. It monitors the latency of I/Os to a datastore for each ESXi host sharing the device. When the average latency for a datastore exceeds a threshold (set by SIOC based upon storage type), SIOC distributes the storage resources to virtual machines according to their assigned shares. It accomplishes this by reducing the number of I/O queue slots available to lower priority virtual machines and increasing the slots for virtual machines with higher shares. By controlling the ESXi device-queue depths in proportion to the virtual machine shares, SIOC is able to control storage congestion for the datastore and distribute HP 3PAR StoreServ Storage array resources appropriately. Note that the congestion threshold represents a tradeoff between lower I/O latencies and throughput. When the threshold is set low, I/O throttling will be engaged more aggressively, which will help to maintain a lower I/O latency for the datastore, but will also reduce the overall throughput for the datastore.

The default latency threshold is 30 ms, but the optimal setting depends upon the storage type used for the datastore. A new feature in SIOC for vSphere 5.1 is the I/O injector, which calculates the peak throughput for a storage device, detects the 90 percent throughput value and measures latency at that point to determine the optimal threshold value for the storage device. The latency threshold is set automatically to the value determined by the I/O injector, but you can change the 90 percent throughput value or set the threshold in milliseconds if desired.

To enable SIOC for a datastore:

- In the vSphere Web Client, select the datastore.
- From the Manage tab, select Settings and click the Edit button next to Datastore Capabilities.
- Click the Enable Storage I/O Control check box, as shown in Figure 22.
- If you wish to change the peak throughput threshold, click on the drop down menu next to “Percentage of peak throughput,” and select a new value.
- Alternatively, the threshold can be set to a specific latency by clicking on the Manual radio button and then selecting a value in milliseconds from the drop down menu.
The VMware white paper *Storage I/O Control Technical Overview and Considerations for Deployment* makes the following recommendations for determining the congestion threshold values for various types of storage, including auto-tiered storage.

**Table 7. Recommended congestion threshold values**

<table>
<thead>
<tr>
<th>Type of storage backing the datastore</th>
<th>Recommended threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSD</td>
<td>10-15 ms</td>
</tr>
<tr>
<td>Fast Class</td>
<td>20-30 ms</td>
</tr>
<tr>
<td>Nearline</td>
<td>30-50 ms</td>
</tr>
<tr>
<td>Auto-tiered storage</td>
<td>Combine ranges of fastest and slowest storage types</td>
</tr>
</tbody>
</table>

The default threshold of 30 ms should be acceptable for most workloads using Fast Class or Nearline drives. If Adaptive Optimization is employed, then the threshold should be set to a value that is within the recommended ranges for the fastest and slowest storage types in use. For example, if Fast Class and SSD drives are specified by the AO policy, then the threshold
for the datastore should be set in the range of 10 to 30 ms. The exact setting should be determined by the requirement to favor low latency (using a low congestion threshold) versus throughput (using a high threshold).

The virtual machine’s relative priority on the datastore is determined by its number of disk shares. This is configured by editing the settings for the VM as shown in Figure 23:

**Figure 23.** Changing disk shares for a VM

Select the Virtual Hardware tab, and select the Hard disk of interest. The default number of disk shares is 1000. To increase the priority of a VM relative to other VMs using the same datastore, increase the number of disk shares by clicking on the drop down menu next to Shares and change the value to High, or select Custom and enter a new value in the adjacent field.

**Adaptive queue depth throttling**

**Note**
Adaptive queue depth throttling is not needed if Storage I/O Control is enabled.

Adaptive queue depth throttling is not compatible with Storage DRS.

If adaptive queue depth throttling is enabled, it is important to enable it for all hosts which are accessing the HP 3PAR StoreServ Storage.

Each port on the HP 3PAR StoreServ Storage system has a finite queue depth that depends on the host bus adapter (HBA) model; each server attached to a port shares that port’s queue. If a host sends an I/O request to a port with a full queue, the
A host receives a “queue full” SCSI response from the HP 3PAR array. I/O commands sent to a port in an HP 3PAR StoreServ array that has reached its maximum queue depth are not processed beyond the “queue full” SCSI response.

