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# Storage Foundation and High Availability for Windows

Enhancing Storage Management and Availability in a Hyper-V Environment

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## Enhancing Storage Management and Availability in a Virtualized Environment

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## Introduction

With the move to virtual server environments accelerating, businesses are faced with several new challenges. More of a communal society, server virtualization takes advantage of sharing of common resources among many different operating systems. While providing benefits such as hardware and space consolidation, and increased utilization, it also poses new challenges in the datacenter, such as all eggs in one basket and how best to protect that basket, keeping it highly available and providing efficient means to recover from the inevitable disaster.

There are several platforms for virtualization available today, the most widely known being VMWare's ESX, Microsoft's Hyper-V and Citrix XenServer. While VMware may be ahead in points in this ball game, it's still yet early and opportunity abounds for the other players.

With Hyper-V, Microsoft has made a large wager in the virtualization space, proffering a platform that, both directly and indirectly target the leader, Third party vendors have to, at a minimum, consider it a potentially viable server virtualization platform and, if they want to remain competitive, develop their solutions to at least work with Hyper-V and, depending on the vendor, think of how they can provide solutions to some of the challenges that moving to a virtual server environment might pose and solutions that answer the question "why should I deploy Hyper-V in my datacenter?" so that they're not only meeting those challenges, but also acting as enablers for Hyper-V and Microsoft..

## Hyper-V

### Overview

Microsoft Hyper-V, formerly known as Windows Server Virtualization, is built on hypervisor technology targeted at x64 systems running Windows Server 2008. Hyper-V is available as a free, stand-alone version, running in Windows Server 2008 Core, in which all other Windows 2008 Server Roles are disabled and limited Windows Services run. This version is limited to a command-line interface method of management using shell commands. Hyper-V is also available as a Server Role running on a full version of Windows Server 2008, where management can be done through a management console.

## Architecture

Hyper-V separates operating system instances by partitions, which are logical units of isolation that sit on top of the hypervisor, a software layer that sits directly on top of the hardware layer, abstracting it so that multiple guest operating systems above can share access to the host's hardware.

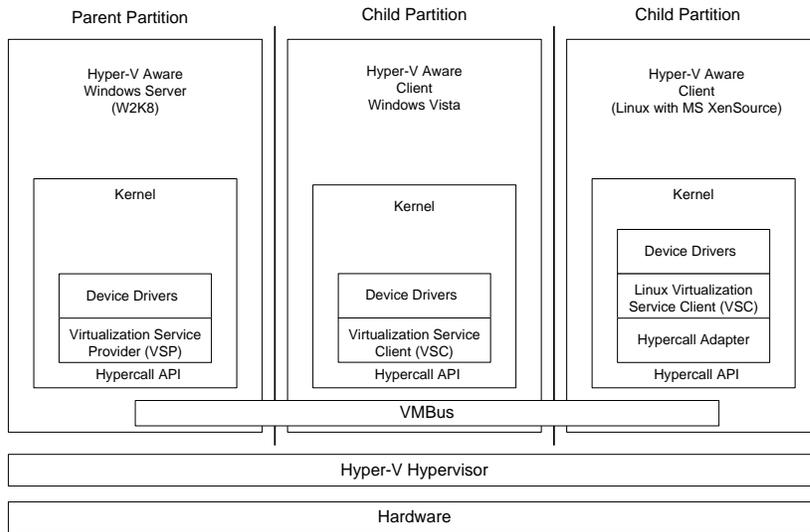
Each instance of a hypervisor has to have at least one control partition, called the parent (or root) partition, which runs an instance of Windows Server 2008. The parent partition runs the virtualization stack and has direct access to the hardware devices. From the parent partition, child partitions, which run instances of guest operating systems, can be created via the hypercall API. Child partitions access hardware resources through the parent partition via the VMBus, a logical channel for communication between partitions.

The Virtualization Service Provider (VSP) runs in the parent partition, connects to the VMBus and handles requests from the child partition for device access. Virtual devices in the child partition run the Virtualization Service Client (VSC), which redirects requests from the child partition to the VSP in the parent partition via the VMBus.

For guest operating systems that support it, Hyper-V offers the Enlightened I/O feature, which allows virtual devices such as storage and networking subsystems to take advantage of direct communication with the VMBus, bypassing any device emulation layer, making for more efficient communication.

