

VMware® vSphere™ vMotion™ : 5.4 times faster than Hyper-V™ Live Migration



Businesses using a virtualized infrastructure have many reasons to move active virtual machines (VMs) from one physical server to another. Whether the migrations are for routine maintenance, balancing performance needs, work distribution (consolidating VMs onto fewer servers during non-peak hours to conserve resources), or another reason, the best virtual infrastructure platform executes the move as quickly as possible and with minimal impact to end users.

We tested two competing features that move active VMs from one server to another, VMware vSphere 5 vMotion and Microsoft® Windows Server® 2008 R2 SP1 Hyper-V Live Migration. While both perform these moves with no VM downtime, in our testing the VMware solution did so faster, with greater application stability, and with less impact to application performance – clearly showing that not all live migration technologies are the same. VMware also holds an enormous advantage in concurrency: VMware vSphere 5 can move eight VMs at a time while a Microsoft Hyper-V cluster node can take part only as the source or destination in one live migration at a time. In our two test scenarios, the VMware vMotion solution was up to 5.4 times faster than the Microsoft Hyper-V Live Migration solution.

WHY VM MIGRATION PERFORMANCE MATTERS

Being able to move active VMs as quickly and as seamlessly as possible from one physical server to another with no service interruption is a key element of any virtualized infrastructure. With VMware vSphere, maintenance windows are kept shorter and service level agreements (SLAs) are maintained or even improved because your virtual infrastructure platform is shifting your VM workloads faster and with more stability.

- **Maintenance windows.** Maintenance windows are critical slices of time where vital work is performed on the hardware that fuels your core business; the smaller the maintenance window, the better. These maintenance windows require time buffers on both ends for evacuating your hosts, then redistributing workloads afterwards. This is where VM migration performance is critical. The industry is trending towards denser virtualization; with Hyper-V Live Migration, these larger numbers of VMs take longer and longer to move to other servers. However, with the high performance of vMotion with VMware vSphere, you can keep maintenance windows to a minimum, moving VMs up to 5.4 times faster than with Hyper-V.
- **SLAs.** The indicator of your level of quality is the SLA with your customer, and your ability to keep this SLA is critical. Adaptive workload balancing, such as VMware vSphere Distributed Resource Scheduler (DRS), uses migration technologies to balance workloads across your hosts. This ever-changing, dynamic balancing act must happen as quickly and efficient as possible – vMotion with VMware vSphere is a key enabler of DRS. vSphere shows superior speed and quality of service over Hyper-V, as we demonstrate in this report.
- **Low-impact migrations.** Whatever the reason for moving your VMs, whether for maintenance or for SLA and quality of service, the end user should experience as little impact as possible from the migration. In our tests, application performance degradation during the migration window, as we show in this report, was significantly greater with Hyper-V than with vSphere.

VMWARE VMOTION ARCHITECTURE AND FEATURES

VMware vMotion transfers the entire execution state of the virtual machines being migrated. To do this, VMware breaks down the elements to be transferred into three categories: the virtual device state of the VM, the networking and SCSI device connections, and the physical memory of the VM.

The virtual device state includes the state of the CPU and hardware adapters, such as network adapters and disk adapters. The contents of the virtual device state are typically quite small and can be transferred quickly. The networking and SCSI device connections of the VM can also be quickly transferred, given that the MAC address of the VM is independent of the hosts' MAC addresses; the switch is simply informed by

the destination host via a RARP packet of the VM migration and shared storage makes seamless disk connection changes possible.

The largest data component transferred as part of a vMotion event is the physical memory. To accomplish this transfer, VMware implements the technology in stages: first is a guest trace phase where memory pages are traced to track alterations in data; next is an iterative precopy phase where memory pages are copied to the destination host and then copies are repeated to capture changes pages during the prior copies; and finally comes the switchover phase, where the VM actually switches from one host to another. For more details on vMotion architecture, see the paper *VMware vSphere vMotion Architecture, Performance and Best Practices in VMware vSphere 5*.¹

In vSphere 5, VMware has added new features to improve its already solid vMotion technology. Some of the most important features include the following:

- **Multi-NIC vMotion capabilities.** New with VMware vSphere 5, the hypervisor uses multiple NICs to push vMotion traffic over the vMotion network as fast as possible, using all available bandwidth on your multiple vMotion NICs. You simply assign multiple NICs to vMotion traffic in vSphere, and need not make any changes on the physical switch. For our testing, we used only a single 10Gb NIC and still achieved superior migration performance over Hyper-V.
- **Metro vMotion - support for higher-latency links.** New with VMware vSphere 5, vMotion support now extends to links with latencies of up to 10 milliseconds, adding flexibility for customers moving VMs across metropolitan distances.
- **Stun During Page Send (SDPS).** In the rare case that a VM workload modifies memory pages faster than they can be transferred over the high-speed vMotion network, vSphere 5 will slow the VM activity by injecting tiny sleeps in the vCPU of the VM, allowing the vMotion to complete.

HOW WE TESTED

To explore the migration speed and stability advantages of VMware vMotion over Hyper-V Live Migration, we tested two scenarios: a host evacuation test and a tier-one application test. For each scenario, we set up three servers in a cluster for each platform, along with their respective management tools: vCenter Server and System Center Virtual Machine Manager (SCVMM). Each server contained a single dedicated 10Gb network interface card (NIC) for vMotion or Live Migration. In both testing scenarios, we used DVD Store Version 2 (DS2),² a benchmark that measures database performance. Whereas some other benchmarking tools exercise only certain elements of a system, such as CPU or storage, this database benchmarking tool is an ideal

¹ <http://www.vmware.com/files/pdf/vmotion-perf-vsphere5.pdf>

² For more details about DS2, see <http://www.delltechcenter.com/page/DVD+Store>.

workload for testing real-world VM migration, as it exercises all elements of the solution, just as real-world applications do: CPU, memory, networking, and disk.

In the host evacuation test, each of the three servers ran 10 two-vCPU VMs (30 VMs total in the cluster), sized as follows: seven VMs were assigned 4 GB of RAM, two VMs were assigned 8 GB of RAM, and one VM was assigned 16 GB of RAM. Knowing that users and applications do not perform the same as benchmarking tools, we throttled back our workloads across our VM mix to reflect a more realistic scenario. By injecting “think time,” or artificial waits, into the benchmarking tool, we more closely simulated real users and real applications doing real work. We varied our think time mix across our VM mix (see Figure 1 on the next page) to provide for three profiles: an idle load, light load, and medium load. The idle profile loads were VMs with their database working set resident in RAM but otherwise idle. The light profile loads ran the workload with 500ms think time. The medium profile loads ran the workload with only 100ms think time, doing much more work than the medium profile loads by spending less time waiting between operations. We performed this test on both our Hyper-V environment and our vSphere environment.

In the tier-one application test, we simulated a tier-one, heavily utilized, mission-critical workload. To do this, we ran one large four-vCPU VM on one server with 16 GB of RAM and a 16GB database. To show heavier usage in this scenario, we ran a heavier workload with more execution threads and no user think time, as we discuss further below. We performed this test on both our Hyper-V environment and our vSphere environment.

Host evacuation scenario

All VMs ran Windows Server 2008 R2 SP1 and Microsoft SQL Server® 2008 R2. All 30 VMs contained copies of the DS2 database in varying sizes: the 4GB VMs contained a 4GB database, the 8GB VMs contained an 8GB database, and the 16GB VM contained a 16GB database. Using DS2, we warmed up each of the 30 VMs for a period of time to allow the VM’s memory pages to be utilized (see [Appendix F](#) for details on the warm-up period). Then we left 1 VM on each server idle and ran DS2 against the remaining 27 VMs (9 on each server) during the migration window, and varied the think time parameter to the DS2 workload. We created this mix to simulate a real-world system containing idle, light, and medium workloads running on VMs of different sizes. All workloads ran with 10 DS2 threads. We designated Server 1 as the server to evacuate and relied on vSphere DRS and Microsoft SCVMM to use their respective method of redistributing the VMs. Figure 1 provides details of the specifics of our varied workload mix.