Historically, an ESX host’s default reaction to this response would be to recognize it as a valid command and to continue sending requests to that port. Lack of I/O responses can result in VMs becoming unresponsive and can lead to a crash of the ESX host. ESX 3.5 Update 4 and later include an adaptive queue depth throttling algorithm which adjusts the LUN queue depth in the VMkernel I/O stack. This algorithm is activated when the storage array indicates I/O congestion by returning a “queue full” SCSI status. When congestion is detected, the VMkernel throttles the LUN queue depth and attempts to gradually restore the queue depth when congestion conditions subside.

Without adaptive queue depth throttling, administrators are forced to limit the number of VMs per physical server so as to reduce the risk associated with any particular VM overrunning I/O queues. Administrators are also forced to manually tune the number of VMs when they detect congestion – a reactive, slow, and error-prone process. By automating congestion control, administrators can confidently create a higher number of VMs per physical server without the need for manual congestion control.

The adaptive queue depth algorithm is disabled by default. For ESXi 5.1, it is enabled on a per datastore basis by setting the queue-full-sample-size and queue-full-threshold parameters. Setting the queue-full-sample-size parameter to a value greater than zero activates the algorithm. The queue-full-threshold parameter must be set to a value less than or equal to queue-full-sample-size. To set these parameters to optimal values for HP 3PAR StoreServ Storage, run the following command for each HP 3PAR StoreServ device utilized by the ESXi host:

```
#esxcli storage core device set --device device_name --queue-full-threshold 4 --queue-full-sample-size 32
```

These settings take effect immediately and are persistent across reboots of the ESXi hosts. Note that it is important to make the changes across all ESXi hosts sharing the storage.

For ESXi versions prior to 5.1, the algorithm was enabled by setting two VMware system-wide configuration parameters, QFullSampleSize and QFullThreshold on the ESXi hosts. The new per-device settings are preferred because the optimal settings differ by storage type. For more information, refer to the VMware Knowledge Base entry: http://kb.vmware.com/kb/1008113.

**Tech tip**

You can monitor the “Qlen” values on the system (using System Reporter or the command `statvlun -ni -rw -host <ESX host>`) to make sure you are not exceeding these values.

**Summary**

HP 3PAR StoreServ Storage provides the high I/O throughput and low latency required for optimal performance in a VMware vSphere environment. The usage of HP 3PAR thin provisioning offloads the management of thin provisioned volumes from the ESXi host and reduces host overhead. VMware vSphere performance features such as paravirtualized SCSI storage adapter and Storage I/O Control also contribute to optimal I/O performance. SIOC and adaptive queue depth throttling are two methods to provide more predictable performance for VMs during periods of I/O congestion. SIOC provides finer-grained control than adaptive queue depth throttling and is also compatible with Storage DRS thus it is a more robust solution.

**HP 3PAR Recovery Manager Software for VMware vSphere**

HP 3PAR Recovery Manager for VMware vSphere is an array-based, online VM snapshot and recovery solution that gives superior control over data protection and recovery in VMware vSphere environments – including granular, rapid online recovery of files. As with the HP 3PAR Management Plug-In for VMware vCenter, HP 3PAR Recovery Manager gives administrators access to all of this functionality from within the familiar and easy-to-use VMware vCenter Server virtualization management console.

Providing virtual copy management and LUN-level snapshot capabilities, the HP 3PAR Recovery Manager for VMware vSphere delivers array-based snapshots that are fast, space-efficient and VM aware, while traditional backup schemes are slow, complex and lacking in both flexibility and granularity. HP 3PAR Recovery Manager for VMware vSphere snapshots offload the workload associated with performing backups from VMware host to the HP 3PAR StoreServ Storage.

HP 3PAR Recovery Manager for VMware vSphere makes possible the creation, and subsequent restoration, of hundreds of virtual copies, with the retention periods of those copies easily specified by an administrator. Once a virtual copy has been created, HP 3PAR Recovery Manager for VMware vSphere allows flexible and highly-granular restorations, at the VMFS layer.
As HP 3PAR Recovery Manager for VMware vSphere is not installed on the VMware ESXi hosts, its operation does not impact server performance. Snapshots with HP 3PAR Recovery Manager for VMware vSphere are quick and non-disruptive. Space used for snapshots is minimal and has a smaller footprint than VMware’s own snapshots because HP 3PAR Recovery Manager for VMware vSphere leverages HP 3PAR Virtual Copy to perform those tasks.