Hyper-V saves each guest OS in its entirety to a .VHD file. Other files can also be configured with information such as undo information to allow reverting to previous states, and to store application data.

Figure 1. gives a high level overview of Hyper-V.



**Figure 1. Hyper-V Architecture Overview**

NOTE: See the Glossary at the end of this document for an explanation of acronyms and terms used in the above diagram.

### *VHD (Virtual Hard Disk)*

Virtual hard disks are stored as .VHD files, which contain everything, contents and structure, needed to represent a hard disk drive used by Hyper-V. Virtual hard disks store guest operating systems and their associated programs in a single file. Virtual hard disks used to store data for applications that run in the guest can also be provisioned as individual .VHD files. A .VHD file can be local, or located anywhere the host can access them.

Hyper-V allows secure access to files within a VHD without having to bring up a virtual machine. This provides a mechanism to perform some virtual machine management tasks offline.

### *Pass-through disks*

Pass-through disks allow a physical disk or LUN to be directly mapped to a virtual machine. Using pass-through disks allows for bypassing of the NTFS file system in the parent partition during disk operations, minimizing CPU overhead and maximizing I/O performance.

## Quick Migration

Quick migration takes advantage of Windows Server 2008 Failover Cluster and Hyper-V technologies to provide a means for running virtual machines to be moved from one host server to other host servers with minimal downtime. In the event of a physical host server experiencing either scheduled or unscheduled service interruption, another physical server can quickly take over hosting duties for its virtual machines.

With quick migration, the state of a running virtual machine is saved (its memory is saved to a disk on shared storage), storage connections are moved to a new physical server and the virtual machine is restored to the new server. This applies to a planned interruption. The time it takes to migrate depends on the amount of memory that has to be written to disk and the speed of the storage connection. With unplanned interruptions, the virtual machine is failed over automatically without its state being saved.

While previous versions of Windows didn't recognize virtual machines, just the LUNs on which their VHD files lived, and, hence couldn't control i.e. shut down, move and restart those VMs, Windows Server 2008 recognizes virtual machines and can control them as they are moved from one physical host to another.

Note that quick migration is only supported with the Enterprise and Datacenter Editions of Windows Server 2008, as it requires an underlying cluster.

## Windows Server® 2008 R2 Hyper-V™

Windows Server® 2008 R2 Hyper-V™ adds several new features, including Live Migration, which allows uninterrupted service during relocation of virtual machines, and Dynamic Virtual Machine storage, which allows hot plug-in and removal of VM storage.

### *Live Migration*

Live migration provides functionality that allows active virtual machines to be moved from one physical Hyper-V host server to another in a cluster without any disruption or noticeable loss of service. Microsoft notes in their paper Windows Server® 2008 R2 Hyper-V™ Live Migration, *“Live migration provides the core technology required for dynamic load balancing, virtual machine (VM) placement, high availability for virtualized workloads during physical computer maintenance and reduced data center power consumption.”*

### *Cluster Shared Volumes (CSV)*

Introduced in Windows Server 2008 R2, Cluster Shared Volumes can be configured in clusters with the Hyper-V role to allow multiple nodes simultaneously access to shared LUNs . CSVs provide a single, consistent file name space, providing the same name and path from all nodes in the cluster. Drive letter limitations are no longer an issue with CSVs, as they can host multiple virtual machines. Cluster shared volumes allow for Live Migration of virtual machines.

### *Dynamic Virtual Machine Storage*

With Windows Server 2008 R2 Hyper-V, VHD files and pass-through disks can be added and removed while a virtual machine is running, making it possible to quickly reconfigure virtual machines as necessary. Hyper-V Integration Services have to be installed on the guest operating system for this to be supported.

### **System Center Virtual Machine Manager**

System Center Virtual Machine Manager (SCVMM) belongs to the family of system management products known as Microsoft System Center. The latest release, System Center Virtual Machine Manager 2008, provides support for consolidating multiple physical servers onto a virtual infrastructure and allows rapid provisioning of virtual machines. SCVMM provides support for managing virtual machines running on Windows Server 2008 Hyper-V, Microsoft Hyper-V Server, Microsoft Virtual Server and VMware ESX. It also provides the Performance and Resource Optimization feature for dynamic and responsive management of the virtual infrastructure, and Intelligent Placement, which places virtual workloads on the most suitable physical host servers.