	VM RAM (GB)	DVD Store database size (GB)	Number of vCPUs	Threads	Workload mix (think time during migration (ms))
Server 1					
VM 1	4	4	2	10	Idle
VM 2	4	4	2	10	500
VM 3	4	4	2	10	500
VM 4	4	4	2	10	500
VM 5	4	4	2	10	100
VM 6	4	4	2	10	100
VM 7	4	4	2	10	100
VM 8	8	8	2	10	500
VM 9	8	8	2	10	100
VM 10	16	16	2	10	100
Server 2					
VM 11	4	4	2	10	Idle
VM 12	4	4	2	10	500
VM 13	4	4	2	10	500
VM 14	4	4	2	10	500
VM 15	4	4	2	10	100
VM 16	4	4	2	10	100
VM 17	4	4	2	10	100
VM 18	8	8	2	10	500
VM 19	8	8	2	10	100
VM 20	16	16	2	10	100
Server 3					
VM 21	4	4	2	10	Idle
VM 22	4	4	2	10	500
VM 23	4	4	2	10	500
VM 24	4	4	2	10	500
VM 25	4	4	2	10	100
VM 26	4	4	2	10	100
VM 27	4	4	2	10	100
VM 28	8	8	2	10	500
VM 29	8	8	2	10	100
VM 30	16	16	2	10	100

Figure 1. Details about the host evacuation test scenario.

During the main workload mix portion of DVD Store testing, we initiated a maintenance mode event on our source server; on both the VMware vSphere and Microsoft Hyper-V platforms, this induced an evacuation of all 10 VMs on the source

server. We measured the time it took for all 10 VMs to migrate from the source server to the remaining two destination servers on each platform.

Tier-one application scenario

We installed Windows Server 2008 R2 SP1 and SQL Server 2008 R2 on one VM and increased the compute resources available to this one VM. The large VM had four vCPUs, 16 GB of RAM, and contained a 16GB DVD Store database. Using DVD Store, we warmed up this VM for a period of time to ensure the VM’s memory pages were adequately utilized (see [Appendix F](#) for details on the warm-up period), and ran a heavy DS2 workload, consisting of 50 threads running with no think time, during the migration window. We designated Server 1 as the server to use for evacuation and relied on each platform, vSphere VMware or Microsoft Hyper-V, to use its respective method of redistributing this large VM to another server in the cluster.

Additionally, we measured the application performance of the VM in this scenario, including user-perceived performance metrics, in this case “orders per minute” as reported by the DS2 benchmarking tool. To capture more granular user-perceived performance, we modified the DS2 source code to output orders per second. Figure 2 provides details of the specifics of our large VM heavy workload mix.

	VM RAM (GB)	DVD Store database size (GB)	Number of vCPUs	Threads	Workload mix (think time) during migration (ms)
VM 1	16	16	4	50	0

Figure 2. Details about the tier-one application scenario.

VMOTION WAS FASTER

As Figure 3 on the following page shows, in the host evacuation scenario, migration using VMware vSphere vMotion was 5.4 times faster than Microsoft Hyper-V Live Migration in evacuating all 10 VMs from Server 1. At its peak, vMotion was transferring eight VMs concurrently, versus Hyper-V Live Migration, which was transferring just one VM at a time.

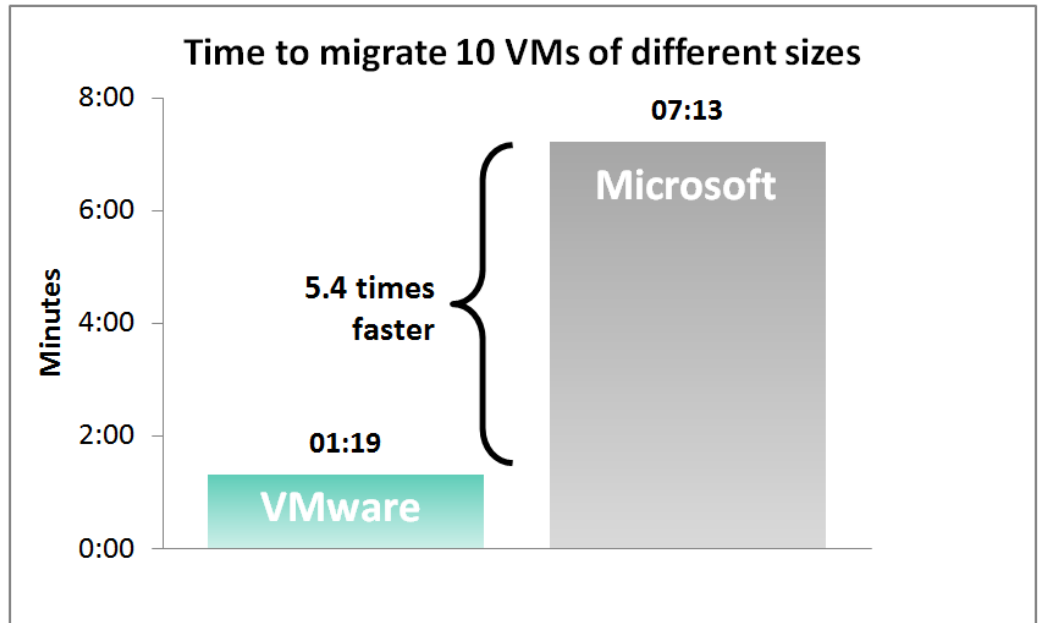


Figure 3. Migration time for 10 VMs, in minutes, for the two platforms in the host evacuation scenario. Less time is better.

As Figure 4 shows, in the tier-one application scenario, migration using VMware vSphere vMotion was 3.4 times faster than Microsoft Hyper-V Live Migration.

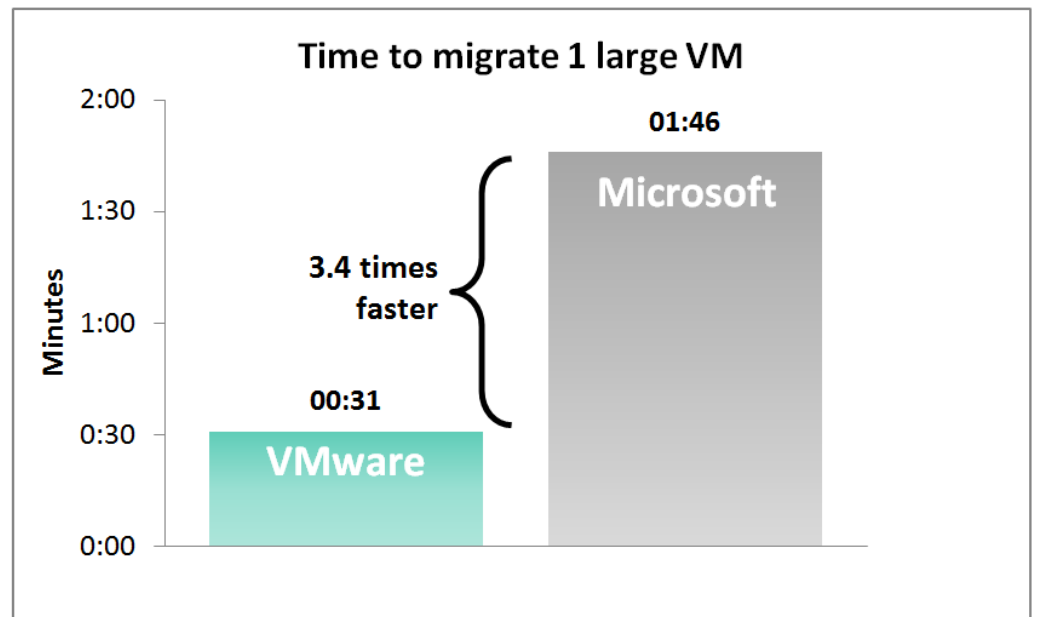


Figure 4. Migration time for one VM, in minutes, for the two platforms in the tier-one application scenario. Less time is better.

In addition to the much faster migration time that VMware vSphere vMotion delivered, this platform also provided a much less disruptive and more productive

experience to end users. Figure 5 shows application performance of a single VM in the tier-one application scenario over roughly 4 minutes; migration begins 1 minute into this period. With vSphere vMotion, performance dips for one very brief period, and then returns to its previous high level.

With Hyper-V Live Migration, once migration begins, performance drops off briefly, climbs to roughly 80 percent of its pre-migration level, and then drops again for an extended period. It then returns to pre-migration levels. This extended period of application disruption could cause service disruption for some environments.