HP 3PAR Recovery Manager for VMware vSphere includes several software components that lower the cost and time required to manage and protect VMware vSphere environments:

- **HP 3PAR Host Explorer for VMware vSphere** – discovers VMware host configurations
- **HP 3PAR VMware vSphere Storage APIs for Storage Awareness (VASA)**, allowing VMware vCenter insight into:
  - Provisioning Type
  - Volume Type
  - Drive Type
  - RAID Type
  - Remote Copy
- **HP 3PAR Management Plug-in for VMware vCenter** – displays virtual volume mapping for easy identification of HP 3PAR StoreServ volumes used by virtual machines and datastores

The following features of Virtual Copy are key to making HP 3PAR Recovery Manager for VMware vSphere a superior snapshot management product:

- Non-duplicative snapshots reduce the capacity required for disk-to-disk (D2D) backups. When a production volume is changed, a single copy-on-write operation is performed, and little capacity is consumed regardless of the number of snapshots associated with the production volume.
- Reservationless snapshots reduce management overhead and the wasted capacity introduced by snapshot reservations in other technologies.
- Read-write snapshots can be mounted directly by the hosts and used for processing. This extends the benefit of snapshots to their use in test or development environments. Traditional read-only snapshots can be read but not mounted for processing.

**Architecture**

HP 3PAR Recovery Manager for VMware vSphere utilizes HP 3PAR Virtual Copy technology to create a thin snapshot of the selected data, with copy-on-write de-duplication performed to reduce the size of the thin snapshot. HP 3PAR Recovery Manager for VMware vSphere does not require VM operation to be suspended prior to the creation of the snapshot, allowing for the creation and restoration of hundreds of VM snapshots, with no effect on application performance or availability.

Once implemented, the snapshot process becomes an automated activity, allowing for quick and granular recovery. The data protection and recovery includes:

- Individual VM disks (VMDKs) including any included directories
- Individual files
- Entire virtual data store, comprising VMware vStorage VMFS

HP 3PAR Virtual Copy Software uses a unique system of pointers to increase performance, reduce disk capacity requirements, and enable read-write snapshots that can be mounted for rapid recovery or used in test and development environments.

As shown in Figure 24, the copy-on-write I/O overhead grows with a traditional array volume as each snapshot requires its own copy of the changed data. I/O is multiplied by every new snapshot created and free capacity is reduced by the storage required for each snapshot reservation. Conversely, with Virtual Copy, the copy-on-write penalty is minimized by a single copy required for all Virtual Copy snapshots of a given volume. I/O overhead is minimized, and there is no wasted capacity consumed by snap reservation space.
Figure 24. Illustration of a traditional snapshot vs. an HP 3PAR StoreServ snapshot.

Benefits

No more backup window
HP 3PAR Virtual Copy Software snapshots eliminate the need for a backup window by integrating with VMware vSphere to create an instant, non-disruptive point-in-time snapshot.

Maintaining multiple recovery points
Not only can HP 3PAR Recovery Manager for VMware vSphere eliminate the problem of a shrinking backup window, it also enables administrators to maintain multiple recovery points throughout the day.

Improved hot backup
Hot backup capabilities can be used without a snapshot-based backup. The downside of backing up in this fashion is that the applications in “hot backup” mode can have either a processing impact due to the overhead of transaction logging, a disk capacity impact due to long term storage of the state of the disk, or both. However, by integrating Virtual Copy snapshots with VMware vSphere, the duration of time during which the application is quiesced is greatly reduced, and so is the potential impact to performance and capacity consumption. HP 3PAR Recovery Manager for VMware vSphere makes hot backup better, providing the application with multiple points of recovery via high-performance, non-duplicative snapshots.