### **Central-Point Control with Veritas Storage Foundation for Windows**

Veritas Storage Foundation for Windows (SFW) is a host level volume manager that provides a means to virtualize storage seen by the host it runs on, providing advanced management of that storage space and many advanced features and functionality such as multi-pathing, replication data migration and snapshots, which further extend the capabilities of Windows in the datacenter. By being able to run SFW in the Hyper-V parent partition, these features and functionality extend to virtual machines, offering benefits that would otherwise be unavailable at the guest level.

## Veritas Storage Foundation for Windows in the Parent

In virtual environments, managing the storage that is used by guests is not an easy task. Typically, the guest is separated from the physical storage .... With Hyper-V, guests sit on VHD files, which in turn are located on volumes that sit on physical storage. Direct access is not available to those volumes or the LUNs they sit on from the guest, making it difficult to effectively manage space requirements on an ongoing basis or to relocate a guest from one storage location to another.

Virtual machines sit on VHD files, which are provisioned by the parent on storage accessed by the parent partition. As storage needs change in the child, they may require additional space. SFW allows for dynamically growing the volumes that host the guest VHDs. As SFW allows for growth of all volume types, the volumes that host the VHD files can be configured for performance via RAID-5, striping or mirrored-stripes. Additionally, in environments using thin provisioned storage, SFW can be configured to automatically grow volumes based on user defined space thresholds and policies for amount to grow volume by and whether that growth should be restricted or unrestricted. This will counter the effects of NTFS' uncontrolled growth tendencies in a thin environment, by allowing the creation of small volumes on the thin storage, which will grow automatically as needed, triggering corresponding growth in the hardware.

As a host level volume manager, SFW also allows for mirroring volumes across arrays and , with its support for dynamic disk operations in a cluster, the creation of stretch or Campus clusters.

## Setting up the environment

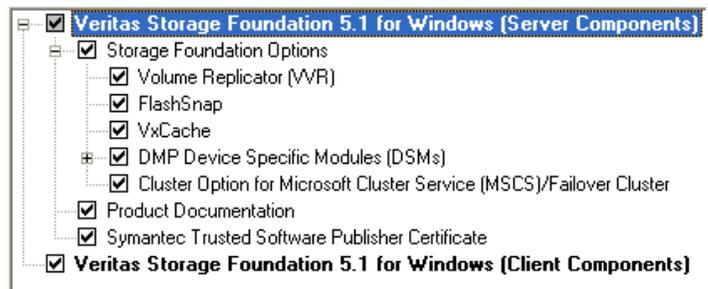
In addition to setting up the Hyper-V role or Hyper-V Server and creating virtual machines in child partitions to host guest operating systems and applications, a few additional steps are required to leverage the benefits of SFW in the parent.

Veritas Storage Foundation 5.1 for Windows should be installed in the parent instance of Windows Server 2008. Required options should be selected during the installation. There is also a list of required patches that have to be installed.

## Installing SFW in the parent

Veritas Storage Foundation 5.1 for Windows can be installed via the GUI or CLI. Run Setup.exe to start the installation. The following options should be installed to provide the functionality described:

- Cluster Option for Microsoft Cluster Service (MSCS)/Failover Cluster – Provides dynamic disk support in a cluster
- DMP Device Specific Modules (DSMs) – Select the appropriate arrays from the list for multi-pathing support
- FlashSnap – Provides snapshot support
- Volume Replicator (VVR). – Provides replication support



## Patches

The following patches should also be installed:

### *Symantec Patches*

All required patches are included in Veritas Storage Foundation 5.1 Service Pack 1 (SP1). If not running SP1, the following patches should be applied:

- The Storage Foundation for Windows (SFW) 5.1 Command Line Interface (CLI) vxvol command does not include the volume GUID – <http://seer.entsupport.symantec.com/docs/326256.htm>
- Failure to enumerate Storage Foundation 5.1 for Windows Volume Manager Disk Group (VMDg) resources in a Microsoft Windows Server 2008 Failover Cluster – Error 0x8007000d The data is invalid – <http://seer.entsupport.symantec.com/docs/322841.htm>