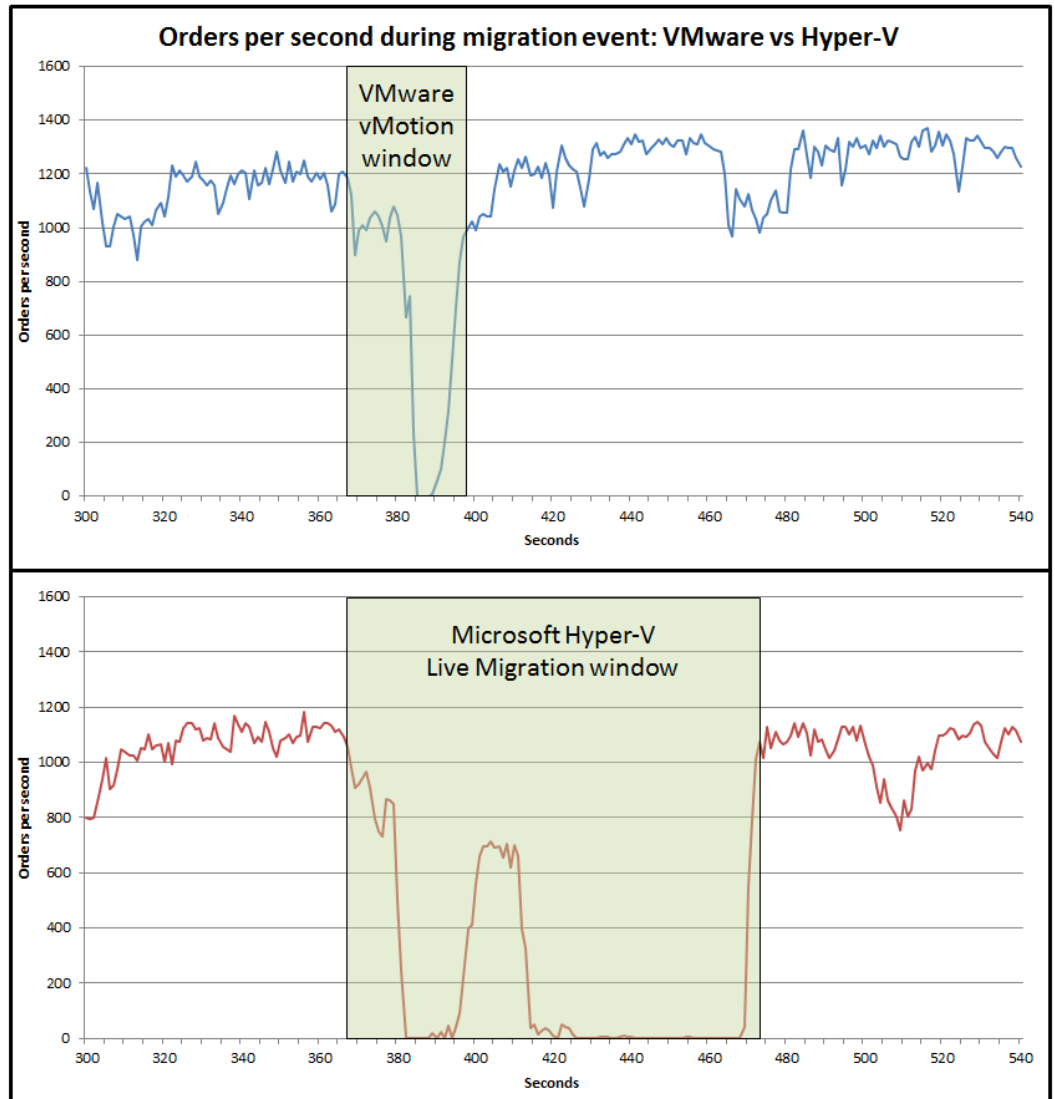


Figure 5. Application performance for the VMware vMotion and Microsoft Hyper-V, in orders per second, before, during, and after migration. Higher orders per second and less time are both better.

Finally, as Figure 6 shows, in the tier-one application scenario, the greater speed at which VMware vSphere migrates VMs benefits users and their applications from a

performance and throughput perspective. In our tier-one application scenario, the increased Hyper-V Live Migration application degradation allows VMware vSphere to achieve over 63 percent more orders than Microsoft Hyper-V during this four minute migration period.

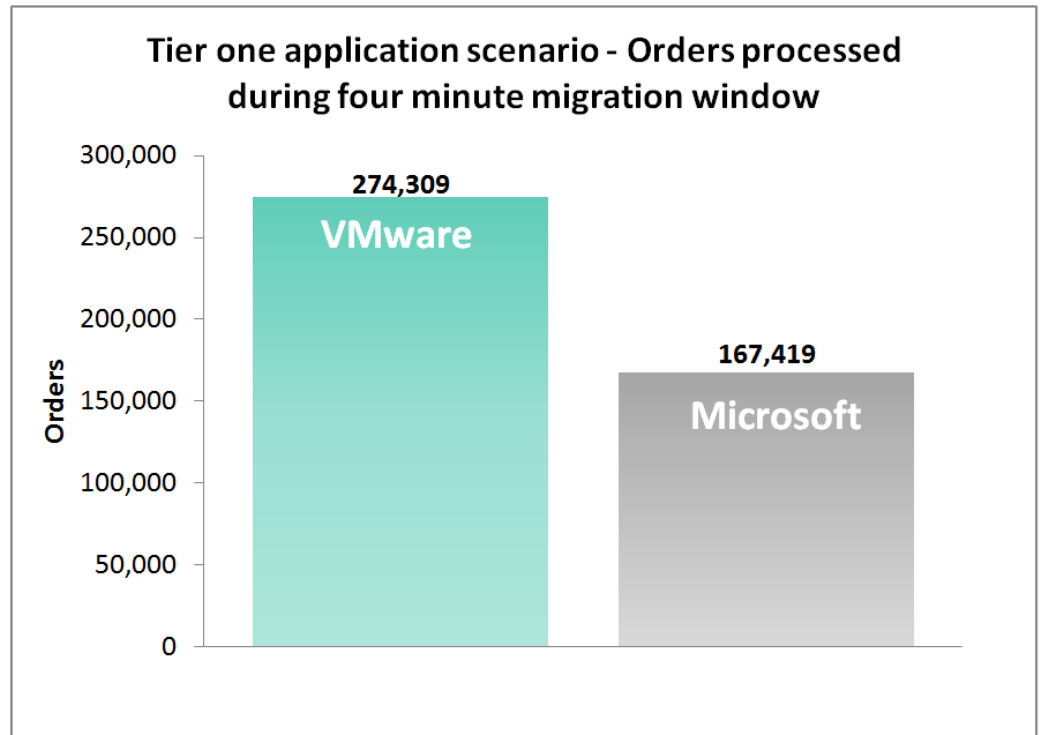


Figure 6. Tier one application scenario - Total orders processed during the 4 minutes surrounding the migration event for both VMware vSphere and Microsoft Hyper-V. More orders are better.

APPLICATION STABILITY

During our testing on the host evacuation scenario, we also tracked VM stability at a high level. While we know migrations affect application performance to some degree, we wanted to see whether the migration process functioned as advertised to keep all VMs up and running and available for use during migrations. The answer to this question for VMware was a resounding yes. In the host evacuation scenario for VMware, all of our 30 VMs remained up and running, successfully serving application requests as they migrated from host to host, and after the migration throughout the test duration.

Hyper-V migrations did not achieve this 100 percent success rate. On every Hyper-V test we conducted under the host evacuation scenario, at least one VM failed with a “blue screen of death” (see Figure 7). The failed VM typically migrated successfully to the new host, but within a few minutes of migration experienced a fatal

error and restarted, immediately causing the workload to fail. This failure was reproducible, in that it occurred on each of our three iterations for the Hyper-V host evacuation scenario. However, it was also unpredictable, in that the same VM did not fail every time.

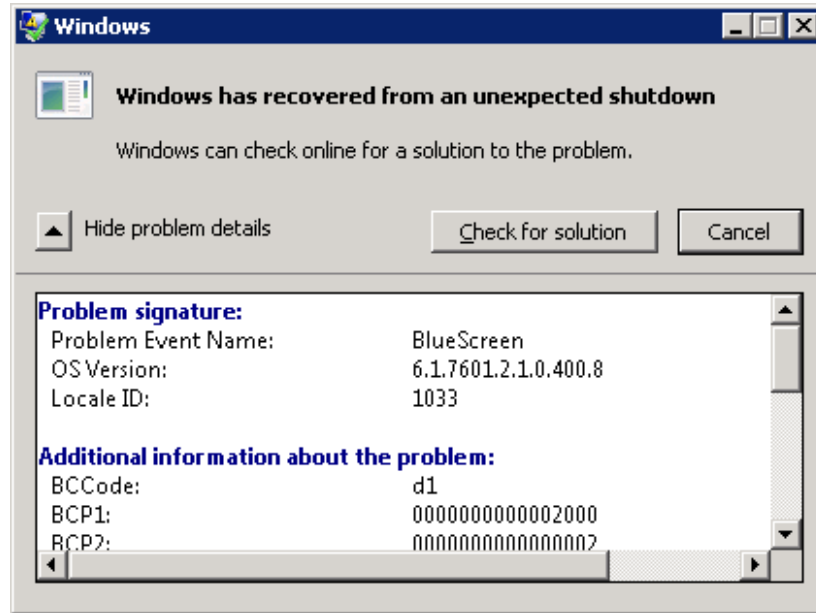


Figure 7. Blue screen error from Microsoft Hyper-V VM during the host evacuation scenario.