Low-impact topology
Where traditional backups require added SAN or LAN capabilities in order to handle increased bandwidth at multiple touch points in the data center, with HP 3PAR Recovery Manager for VMware vSphere, snapshots are presented to the backup host directly by the array. Instead of increasing the SAN and LAN bandwidth for every host, HP 3PAR Recovery Manager for VMware vSphere requires only a single backup server. This reduces the CPU and SAN traffic utilization on the production servers.

Flexible RPO and RTO
HP 3PAR Recovery Manager for VMware vSphere’s scalable, non-duplicative snapshots allow the administrator to specify a greater number of snapshots for a frequent or extended history of recovery points, giving flexibility when committing to a given Recovery Point Objective (RPO). Flexibility to restore from snapshot or to mount the snapshot directly on the host instantly allows administrators to offer increasingly aggressive Recovery Time Objective (RTO) service level agreements to their internal customers.
Thin snapshot technology reduces sprawl
Non-duplicative snapshots also reduce the redundant copies of data that result from traditional D2D backups without the complexity of additional data deduplication appliances.

Usage
When faced with needing to achieve the fastest possible Recovery Time Objective (RTO), there are several items that should be taken into account and addressed when recovering from a failure. During a failure, rollback, or corruption of a VM or datastore, the fastest RTO can be met by mounting a Virtual Copy snapshot directly to the original host, replacing the original data volumes. The administrator can operate the application on this snapshot indefinitely, allowing the flexibility to choose a planned outage at a later date in order to promote the snapshot data back into the primary volume.

The ability to accomplish this task is integrated into HP 3PAR Recovery Manager for VMware vSphere. Right-clicking on a dataset presents the “mount” option, simplifying the administrator’s duties during the critical time period while the application is down. The later promotion of the snapshot back into the primary volume is a simple step and is also integrated into HP 3PAR Recovery Manager for VMware vSphere.

Because of the ability of Virtual Copy to maintain high-performance read-write snapshots with no special configuration, the ability to promote any given snapshot back into the primary volume can be completed with only a few clicks. Promotion is an internal, array-driven operation that pushes the differences of the altered read-write snapshot back into the original volume. The primary volume is then remounted and the application restarted. The array-based copy of data from the snapshot back to the original volume is referred to as a “Promote.” Promotion is performed inside the array for the highest performance and lowest network impact.

Another option that is available with HP 3PAR Recovery Manager for VMware vSphere is rapid recovery from snapshot. This recovery method involves mounting the snapshot and then copying the data to the production volume in a D2D operation. This process is automated via HP 3PAR Recovery Manager for VMware vSphere, integrating with VMware vSphere for a supportable restoration of data. This process takes longer than the first recovery option specified, but does not require planned downtime at a later date.

Best practices
For the best performance and reliability, HP 3PAR Recovery Manager for VMware vSphere should be installed on a dedicated Microsoft® Windows® server residing in the network, so that it may interface with the vSphere clusters and the HP 3PAR Storage. It is also not a replacement for provisioning using the HP 3PAR Management Console. If provisioning requires specific attributes, the HP 3PAR Management Console should be used.

When using HP 3PAR Recovery Manager for VMware vSphere for datastore restoration through the promotion of a virtual copy, it does not check if a volume being unmounted is in use. Ensure that the volume is inactive prior to unmounting it in preparation for the restoration of the copy. Also, when a VM or datastore is removed, the associated scheduled tasks continue to run but are no longer manageable from the HP 3PAR Management Plug-in and Recovery Manager for VMware vSphere scheduling interface. In this case, the task needs to be manually removed from the Windows scheduler.

When copying or cloning a virtual machine (VM) to a different datastore, the source VM’s Universally Unique Identifier (UUID) is retained in the target VM. When using HP 3PAR Recovery Manager for VMware vSphere to show the virtual copies on the target VM, the virtual copies from the source VM will be displayed. To resolve this problem, the target VM’s UUID should be changed by editing the VMX configuration file (.vmx) while the VM is powered-off. By deleting the uuid.bios="..." line, a new uuid.bios entry is generated.

When using the “Copy to Datastore” option to copy a virtual disk to a datastore, it is recommended that the copy and paste functions of the datastore browser be used in order to preserve the VMware Thin Provisioning disk feature. Using other features like SCP will not preserve the thin provisioning.