### *Microsoft Patches*

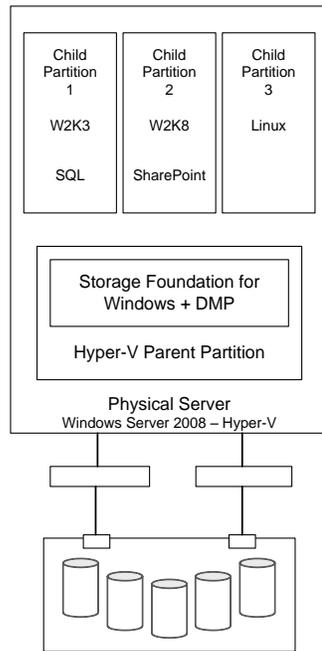
- You cannot configure a Hyper-V virtual machine by using Windows Server 2008 Failover Clustering when the virtual machine uses a storage device that is managed by a third-party clustered file system or a third-party replication solution – <http://support.microsoft.com/default.aspx?scid=kb;EN-US;958065>
- Recommended hotfixes for System Center Virtual Machine Manager 2008 – <http://support.microsoft.com/default.aspx?scid=kb;EN-US;962941>

## **Dynamic Multi-Pathing**

Multi-pathing software provides the intelligence necessary to manage multiple I/O paths between a server and a storage subsystem. This becomes even more important in virtual environments, where a single physical server hosts multiple operating system instances and applications. Loss of access to storage due to an HBA, cable or controller failure can cause widespread impact, with potential for greater disruption than would be the case with a single physical system.

While most multi-pathing solutions are developed by storage vendors for their specific brand of storage and, as such, generally cannot service the many various types of storage that exist in many of today's heterogeneous SAN environments, solutions such as Symantec's Veritas Storage Foundation for Windows Dynamic Multi-pathing (DMP) and Microsoft's in-box MPIO solution offer more wide ranging support from a single control point, making for easier management and increased ROI. Microsoft's solution provides support for heterogeneous environments via its generic device specific module (DSM), MSDSM for Windows Server 2008, and the iSCSI DSM included with their iSCSI Software Initiator for Windows Server 2003. Veritas Storage Foundation for Windows DMP is a truly heterogeneous solution which fully integrates with the Microsoft® Multipath I/O (MPIO) architecture and includes several Device Specific Modules (DSMs) which provide array specific support for a wide variety of the most popular array families available.

In virtual environments, such as with VMware ESX and Microsoft Hyper-V, a hypervisor separates VMs from the physical hardware, making it difficult to directly map virtual host bus adapters (HBA) in the guest to the physical HBAs that service the physical host, and to therefore have a true multi-pathing solution in the guest. With Hyper-V, solutions that can run on Windows Server 2008 can be installed in the parent partition to allow for true multi-pathing, providing failover and load-balancing to the LUNs that host the VMs in the child. This gives Hyper-V a leg up on the competition by allowing for truly advanced multi-pathing in a virtual environment.



**Figure 2. DMP in the Parent Partition**

In the above figure, the physical server that hosts the parent partition connects to its storage via two paths. DMP in the parent will provide path management, load balancing and fault tolerance for the VMs running in child partitions.

While Live Migration of virtual machines is not supported with Storage Foundation due to its dependence on cluster shared volumes, it is supported with DMP when basic disks are used.

## Virtual Machine Volume Snapshots

Snapshot technology is available with SFW's FlashSnap option. Running in the guest, snapshot copies of data volumes can be created, allowing for quickly recovering from a disaster, or for off-host operations, which can occur to another VM or to a physical server connected to storage shared with the guest when it uses pass-through disks. However, this offers no protection against possible disaster that can occur at the VM level. If the VHD file that holds a VM is corrupted, the volume that hosts the VHD file(s) is lost, or the LUN hosting the volume used by the VHD file fails, snapshots in the guest will be useless until the VM can be rebuilt and the application(s) reinstalled – all very time consuming. Being able to capture a copy of the volumes hosting the VHD files will allow for recovery of an entire VM in the event of a disaster. This becomes an advantage when running SFW in the parent partition, as fully redundant snapshots of the volumes can be created and used to quickly recover from a disaster, or to be moved to another server and brought online to be backed up or used for other operations such as testing etc.