CONCLUSION: VSPHERE IS MORE RELIABLE

The ability to move active VMs between physical servers greatly enhances your ability to meet the demands of your business, and can even conserve resources by shifting workloads to optimize power usage. Choosing a virtual infrastructure platform that executes these moves quickly and with minimal impact to application performance is critical. Our tests show that VMware vSphere 5 not only meets these requirements with its latest vMotion functionality, but delivers performance superior to that of Microsoft Hyper-V Live Migration, in terms of both time to migrate and end-user experience. This superior performance is due to the ability to migrate multiple VMs concurrently, a highly optimized migration design, and maturity of vMotion over many releases.

APPENDIX A – TEST CONFIGURATION OVERVIEW

Figure 8 presents our test infrastructure. We used 21 load generator client virtual machines for the host evacuation scenario. Because of our differing workload mixes with different incoming parameters to the DVD Store workload, each client VM targeted either one or two target VMs. We first tested the VMs on VMware vSphere 5, and then on Microsoft Windows Server 2008 R2 SP1 (build 6.1.7601). We ran both environments, one by one, on the same hardware.

Where necessary, we took advantage of the ability of DVD Store 2.1 to exercise multiple VMs with each instance targeting two databases. Each client VM was a two-vCPU VM running with 4 GB of RAM, running Windows Server 2003 R2 SP2 with the .NET framework 3.5 SP1 installed.

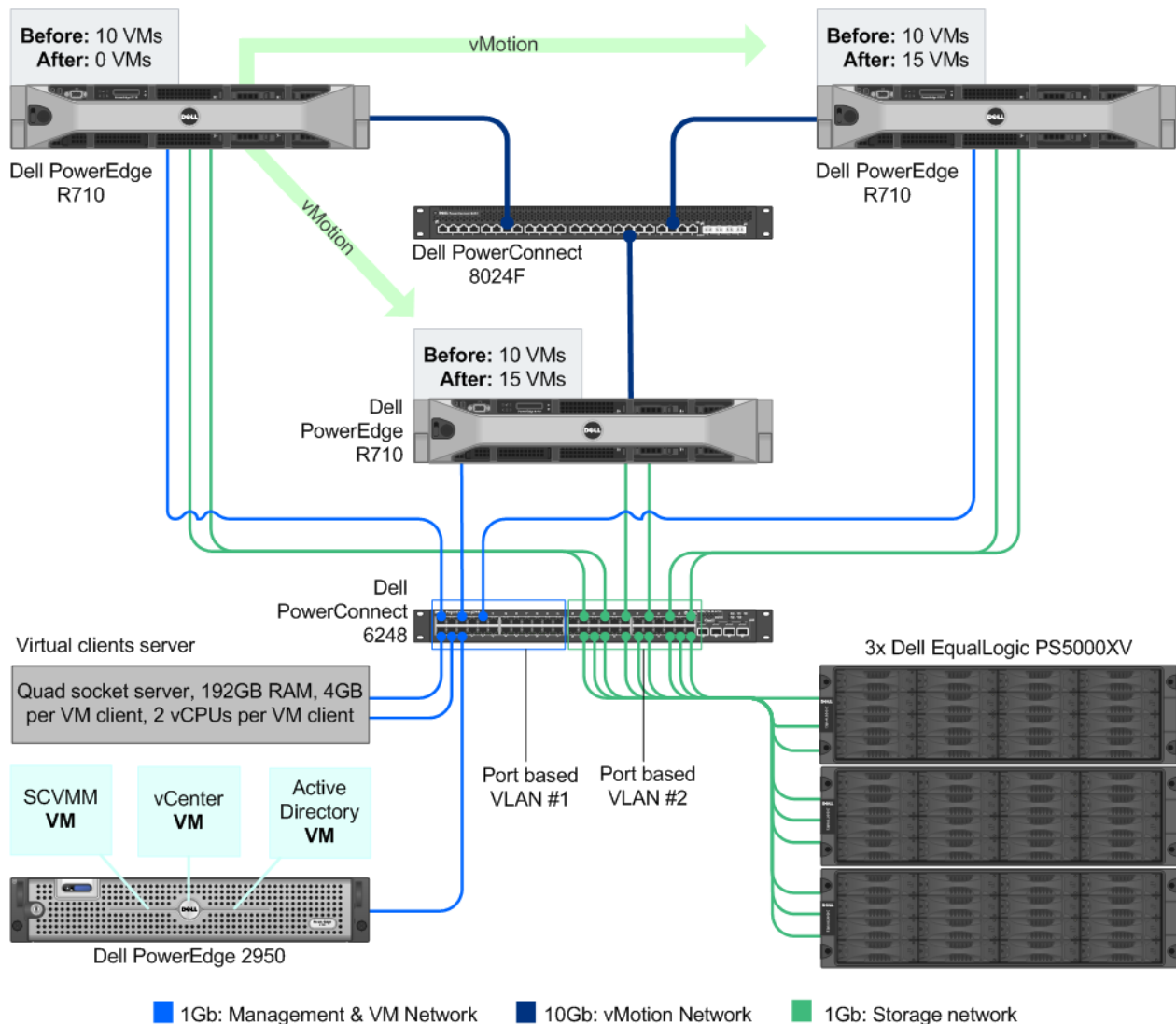


Figure 8. The test infrastructure we used for both the VMware vSphere 5 vMotion and Microsoft Hyper-V Live Migration testing.

APPENDIX B – SETTING UP THE STORAGE

Three Dell PowerEdge R710 servers and Dell EqualLogic PS5000XV storage configuration overview

Our complete storage infrastructure consisted of four internal drives in each of the three servers, a PERC 6/i internal RAID controller in each server, two onboard Broadcom® NICs dedicated to iSCSI traffic, a Dell PowerConnect™ 6248 switch with a port-based VLAN dedicated to iSCSI traffic, and a port-based VLAN dedicated to VM and management traffic, and three Dell EqualLogic™ PS5000XV storage arrays. Figure 8 on the previous page shows the complete layout of our test infrastructure.

We configured the internal drives on the servers in two RAID 1 volumes, each volume containing two physical disks. We dedicated one volume to the VMware vSphere 5 partition, and the other to the Microsoft Windows Server 2008 R2 SP1 partition. To switch between environments during testing, we toggled the assigned boot volumes on each server's RAID controller BIOS.

For external storage, we used three Dell EqualLogic PS5000XV arrays, each containing 16 drives. We cabled each Dell EqualLogic PS5000XV to the Dell PowerConnect 6248 switch via their three available ports, and we cabled each server to the same switch using two onboard server NICs for iSCSI traffic. For specifics on multipathing drivers used on each platform, see the sections below specific to each server setup.

We enabled jumbo frames on each server's two iSCSI-dedicated NICs. To do this in Windows, we adjusted the MTU to 9,000 via the NIC properties window, while in vSphere we adjusted the MTU for the relevant vSwitches and the bound VMkernel ports. We also enabled jumbo frames on the relevant iSCSI-dedicated ports on the Dell PowerConnect 6248 switch, and on each NIC on the Dell EqualLogic PS5000XV storage. For specific configurations on the Dell PowerConnect 6248, we used the recommended settings from the document *Dell EqualLogic Configuration Guide, Appendix E: PowerConnect 62xx Switch Configuration*.

Each Dell EqualLogic PS5000XV contained 16 drives. We configured each Dell EqualLogic PS5000XV in RAID 10 mode. We created two storage pools, one containing an array with 10K drives, and the other storage pool containing two arrays with 15K drives.

For volumes, we created the following for each hypervisor:

- In storage pool 1, 4 x 460GB volumes to be used to hold virtual machine operating system virtual disks
- In storage pool 2, 4 x 750GB volumes to be used to hold virtual machine SQL Server database file virtual disks, SQL Server transaction log virtual disks, and a utility virtual disk for each VM.

Setting up the internal storage for host operating system installation

1. Enter the RAID controller BIOS by pressing Ctrl+R at the relevant prompt during boot.
2. Highlight Controller 0, and press F2.
3. Select Create New VD.
4. Select the first two drives, select RAID level 1, tab to the OK button, and press Enter. Accept the warning regarding initialization.
5. Select the new virtual drive, press F2, and select Initialization→Start Init.
6. Wait for the initialization operation to complete.
7. Repeat steps 2 through 6 for the remaining internal volume, selecting drives three and four.
8. Press Escape, and choose Save and Exit to return to the boot sequence.
9. Repeat steps 1 through 8 on each server.