Note
A virtual copy set may be retained for up to 1,825 days.

Summary
Leveraging HP 3PAR Recovery Manager Software for VMware vSphere enables VMware administrators to non-disruptively create hundreds of space-efficient, application-consistent, point-in-time snapshots to protect and recover Virtual Machine Disks (VMDKs), Virtual Machine File Systems (VMFS), individual virtual machines, or individual files. Along with the HP 3PAR Management Plug-In for VMware vCenter, HP 3PAR Recovery Manager gives administrators access to all of this functionality from within the familiar and easy-to-use VMware vCenter Server virtualization management console.
HP 3PAR Integration with VMware vCenter Site Recovery Manager (SRM)

VMware vCenter Site Recovery Manager is a management and automation product that helps build, manage, test and execute disaster recovery plans for a VMware virtual infrastructure. The HP 3PAR StoreServ Storage system, as the storage component in a VMware virtual infrastructure, holds virtual machine information for a protected site/location and recovery site/location. HP 3PAR Storage Replication Adapter for VMware vCenter SRM 5 is an important integration component that communicates with HP 3PAR StoreServ Storage systems to execute specific storage and HP 3PAR Remote Copy functions needed for VMware vCenter Site Recovery Manager operation.

Architecture

VMware vCenter SRM provides business continuity and disaster recovery protection for VMware virtual environments. Protection can range from individual virtual machines (VMs) residing on a single, replicated datastore to all the VMs in a data center. VMware SRM helps IT administrators plan, test, and execute the recovery of virtual machines between the protected site and the recovery site.

As demonstrated in Figure 25, VMware SRM coordinates the recovery process with HP 3PAR Remote Copy Software to ensure that the virtual machines at the protected site are shut down cleanly (in the event that the protected site virtual machines are still available when recovery is invoked) so that the replicated virtual machines can be recovered and powered up at the recovery site. Recovery of protected virtual machines to the recovery site is guided by a recovery plan that specifies the order in which virtual machines are started up. The recovery plan also specifies network parameters, such as IP addresses, ensures the replicated storage holding the protected VMs is brought online and presented to the recovery hosts properly, and can contain user-specified scripts that can be executed to perform custom recovery actions.

After a recovery has been performed, the running virtual machines are no longer protected. To address this reduced protection, SRM supports a reprotect operation for virtual machines protected on array-based storage. The reprotect operation reverses the roles of the two sites after the original protected site is back up. The site that was formerly the recovery site becomes the protected site and the site that was formerly the protected site becomes the recovery site. At this point a planned migration back to the original site can be scheduled, if desired.

**Best practices**

In conjunction with the white paper referenced above, the following best practices should also be observed.

When creating virtual volumes and presenting them to your ESXi host, the same LUN ID should be used for every host in the same Access group. According to VMware’s ESXi configuration guide, LUNs must be presented to each HBA of each host with the same LUN ID.

When protecting a virtual machine which has two or more virtual volumes on two or more datastores, it is recommended to include all the virtual volumes in the same Remote Copy group. The same is also true for if a virtual machine sits on a spanned datastore, a single data store comprised of multiple volumes. All virtual volumes used for the spanned datastore need to be included in a single Remote Copy group.

Also when leveraging an HP 3PAR StoreServ virtual volume set, be sure to include all virtual volumes in a single HP 3PAR Remote Copy group and in the same protection group. Otherwise there is a potential of losing connectivity to the VMs if virtual volumes are included in more than one HP 3PAR Remote Copy group and not all Remote Copy groups are included in the protection group. It is also noteworthy to mention that although HP 3PAR SRA can handle virtual volumes or a virtual...
volume set exposed to a host set, it does not support it. In the event of failover, LUNs will be exposed to the ESXi host(s) as individual LUNs and not a set. If the virtual volumes were exposed to the host set, LUNs will be exposed to an individual host as opposed to a host set.

It is strongly recommended to configure one protected group per Remote Copy group. Although not recommended, if multiple Remote Copy groups are included in one protected group, it is recommended to set the same sync time on all of the periodic Remote Copy groups. If this is not done, data could be inconsistent in the case of a failover. HP 3PAR SRA will log a warning to the user if multiple instances of such configurations are detected during the Test or Recovery operation since this might be an indication that VMs are using virtual volumes from different Remote Copy groups. Also Remote Copy reserves .r for naming. Do not include the reserved naming in your Remote Copy group name otherwise failure may occur.