## Quick Recovery

Setting up a quick recovery environment for VMs is simple with SFW and FlashSnap running in the parent partition. Volumes that host the VHD files for the VMs can be snapshot, creating fully redundant, point-in-time copies, which can be used to recover from disaster. SFW also supports Microsoft's VSS framework for creating consistent snapshots.

Snapshots can be created directly from the SFW GUI, also known as the Veritas Enterprise Administrator (VEA), or by using the *vxsnap* command line utility. Multiple snapshots can be created simultaneously, so that snapshots of interdependent volumes can maintain consistency.

Prior to creating snapshots, the prepare operation has to be performed to create snapshot mirrors of the volumes. This operation only has to be performed once; the snapshot volumes remain attached to and synchronized with the original volumes until a snapshot operation is performed. After a snapshot is done, the volumes are separated, but remain associated with the original volumes so that they can later be resynchronized to either update them or recover from a disaster.

### *Creating snapshots from the GUI (VEA)*

To create snapshots of the VHD volumes, perform the following steps:

- 1) Open the Veritas Enterprise Administrator – Start>Programs>Symantec>Veritas Storage Foundation>Veritas Enterprise Administrator
- 2) Connect to the server running in the parent partition
- 3) Expand Disk Groups in the tree view (left pane)
- 4) Click on the disk group that contains the disks which host the files for the VMs to be backed up
- 5) Select the Volumes tab in the right pane
- 6) Right-click the volume that contains the VHD files and select Snap>Snap Shot from the context menu
- 7) Click Next in the Snap Shot Volume Wizard
- 8) Select any other volumes under Available Volumes that should be included in the snapshot set and click Add to add them to Selected Volumes. Click Next
- 9) Modify attributes in the Change Attributes screen if desired and click Next
- 10) Click Finish

### *Creating snapshots using vxsnap*

Use the following command line syntax to create snapshots with the vxsnap utility:

```
vxsnap -x <Filename> create source=<Volume> [/DriveLetter=<DriveLetter>]/[DrivePath=<DrivePath>]  
[/Newvol=<NewVolName>]/[Plex=<PlexName>]...[-o]
```

#### **Attributes:**

-x <Filename>	Indicates the name to be assigned to the XML metadata file that will be created with the command. The file name must include the ".xml" extension.
source=<Volume>	Indicates the source volume for the split-mirror snapshot specified by a drive letter, drive path (mount point), or volume name of the form "\\?\Volume{GUID}\". Repeat this parameter for each volume associated with the specified component.
[/plex=<PlexName>]	Specifies the name of the mirror or plex that is to be detached. Use this parameter if there are multiple snap plexes available to be snapshotted.
[/DriveLetter=<DriveLetter >]	The drive letter to be assigned to the new snapshot volume.

- [/DrivePath=<DrivePath>] The drive path to be assigned to the new snapshot volume. The drive path must reference an empty local NTFS folder, which was created beforehand. The path must include the drive letter and folder to be mounted, for example, C:\DB1VOL.
- [/Newvol=<NewVolName>] Specifies the name of the new snapshot volume that is created. If the name is not specified using this option, the form "SnapVolume01" is created. The full device path becomes: \Device\HarddiskDmVolumes\  
<DiskGroupName>\<NewVolName>
- o Allows an existing XML file of the same name to be overwritten. If -O is not specified the vxsnap create command does not overwrite an existing XML file of the same name and the operation fails.