Setting up the external storage

1. Using the command-line console, via serial cable, reset the first Dell EqualLogic PS5000XV by using the reset command.
2. Supply a group name, group IP address, and IP address for eth0 on the first of three arrays.
3. Reset the remaining two arrays in the same manner, supply the group name to join and IP address created in Step 2, and supply an IP address in the same subnet for eth0 on each remaining tray.
4. After group creation, using a computer connected to the same subnet as the storage, use the Dell EqualLogic Web interface to do the following:
 - a. Assign IP addresses on the remaining NICs (eth1 and eth2) on each array. Enable the NICs.
 - b. Verify matching firmware levels on each array and MTU size of 9,000 on each NIC on each array.
 - c. To create two storage pools, right-click Storage pools, select choose Create storage pool. Designate one storage pool for VM OS. Designate the other storage pool for VM SQL Server data, SQL Server transaction logs, and the utility virtual disk.
 - d. Click each member (array), and choose Yes when prompted to configure the member. Choose RAID 10 for each array.
 - e. Assign the two arrays containing 15K drives to the SQL Server data storage pool. Assign the one array containing 10K drives to the VM OS storage pool.
 - f. Create eight 750GB volumes in the database storage pool—four for VMware vSphere 5 usage and four for Microsoft Hyper-V R2 SP1 usage.
 - g. Create eight 460GB volumes in the OS storage pool—four for VMware vSphere 5 usage and four for Microsoft Hyper-V R2 SP1 usage.
 - h. Enable shared access to the iSCSI target from multiple initiators on the volume.
 - i. Create an access control record for the volume without specifying any limitations.
 - j. During testing, offline the volumes not in use by the current hypervisor.

APPENDIX C – SETTING UP THE MICROSOFT WINDOWS ENVIRONMENT

Adjusting BIOS settings

We used the latest released BIOS updates on each of the three Dell PowerEdge R710s, version 3.0.0, and adjusted the default BIOS settings. We enabled Virtualization Technology, disabled C-States, and set the performance profile to maximum performance on each server.

Setting up and configuring an Active Directory VM

Windows Failover Clustering requires an Active Directory® domain server. We configured a virtual machine to be used as an Active Directory server on a separate utility hypervisor.

Installing Windows Server 2008 R2 SP1 on the Active Directory VM

1. Create a VM on a separate hypervisor host, choose two vCPUs, 4GB RAM, and 30GB virtual disk size.
2. Install the operating system on the VM.
 - a. Insert the installation DVD for Windows Server 2008 R2 SP1 into the DVD drive. Mount the DVD to the guest VM.
 - b. Power on the VM, choose the language, time and currency, and keyboard input. Click Next.
 - c. Click Install Now.
 - d. Choose Windows Server Enterprise (Full Installation), and click Next.
 - e. Accept the license terms, and click Next.
 - f. Click Custom.
 - g. Click the Disk, and click Drive options (advanced).
 - h. Click New→Apply→Format, and click Next.
 - i. Let the installation process continue. The server will reboot several times.
 - j. After the installation completes, click OK to set the Administrator password.
 - k. Enter the administrator password twice, and click OK.
 - l. Install hypervisor integration tools on the VM, such as VMware tools if using ESXi as the utility hypervisor, or Hyper-V Integration services if using Hyper-V as the utility hypervisor. Restart as necessary.
 - m. Run Windows Updates, and install all available updates.

Configuring TCP/IP and computer name on the Active Directory VM

1. Connect to the AD VM.
2. After the initial installation, you are presented with Initial Configuration Tasks. Click Configure networking.
3. In Network Connections, right-click Local Area Connection, and click Properties.
4. Click Internet Protocol Version 4 (TCP/IPv4), and click Properties.
5. Select Use the following IP address and enter an appropriate IP address, subnet mask, and Preferred DNS.
6. Close the Network Connections window.
7. In Initial Configuration Tasks, click Provide computer name and domain.
8. In System Properties, click Change. In Computer name, type the name of the domain controller machine, click OK twice, and click Close. When you are prompted to restart the computer, click Restart Now.
9. After restarting, log in using the local administrator account.
10. In Initial Configuration Tasks, click Do not show this window at logon, and click Close.

Configuring the Active Directory VM as a domain controller and DNS server

1. Log into the AD VM.
2. In the console tree of Server Manager, click Roles. In the details pane, click Add Roles, and click Next.
3. On the Select Server Roles page, click Active Directory Domain Services, click Add Required Features, click Next twice, and click Install. When installation is complete, click Close.

4. To start the Active Directory Installation Wizard, click Start, type `dcpromo` and press Enter.
5. In the Active Directory Installation Wizard dialog box, click Next twice.
6. On the Choose a Deployment Configuration page, click Create a new domain in a new forest, and click Next.
7. On the Name the Forest Root Domain page, type the desired domain name, and click Next.
8. On the Set Forest Functional Level page, in Forest Functional Level, click Windows Server 2008 R2, and click Next.
9. On the Additional Domain Controller Options page, click Next, click Yes to continue, and click Next.
10. On the Directory Services Restore Mode Administrator Password page, type a strong password twice, and click Next.
11. On the Summary page, click Next.
12. Wait while the wizard completes the configuration of Active Directory and DNS services, and click Finish.
13. When the wizard prompts you to restart the computer, click Restart Now.
14. After the computer restarts, log into the domain using the Administrator account.

Setting up the Hyper-V R2 SP1 host servers

We used the following steps when setting up the three Dell PowerEdge R710s in our Hyper-V cluster.

Installing Windows Server 2008 R2 SP1

1. Insert the installation DVD for Windows Server 2008 R2 SP1 into the DVD drive.
2. Choose the language, time and currency, and keyboard input. Click Next.
3. Click Install Now.
4. Choose Windows Server 2008 R2 Enterprise (Full Installation), and click Next.
5. Accept the license terms, and click Next.
6. Click Custom.
7. Click the Disk, and click Drive options (advanced).
8. Click New→Apply→Format, and click Next.
9. After the installation completes, click OK to set the Administrator password.
10. Enter the administrator password twice, and click OK.
11. Connect the machine to the Internet and install all available Windows updates. Restart as necessary.
12. Enable remote desktop access.
13. Change the hostname, and reboot when prompted.
14. Create a shared folder to store test script files. Set permissions as needed.
15. Set up networking for the network that DVD Store traffic will use:
 - a. Click Start→Control Panel, right-click Network Connections, and choose Open.
 - b. Right-click the VM traffic NIC, and choose Properties.
 - c. Select TCP/IP (v4), and choose Properties.
 - d. Set the IP address, subnet, gateway, and DNS server for this NIC, which will handle outgoing server traffic. Click OK, and click Close.
 - e. Repeat steps b through d for the two onboard NICs to be used for iSCSI traffic, the onboard NIC to be used for Cluster Shared Volumes, and the Fibre Channel 10Gb NIC to be used for live migration.
 - For the iSCSI NICs, assign IP addresses on the same subnet as the storage configuration you configured on the Dell EqualLogic arrays. Open the connection properties, and click configure for each respective NIC. Modify the advanced properties of each NIC, setting the MTU to 9000.
 - For the Live Migration 10Gb NIC, assign the IP for the live migration network. In our testing, we chose 10.10.1.X.
 - For the Cluster Shared Volumes and cluster traffic NICs, assign IPs on the same subnet as the domain controller.
16. Join the active directory domain.

17. After joining the domain and rebooting, log in using the domain administrator credentials.
18. Repeat steps 1 through 17 on the remaining two servers.

Adding the Hyper-V R2 SP1 role

1. Open Server Manager, and click Roles.
2. Click Add Roles.
3. On the Before You Begin page, check the Skip this page by default box, and click Next.
4. Select Hyper-V, and click Next.
5. On the Hyper-V Introduction page, click Next.
6. On the Create Virtual Networks page, click Next.
7. Confirm installation selections, and click Install.
8. Once the installation is complete, click Close.
9. When the system prompts a restart, click Yes.
10. Allow the system to fully reboot, and log in using the administrator credentials.
11. Once the desktop loads, the Hyper-V Installation Results window will finish the installation.
12. Click Close. The Hyper-V role will now be available in Server Manager under Roles.
13. Repeat steps 1 through 12 on the remaining two servers.