When naming your volumes, take note that SRM_RO_<VVID>, SRM_RW_<VVID>, SRM_RECOVER_RO_<VVID>, and SRM_TARGETBK_RO_<VVID> are reserved virtual volume naming conventions for HP 3PAR SRA.

Summary

The cost and complexity of replicating data using traditional recovery products can deter some customers from implementing a disaster recovery plan at all. By leveraging the simplicity and efficiency of HP 3PAR Remote Copy, HP 3PAR Replication Adapter for VMware vCenter Site Recovery Manager enables HP 3PAR StoreServ customers to easily implement VMware vCenter Site Recovery Manager for end-to-end management of array-based replication and failover of virtual machines. The combination of HP 3PAR Remote Copy and VMware vCenter Site Recovery Manager lets customers build resilient utility computing infrastructures, protect applications at a lower cost, and recover data more quickly and efficiently compared to traditional disaster recovery offerings.

Summary

Deploying HP 3PAR StoreServ Storage in VMware vSphere environments helps remove the performance, efficiency, availability, and management headaches associated with traditional storage platforms. Not only does leveraging HP 3PAR StoreServ Storage enable seamless integration with VMware vCenter to deliver enhanced performance, agility, and scalability in vSphere environments, but it also enables organizations using VMware vSphere with HP 3PAR StoreServ several other key benefits:

- Tight integration of VMware vCenter Server and the HP 3PAR Recovery Manager Software for VMware vCenter allows administrators to monitor and manage HP 3PAR Storage volumes to create point-in-time, VM- and application-aware, disk-based snapshots from within the vSphere Client.
- Using HP 3PAR StoreServ Storage with VMware vSphere enables its users to double virtual machine density on physical host servers as compared with traditional storage platforms.
- HP 3PAR Thin Provisioning Software allows physical storage to be consumed only when required for actual written data, rather than when allocated.
- With HP 3PAR Thin Persistence, as the ESXi host writes zeros to the VMDK file, the zeros are detected in-line by the HP 3PAR StoreServ ASIC, and no space is allocated for the VMDK in the thin provisioned volume. Also, when a VM is deleted or moved to another data store, that now unallocated storage can be released back to the array rather than keeping it assigned to the LUN.
- HP 3PAR Persistent Ports allows for Online Software Upgrades, non-disruptive HBA Firmware upgrades and node maintenance on HP 3PAR StoreServ arrays all while the normally affected host path remains online. There is no dependency on the software multi-pathing as the host port remains online.
- HP 3PAR Peer Persistence software enables HP 3PAR StoreServ systems located at metropolitan distances to act as peers to each other, presenting a nearly continuous storage system to hosts and servers connected to them. This capability allows you to configure a high-availability solution between two sites or data centers where failover and failback remains completely transparent to the hosts and applications running on those hosts.
- HP 3PAR Adaptive Optimization Software can be used to tailor storage performance without disruption to VMware vSphere and contribute new autonomic space reclamation functionality.
- The combination of HP 3PAR Remote Copy and VMware vCenter Site Recovery Manager lets customers build resilient utility computing infrastructures, protect applications at a lower cost, and recover data more quickly and efficiently compared to traditional disaster recovery offerings.

These are among the unique advantages that make HP 3PAR StoreServ Storage the ideal foundation for building or expanding a virtualized server environment with VMware vSphere as part of a converged infrastructure to meet the needs of the Instant-on Enterprise.
For more information

HP 3PAR StoreServ Storage Family, hp.com/go/3PAR
HP Insight Control for vCenter, hp.com/go/icvcenter
HP Storage for VMware, hp.com/go/storage/vmware

HP/VMware technical papers
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HP 3PAR VMware ESX Implementation Guide,
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Reference Architecture: Implementing HP 3PAR V400 and ProLiant BL460c Gen8 with Microsoft Exchange 2010 running on VMware vSphere 5,
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