**Example:**

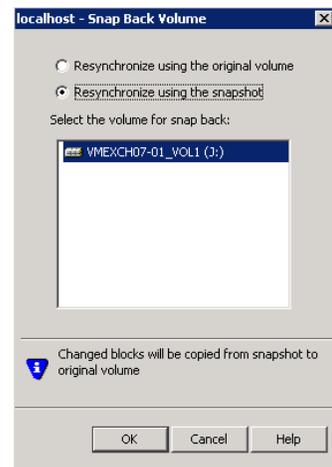
```
Vxsnap -x hyperbackup.xml create source=E: /DriveLetter=J source=F: /DriveLetter=K -o
```

The above command will create simultaneous snapshots of the E: and F: volumes, assigning drive letters J and K to the respective snapshots. The XML metadata file will be given a name hyperbackup.xml. The -o attribute specifies that existing XML files with that name will be overwritten

*Performing snapshot recovery from the GUI*

To recover from snapshots, perform the following steps:

- 1) Open the Veritas Enterprise Administrator – Start>Programs>Symantec>Veritas Storage Foundation>Veritas Enterprise Administrator
- 2) Connect to the server running in the parent partition
- 3) Expand Disk Groups in the tree view (left pane)
- 4) Click on the disk group that contains the snapshot volumes to be used for recovery
- 5) Select the Volumes tab in the right pane
- 6) Right-click a snapshot volume Snap>Snap Back from the context menu
- 7) Select Resynchronize using the snapshot. Click OK
- 8) Click Yes to acknowledge the warning that this will overwrite existing data on the original volume. The volumes will resynchronize and the original volume will be recovered with the data from the snapshot.
- 9) Repeat steps 6 – 8 for the other volumes in the snapshot set



### *Performing snapshot recovery with vxsnap*

Use the following command to restore the volumes in a snapshot set:

```
vxsnap -x <Filename> [-f] [-b] restore
```

#### Attributes:

- |               |  |
|---------------|--|
| -x <Filename> | The file created by the vxsnap create command. Each snapshot set must have a unique name for the metadata file.                      |
| -f            | Forces the snapback. Make sure the volume is not in use by another application before using this command. Use this option with care. |
| -b            | Resynchronizes the volume in the background. A new snapshot cannot be made until the resynchronization is complete.                  |

#### Example:

```
Vxsnap -x hyperbackup.xml restore
```

The above command will restore the volumes in the snapshot set associated with the XML metadata file hyperbackup.xml.

Additional information on snapshots can be found in the Veritas Storage Foundation and High Availability 5.1 for Windows Administrator's Guide.

## **Replicating Virtual Machines**

Copying data across distances lays a foundation for disaster recovery at the site level. While there are host based technologies for replicating data across distances, they're usually expensive, requiring not only more storage, but also exactly the same hardware at both ends. They can also be limited in their ability to provide a solution that accounts not only for the data, but also for the applications that access it.

Veritas Volume Replicator runs at the host level, making it possible to replicate data volumes across distances to provide a means to extended disaster recovery without requiring that the hardware be exactly the same at both ends, and generally requiring less storage. But, while this works fine to protect application data in the guest, allowing recovery at the remote site, running in the guest does nothing to protect the virtual machine.

By installing SFW and VVR in the parent partition, volumes that contain VHD files used for virtual machines and/or application data can be selectively replicated to remote sites, either synchronously or asynchronously, over an IP network. VVR uses a log, the Replicator Log or SRL, to store all writes to the volumes grouped together in what is known as a

Replicated Volume Group in the correct order and replicate them to the remote (secondary) site, maintaining write order fidelity, and thereby, consistency. The replicated VMs remain offline at the secondary site until required to be brought online, either due to an intentional migration of services from the primary site, or due to an outage at the primary site, requiring the secondary to take over services.