Installing the Failover Clustering feature

1. Click Server Manager.
2. At the Features Summary, click Add Features.
3. In the Add Features Wizard, check Failover Clustering, and click Next.
4. On the Confirm Installation Selections, click Install.
5. On the Installation Results screen, click Close.
6. Run Windows Updates, and install all available updates for Hyper-V and Failover Clustering.
7. Repeat steps 1 through 6 on the remaining two servers.

Installing Dell EqualLogic Host Integration Tools for MPIO

1. Log into Windows, and start the Dell EqualLogic Host Integration Tools installer.
2. At the Welcome screen, click Next.
3. At the License Agreement screen, click Next.
4. At the Installation Type screen, select Typical (Requires reboot on Windows Server platforms), and click Next.
5. In the Microsoft iSCSI Initiator service is not running window, click Yes to start the service and enable iSCSI traffic through the firewall.
6. In the Microsoft iSCSI service window, click Yes.
7. When the iSCSI Initiator Properties window pops up, accept the defaults, and click OK.
8. If a Windows Firewall Detected window appears, click Yes to enable echo requests.
9. At the Ready to install the components screen, click Install.
10. In the Microsoft Multipath I/O feature is not detected window, click Yes to install the feature.
11. When installing HIT on a failover cluster node, there will be an additional screen called the Cluster Access Information screen.
12. Enter the appropriate credentials, specify a shared network path, and click Next.
13. At the Installation Complete screen, click Finish.
14. In the System Restart Required window, select Yes, I want to restart my computer now, and click OK.
15. After reboot, open the Dell EqualLogic Host Integration Toolkit remote setup wizard, and click configure MPIO. Under Subnets included for MPIO, ensure only the iSCSI subnet is included in the "include" section.
16. Repeat steps 1 through 15 on the remaining two servers.

Connecting to the volumes with Microsoft iSCSI Initiator

1. Using the Dell EqualLogic Web UI, ensure the Hyper-V-specific volumes are online and the VMware-specific volumes are offline.
2. On the first server, click Start→Administrative Tools→iSCSI Initiator.
3. Select the Discovery Tab, and click Discover Portal.
4. Enter the IP address for the Dell EqualLogic Storage Group, and click OK.
5. Select the Targets tab, and click Refresh.
6. Select the first Inactive Target listed, and click Connect.
7. Ensure that Add this connection to the list of Favorite Targets is selected, check the Enable multi-path check box, and click OK.
8. Repeat until you have connected to all eight volumes, and click OK.

Configuring the external volumes in Windows Server 2008 R2 SP1

1. On the first server, click the Server Manager icon in the taskbar.
2. In the left pane, expand Storage, and click Disk Management.
3. Right-click the first external volume, and choose Initialize Disk.
4. In the right pane, right-click the volume, and choose New Simple Volume.
5. At the welcome window, click Next.
6. At the Specify Volume Size window, leave the default selection, and click Next.
7. At the Assign Drive Letter or Path window, choose a drive letter, and click Next.
8. At the Format Partition window, choose NTFS and 64K allocation unit size, and click Next.
9. At the Completing the New Simple Volume Wizard window, click Finish.
10. Repeat steps 3 through 9 for the remaining external volumes.

Configuring the virtual network

1. In Hyper-V Manager, right-click the server name in the list on the left side of Hyper-V, and choose Virtual Network Manager...
2. Choose External, and click Add.
3. Name the Virtual Network, and choose the appropriate NIC for your VM network from the drop-down menu. We used an onboard NIC on the domain subnet for VM traffic.
4. Click OK.
5. Repeat steps 1 through 4 on each server.

Running the Validate a Configuration Wizard

1. On the first Hyper-V server, open the Server Manager utility.
2. Expand Features, and select Failover Cluster Manager.
3. Click Validate a Configuration...
4. On the Before You Begin page, check the Do not show this page again box, and click Next.
5. At the Select Servers page, type the name of each Hyper-V host server, and click Add. After adding both servers, click Next.
6. On the Testing Options page, select Run all tests (recommended), and click Next.
7. On the Confirmation page, click Next to begin running the validation tests.
8. Once the validation tests complete successfully, click Finish.

Creating and configuring the cluster

1. Ensure all three servers have been prepared with the steps above.
2. On the first Hyper-V server, open the Server Manager utility.
3. Expand Features, and select Failover Cluster Manager.
4. Click Create a Cluster...

5. On the Before You Begin page, check the Do not show this page again box, and click Next.
6. On the Select Servers page, type the name of each Hyper-V host server, and click Add. After adding both servers, click Next.
7. On the Validation Warning page, select No, and click Next.
8. On the Access Point for Administering the Cluster page, enter a cluster name.
9. Select a valid network, enter the desired IP address, and click Next.
10. On the Confirmation page, click Next.
11. Once the new cluster is created and configured, click Finish.
12. The new cluster now appears under Server Manager→Features→Failover Cluster Manager.
13. Select the newly created cluster.
14. Click Enable Cluster Shared Volumes...
15. Read the notice window that appears, check the I have read the above notice box, and click OK.
16. On the left-hand side of the Server Manager window, expand the new cluster, and click Cluster Shared Volumes.
17. Click Add storage.
18. Select the desired disks, and click OK to add the disks to the cluster.
19. Once the Add storage task completes, the added disks will now be listed on the main page for Cluster Shared Volumes.
20. Expand Networks in the left pane, right-click on the first cluster network in the center pane, and click Properties.
21. Determine whether each network will allow cluster network communication and whether clients will be able to connect through the network. For example, using our sample IP scheme, the subnet 192.10.10.X is our iSCSI network, so we selected Do not allow cluster network communication on this network.
 - Take note of which cluster network has the subnet that corresponds to the Private/CSV network, as you will need this information to complete the next step. In our test setup, this subnet is 192.168.20.X and was assigned as Cluster Network 4.
22. Next, designate the Private/CSV network as the preferred network for CSV communication. Click Start→Administrative Tools→Windows PowerShell Modules.
23. Type `Get-ClusterNetwork | ft Name, Metric, AutoMetric, Role` and press Enter to view the current preferred network assignments.
24. Type `(Get-ClusterNetwork "Cluster Network 4").Metric = 900` where "Cluster Network 4" is the Private/CSV Network, and press Enter to set it as the preferred network. Setting the Metric to a lower value than the other networks, in this case a value of 900, will make it the preferred network for CSV communication. To confirm the change, repeat Step 21 and verify that Cluster Network 4 now has a Metric value of 900. For more information, see [http://technet.microsoft.com/en-us/library/ff182335\(WS.10\).aspx](http://technet.microsoft.com/en-us/library/ff182335(WS.10).aspx)
25. Close the PowerShell Module window.

Configuring the first Hyper-V VM

In our testing, we used a mix of 30 VMs with different database sizes, with 10 VMs on each of our three Hyper-V nodes. The 10 VM size breakdown for each server was as follows: one VM with a 16GB database, two VMs with an 8GB database, and seven VMs with a 4GB database. We created one VM, cloned it or copied it on each platform, and modified the RAM settings to reflect the VM mix.

1. On the first Hyper-V host, click Action→New→Virtual Machine.
2. On the Before You Begin window, click Next.
3. Enter the name of the VM, and click Next.
4. Assign 1GB of memory, and click Next. This will later be modified to use Dynamic RAM.
5. Choose the virtual network you created from the drop-down menu, and click Next.
6. Choose to attach a virtual hard drive later.
7. Click Finish.

8. Create the following fixed size VHDs by choosing Action→New→Virtual Hard Drive:
 - a. 20GB VHD stored on storage pool 1 for the VM OS (placed on the assigned OS/log volume)
 - b. 10GB VHD stored on storage pool 2 for backup files (placed on the assigned SQL data/log/backup volume)
 - c. 25GB (35GB for the 16GB database VMs) VHD stored on storage pool 2 for SQL Server data (placed on the assigned SQL data/log/backup volume)
 - d. 15GB (20GB for the 16GB database VMs) VHD stored on storage pool 2 for SQL Server logs (placed on the assigned SQL data/log/backup volume)
9. Right-click the VM, and choose Settings.
10. Add the VM OS VHD to the IDE controller.
11. Add the VM SQL VHD, the VM backup VHD, and the SQL log VHD to the SCSI controller.
12. Click Processors, and adjust the number of virtual processors to 2.
13. Start the VM.
14. Attach the Windows Server 2008 R2 SP1 ISO image to the VM and install Windows Server 2008 R2 on your VM. See [Appendix E](#) for VM-related setup.