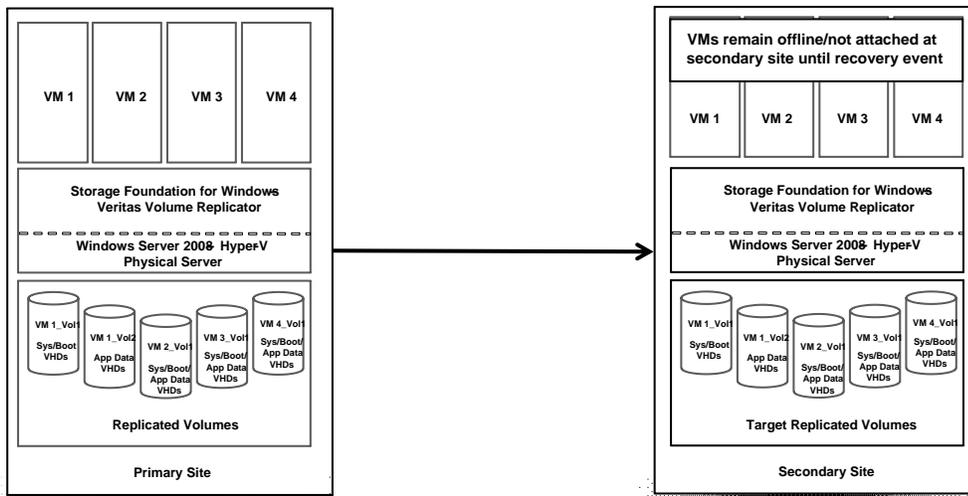


Figure 3. VVR in the Parent Partition

### Migrating the Primary Role

For planned outages at the primary (active) site, perhaps for a maintenance window, the primary role can be migrated to a secondary site, allowing the virtual machines that have been replicated to be brought online and applications that run on them to access data that has also been replicated to the secondary.

### Disaster Recovery Takeover

For unplanned outages at the primary site, operations can be moved to a secondary site via a takeover operation, which turns the secondary into an active primary, allowing VMs to be brought online. Depending on the mode of replication, they can either be completely up to date or behind the previous primary. In either event, consistency will be maintained and applications will be able to successfully attach to their data. The primary can be migrated back to the original site when it becomes available.

### Migrating VMs to New Storage

With its ability to move volumes to new storage locations via the Move Subdisk feature, running SFW in the parent partition allows virtual machines to be moved to new storage without the need to take the VM offline. This gives administrators a lot of flexibility when deploying new hardware, as running VMs can be moved to a new, higher performing array or to LUNs which are configured differently for performance reasons.

### SmartMove

Veritas Storage Foundation 5.1 for Windows also includes the SmartMove feature, which makes resynchronization time for mirror operations directly proportional to the amount of space used by the file system i.e. the less blocks used, the quicker the resynchronization. SmartMove interacts with NTFS to gain knowledge about what portion of the volume it's using and synchronizes only those blocks. A volume with SmartMove that is 50% used by the file system will take half the time it would take for a similar volume without SmartMove to resynchronize during a mirror operation. This allows for improved performance during operations that leverage mirror functionality, such as data migration or snapshot resynchronization.

### Drag and drop

SFW makes it easy to relocate volumes by using the GUI to drag and drop volume subdisks from one storage location (LUN or disk) to another while the volume remains online and accessible. The process uses SFW's mirror functionality to create a mirror of the volume subdisk at the new location. After resynchronization completes, it removes the mirror plex at the original location, leaving the plex at the new location as a standalone volume (subdisk)

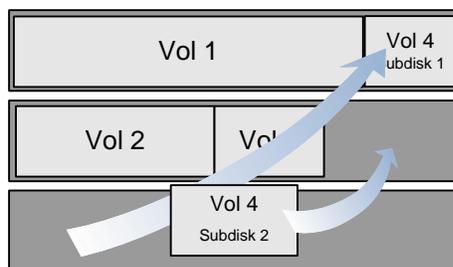
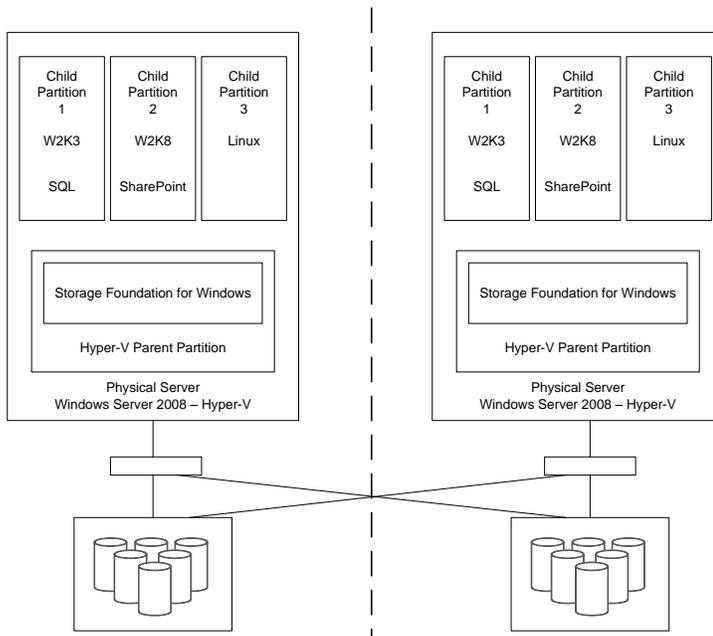


Figure 4. Moving Subdisks

In the above figure, the Move Subdisk feature is used to move the subdisks onto free space on the other two disks; all done while the volume remains online and accessible.