Configuring the cluster network for live migration

1. Expand Services and applications.
2. In the left pane, select a VM to configure.
3. In the center pane, right-click the VM, and click Properties.
4. Click the Network for live migration tab, and select the proper cluster network configured with subnet for live migration.
5. Ensure that no other networks are selected, and click OK. This setting applies to all VMs in the cluster, and will not need to be configured for additional VMs.
6. To ensure the functionality of live migration, select Services and Applications in the left pane.
7. Power on a VM, and right-click it in the center pane.
8. Select Live migrate this service or application to another node, and click another node in the cluster.
9. The running VM will transfer to another node.

Setting up the System Center Virtual Machine Manager VM

To manage our Hyper-V cluster, we used a VM running Windows Server 2008 R2 SP1 and Microsoft System Center Virtual Machine Manager 2008 (SCVMM). We installed this VM on a separate utility hypervisor host.

Installing Windows Server 2008 R2 SP1

Follow the OS installation steps for the SCVMM VM provided in the section titled Installing Windows Server 2008 R2 SP1 on the Active Directory VM, and ensure that all Windows Updates are applied. Rename the system, assign a proper IP address, and join the domain.

Installing the prerequisites for SCVMM 2008

Install the following prerequisites using Server manager to add roles and features prior to installing SCVMM: Windows Remote Management (WinRM) 1.1 or 2.0; Windows Automated Installation Kit (WAIK) 1.1; and WEB ISS 7.0 with Metabase Compatibility, 6 WMI Compatibility, Static Content, Default Document, Directory Browsing, HTTP Errors, ASP .NET, .NET Extensibility, ISAPI Extensions, ISAPI Filters, and Request Filtering. See <http://technet.microsoft.com/en-us/library/cc917964.aspx> for more information.

Installing SCVMM 2008

1. Log into the SCVMM VM.
2. On the SCVMM screen, select VMM Configuration analyzer to verify you have all the prerequisites.

3. On the License Terms screen, select the accept radio, and click Next.
4. On the Customer Experience Improvement Program screen, click I do not wish to participate.
5. On the Product Registration screen, enter a username and company, and click Next.
6. On the Install Location screen, click Next.
7. On the SQL Server settings screen, click Next.
8. On the Installation Settings screen, click Next.
9. Once the installation has finished, click Close, and run Windows Update.
10. After installing updates, run the SCVMM installation auto-start screen, and select the VMM Administration Console.
11. On the License Terms screen, click I accept, and click Next.
12. On the Prerequisites Check screen, click Next.
13. On the Installation screen, click Next.
14. On the Web Server Settings screen, click Next.
15. On the Summary screen, click Install.
16. Once finished, click Close, and run Windows Update.

Adding the Hyper-V failover cluster to the SCVMM administrator console

1. On the SCVMM VM, open the VMM Administrator console.
2. Click Actions → Virtual Machine Manager → Add host.
3. On the Select Host Location page, select Windows Server-based host on an Active Directory domain.
4. Enter the domain administrator credentials, and click Next.
5. On the Select Host Servers page, enter the name of the failover cluster in the Computer name field, and click Add.
6. Click Next.
7. Click Yes on the warning about the Hyper-V role.
8. On the Configuration Settings page, accept all defaults, and click Next.
9. On the Host Properties page, accept all defaults, and click Next.
10. Ensure the added cluster settings are correct, and click Add hosts.
11. Once the job completes in SCVMM, the cluster is listed under all hosts in the VMM Administrator console.

APPENDIX D – SETTING UP THE VMWARE VSPHERE 5 ENVIRONMENT

Adjusting BIOS settings

We used the latest released BIOS updates on each of the three Dell PowerEdge R710s, and adjusted the default BIOS settings. We enabled Virtualization Technology, disabled C-States, and set the performance profile to maximum performance on each server.

Installing VMware vSphere 5 (ESXi) on the PowerEdge R710

1. Insert the disk, and select Boot from disk.
2. On the Welcome screen, press Enter.
3. On the End User License Agreement (EULA) screen, press F11.
4. On the Select a Disk to Install or Upgrade Screen, select the relevant volume to install ESXi on, and press Enter.
5. On the Please Select a Keyboard Layout screen, press Enter.
6. On the Enter a Root Password Screen, assign a root password, and confirm it by entering it again. Press Enter to continue.
7. On the Confirm Install Screen, press F11 to install.
8. On the Installation complete screen, press Enter to reboot.
9. Repeat steps 1 through 8 on each server.

Configuring ESXi after installation

1. On the ESXi screen, press F2, enter the root password, and press Enter.
2. On the System Customization screen, select troubleshooting options, and press Enter.
3. On the Troubleshooting Mode Options screen, select enable ESXi Shell, and press Enter.
4. Select Enable SSH, press Enter, and press ESC.
5. On the System Customization screen, select Configure Management Network.
6. On the Configure Management Network screen, select IP Configuration.
7. On the IP Configuration screen, select set static IP, enter an IP address, subnet mask, and default gateway, and press Enter.
8. On the Configure Management Network screen, press Esc. When asked if you want to apply the changes, type Y.
9. Repeat steps 1 through 8 on each server.

Setting up vCenter Server

1. On a separate utility server running ESXi, import the OVF containing the vCenter Server appliance.
2. Start the vCenter Server appliance VM and perform basic installation steps, such as setting the name, IP, credentials, and so on.
3. Connect to the vCenter Server VM via the vSphere client, create a cluster, and add the three Dell PowerEdge R710s to the cluster.

Configuring Distributed Resource Scheduler on the cluster

1. In the left pane of the vSphere Client window, right-click the cluster name, and click Edit Settings...
2. Under Cluster Features, check the box to Turn On vSphere DRS.
3. Select vSphere DRS, and select Fully Automated.

Configuring iSCSI networking on ESXi

We followed the steps from the VMware document *iSCSI SAN Configuration Guide version 4.1* as a guide for our configuration of iSCSI on VMware vSphere 5. However, we performed most steps in the VMware vSphere 5 client UI as opposed to the command line, as VMware has added the relevant features to the UI in vSphere 5.

1. Using the vSphere client from another machine, connect to vCenter server then browse to the three servers in the cluster. Perform the following steps on each server in the cluster.
2. Add the necessary vSwitches:
 - a. Click the host, click the Configuration tab, and click Networking.
 - b. Click Add Networking.
 - c. Choose VMkernel, and click Next.
 - d. Choose create a vSphere standard switch.
 - e. Choose the first onboard NIC associated with iSCSI traffic.
 - f. Assign the network label, and assign IP settings.
 - g. Click Finish.
 - h. Repeat steps b through g for the remaining NIC assigned to iSCSI traffic.
3. Add the iSCSI software storage adapter:
 - a. Click the host, click the Configuration tab, and click Storage adapters.
 - b. Click Add.
 - c. Click Add software iSCSI adapter.
 - d. Click OK.
4. Configure the iSCSI software storage adapter:
 - a. Right-click the iSCSI adapter that was just added to the system, choose Properties, and ensure it is enabled.
 - b. Inside the iSCSI adapter Properties window, click the Network Configuration tab.
 - c. Under VMkernel port bindings, click Add, and add each VMkernel adapter to the VMkernel port bindings list.
5. Enable jumbo frames in ESXi:
 - a. Click the host, click the Configuration tab, and click Networking.
 - b. On the first vSwitch used for iSCSI, click Properties.
 - c. Select the vSwitch.
 - d. Click Edit.
 - e. Modify the MTU to 9,000.
 - f. Click OK.
 - g. In the vSwitch Properties window, choose the VMkernel port.
 - h. Click Edit.
 - i. Modify the MTU to 9,000.
 - j. Click OK.
 - k. Click Yes if warned about datastore access.
 - l. Click Close.
 - m. Repeat steps b through l the remaining NIC dedicated to iSCSI traffic.
6. Access provisioned Dell EqualLogic storage:
 - a. Using the Dell EqualLogic Web UI, ensure the VMware-specific volumes are online and the Hyper-V-specific volumes are offline.
 - b. In the vSphere client, click the host, click the Configuration tab, and click Storage adapters.
 - c. Right-click the iSCSI software storage adapter.
 - d. Click Dynamic discovery.
 - e. Click Add.
 - f. Enter the Dell EqualLogic group IP address.
 - g. Click Close.
 - h. Click Yes when prompted to rescan the HBA.

Installing the Dell EqualLogic Multipathing Extension Module (MEM) version 1.1 Beta on the ESXi servers

1. Using a file transfer utility, copy the MEM installation ZIP file to each ESXi server.

2. Use the following command to install the Dell EqualLogic MEM beta. Consult the installation and user guide for more details on the VMware MEM integration.

```
esxcli software vib install -d membundlename.zip --no-sig-check
```

3. Using the Dell EqualLogic Multipathing Extension Module Installation and User Guide, verify that the MEM is functional on each server.