### Campus Clusters

Another advantage of using a host based volume manager such as Veritas Storage Foundation for Windows is the ability to mirror volumes across arrays. This allows clusters which rely on shared storage to be stretched beyond the confines of a single datacenter to a datacenter located at a remote site, as long as the distance between the two datacenters doesn't exceed fiber channel latency limitations. These stretched clusters are also known as Campus Clusters, and provide a level of high availability that can withstand a complete site failure.



**Figure 1. Parent Partition Campus Cluster**

With Storage Foundation for Windows running in the parent partition, it can facilitate stretching of the Failover Cluster to another site by providing support for dynamic disks through its Volume Manager Disk Group cluster resource. With dynamic disks now available

in the cluster, volumes can be mirrored across arrays which are located in different datacenters and are seen and shared by cluster nodes located in those respective datacenters. If the active site should experience a failure, virtual machines that were running at that site can be failed over to the cluster node at the other datacenter, and applications running on them can be brought back online.

### **Summary**

Complexities of managing storage in virtual environments built on hypervisors that abstract hardware resources for the guests can be a hindering factor for businesses considering the jump to server virtualization. By allowing Storage Foundation for Windows into the parent partition, Hyper-V leapfrogs over other solutions when it comes to providing protection for the virtual machines that run in its child partitions. With features such as multi-pathing with Dynamic Multi-Pathing (DMP), snapshots for quick recovery with FlashSnap, site to site replication of virtual machines with Volume Replicator and dynamic disk support in Failover Cluster, Hyper-V becomes a more robust virtualization platform and a real contender among the major solutions available today.

### **Glossary**

- Child Partition – Guest operating systems are run in the child partition. Child partitions communicate with physical resources via the VMBus (see below) or the hypervisor. The child partition is created by the Parent partition.
- Hypercall – An interface by which the guest communicates with the hypervisor to request actions or information – The hypercall interface accommodates access to the optimizations provided by the hypervisor.
- Hypervisor – A software layer that sits directly on top of the hardware layer and abstracts it so that multiple guest operating systems above can share access to the host's hardware. In Hyper-V, it isolates environments into partitions and controls access to the underlying hardware.
- IC – Integration component – Function that allows child partitions to communicate with other partitions and the hypervisor. Integration components include Time Synchronization, Heartbeat, Shutdown, Key/Value pair Exchange and Volume Shadow Copy Service (VSS).

- Integration Services – Integration services are installed in child partitions that run supported guest operating systems. They communicate with virtual devices in the parent partition and provide support for components that require a secure interface between parent and child partitions.
- I/O stack – Input/Output stack
- Root Partition – Also known as the parent partition, the root partition manages functions such as device drivers, power management, and the addition and removal of devices at the host level. The root is the only partition that has direct access to physical memory and devices at the host.
- VMBus (Virtual Machine Bus) – Installed with Hyper-V Integration Services, the VMBus is used for communication between partitions and enumerating devices on systems that have multiple partitions. The VMBus is installed with Hyper-V Integration Services.
- VCP – Virtualization Service Provider – Runs in the parent partition and connects to the VMBus to handle requests for device access from child partitions.
- VSC – Virtualization Service Client – VSCs reside in a child partition and utilize hardware resources that are provided by Virtualization Service Providers (VSPs) in the parent partition to satisfy I/O requests by a child partition. Communication takes place over the VMBus.

## Resources

Hyper-V Architecture – <http://msdn.microsoft.com/en-us/library/cc768520.aspx>

Microsoft System Center Virtual Machine Manager 2008 Datasheet –  
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Microsoft Windows Server 2008 R2 Hyper-V Live Migration white paper

Microsoft Windows Server 2008 Quick Migration with Hyper-V white paper

Microsoft System Center Virtual Machine Manager 2008 Reviewer's Guide

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