Configuring VM networking on ESXi

1. Using the vSphere client from another machine, connect to the vCenter Server, and perform the following steps on each server in the cluster.
2. Add the necessary vSwitch for the network that DVD Store traffic will use:
 - a. Click the host, click the Configuration tab, and click Networking.
 - b. Click Add Networking.
 - c. Choose Virtual Machine, and click Next.
 - d. Choose create a vSphere standard switch.
 - e. Choose the NIC associated with VM traffic.
 - f. Assign the network label and assign IP settings.
 - g. Click Finish.

Configuring the vMotion network

1. Using the vSphere client from another machine, connect to the vCenter Server, and perform the following steps on each server in the cluster.
2. Add the necessary vSwitch for the network that vMotion traffic will use:
 - a. Click the host, click the Configuration tab, and click Networking.
 - b. Click Add Networking.
 - c. Choose VMkernel, and click Next.
 - d. Choose the 10Gb NIC associated with vMotion traffic, and click Next.
 - e. Assign the network label, and check the box Use this port group for vMotion.
 - f. Click Next.
 - g. Assign IP settings, and click Next.
 - h. Click Finish.
 - i. Click Properties for the new vSwitch.

Configuring the external volumes in VMware vSphere 5

1. In the vSphere client, select the first host.
2. Click the Configuration tab.
3. Click Storage, and click Add Storage...
4. Choose Disk/LUN.
5. Select the disk, and click Next.
6. Accept the default of VMFS-5 for the file system.
7. Review the disk layout, and click Next.
8. Enter the datastore name, and click Next.
9. Accept the default of using maximum capacity, and click Next.
10. Click Finish.
11. Repeat steps 3 through 10 for the remaining LUNs.

Configuring the first vSphere VM

In our testing, we used a mix of 30 VMs with different database sizes, with 10 VMs on each of our three ESXi nodes. The 10 VM size breakdown for each server was as follows: one VM with a 16GB database, two VMs with an 8GB database, and seven VMs with a 4GB database. We created one VM, cloned it or copied it on each platform, and modified the RAM settings to reflect the VM mix.

1. In the vSphere client, connect to the vCenter Server, and browse to one of the three ESXi hosts.
2. Click the Virtual Machines tab.
3. Right-click, and choose New Virtual Machine.
4. Choose Custom, and click Next.
5. Assign a name to the virtual machine, and click Next.
6. Select the first assigned OS Datastore on the external storage, and click Next.
7. Choose Virtual Machine Version 8, and click Next.
8. Choose Windows, and choose Microsoft Windows Server 2008 R2 (64-bit), and click Next.
9. Choose two virtual processors, and click Next.
10. Choose 4GB RAM, and click Next. After cloning this RAM amount will be adjusted based on the database size.
11. Click 1 for the number of NICs, select vmxnet3, and click Next.
12. Leave the default virtual storage controller, and click Next.
13. Choose to create a new virtual disk, and click Next.
14. Make the OS virtual disk size 20 GB, choose thick-provisioned lazy zeroed, specify the OS datastore on the external storage, and click Next.
15. Keep the default virtual device node (0:0), and click Next.
16. Click Finish.
17. Right-click the VM, and choose Edit Settings.
18. On the Hardware tab, click Add...
19. Click Hard Disk, and click Next.
20. Click Create a new virtual disk, and click Next.
21. Specify 25GB (35GB for the 16GB database VMs) for the virtual disk size, choose thick-provisioned lazy zeroed, and specify the datastore for backups, SQL logs, and SQL Server data usage (storage pool 2).
22. Choose SCSI(1:0) for the device node, and click Next.
23. On the Hardware tab, click Add...
24. Click Hard Disk, and click Next.
25. Click Create a new virtual disk, and click Next.
26. Specify 15GB (20GB for the 16GB database VMs) for the virtual disk size, choose thick-provisioned lazy zeroed, and specify the datastore for backups, SQL logs, and SQL Server data usage (storage pool 2).
27. Choose SCSI(1:1) for the device node, and click Next.
28. On the Hardware tab, click Add...
29. Click Hard Disk, and click Next.
30. Click Create a new virtual disk, and click Next.
31. Specify 10GB for the virtual disk size, choose thick-provisioned lazy zeroed, and specify the datastore for backups, SQL logs, and SQL Server data usage (storage pool 2).
32. Choose SCSI(1:2) for the device node, and click Next.
33. Click SCSI Controller 1, and choose Change Type.
34. Choose VMware Paravirtual, and click OK.
35. Click Finish, and click OK.
36. Click the Resources tab, and click Memory.
37. Adjust the memory reservation for the VM to 1,024MB, to match Hyper-V's minimum guarantee of 1,024MB.

38. Start the VM.
39. Attach the Windows Server 2008 R2 SP1 ISO image to the VM and install Windows Server 2008 R2 on your VM.
See [Appendix E](#) for VM-related setup.

APPENDIX E – CONFIGURING THE VMS ON EACH HYPERVISOR

See the above sections regarding the initial creation of the virtual machines on each hypervisor. We provide steps below for installing the operating system, Microsoft SQL Server, and configuring the VMs.

Installing the VM operating system on the first VM

1. Insert the installation DVD for Windows Server 2008 R2 SP1 Enterprise into the DVD drive, and attach the physical DVD drive to the VM. Alternatively, use an ISO image and connect to the ISO image from the VM console.
2. Open the VM console on vSphere or Hyper-V.
3. At the Language Selection Screen, click Next.
4. Click Install Now.
5. Select Windows Server 2008 R2 Enterprise (Full Installation), and click Next.
6. Click the I accept the license terms check box, and click Next.
7. Click Custom.
8. Click Next.
9. At the User's password must be changed before logging on warning screen, click OK.
10. Enter the desired password for the administrator in both fields, and click the arrow to continue.
11. At the Your password has been changed screen, click OK.
12. *VMware only* - Install the latest VMware tools package on the VM. Restart as necessary. Windows Server 2008 R2 SP1 already includes Hyper-V integration tools.
13. Connect the VM to the Internet, and install all available Windows updates. Restart as necessary.
14. Enable remote desktop access.
15. Change the hostname and reboot when prompted.
16. Create a shared folder to store test script files. Set permissions as needed.
17. Set up networking:
 - a. Click Start→Control Panel, right-click Network Connections, and choose Open.
 - b. Right-click the VM traffic NIC, and choose Properties.
 - c. Select TCP/IP (v4), and choose Properties.
 - d. Set the IP address, subnet, gateway, and DNS server for the virtual NIC, which will handle outgoing server traffic. Click OK, and click Close.
18. In the VM, configure the VM storage:
 - a. Click the Server Manager icon in the taskbar.
 - b. In the left pane, expand Storage and click Disk Management.
 - c. Right-click the first volume, and choose Initialize Disk.
 - d. In the right pane, right-click the volume, and choose New Simple Volume...
 - e. At the welcome window, click Next.
 - f. At the Specify Volume Size window, leave the default selection, and click Next.
 - g. At the Assign Drive Letter or Path window, choose a drive letter, and click Next.
 - h. At the Format Partition window, choose NTFS and 64K allocation unit size, and click Next.
 - i. At the Completing the New Simple Volume Wizard window, click Finish.
 - j. Repeat steps c through i for the remaining VM volumes.
19. Copy the pre-created DVD Store backup file to the backup virtual disk inside the first VM.

Installing SQL Server 2008 R2 SP1 on the first VM

1. Open the Hyper-V or vSphere console for the VM.
2. Log into the virtual machine.

3. Insert the installation DVD for SQL Server 2008 R2 into the appropriate Hyper-V or vSphere host server's DVD drive.
4. Attach the physical DVD drive to the VM.
5. Click Run SETUP.EXE. If Autoplay does not begin the installation, navigate to the SQL Server 2008 R2 DVD, and double-click.
6. If the installer prompts you with a .NET installation prompt, click Yes to enable the .NET Framework Core role.
7. In the left pane, click Installation.
8. Click New installation or add features to an existing installation.
9. At the Setup Support Rules screen, wait for the check to complete. If there are no failures or relevant warnings, click OK.
10. Select the Enter the product key radio button, and enter the product key. Click Next.
11. Click the checkbox to accept the license terms, and click Next.
12. Click Install to install the setup support files.
13. If there are no failures displayed, click Next. You may see a Computer domain controller warning and a Windows Firewall warning. For now, ignore these.
14. At the Setup Role screen, choose SQL Server Feature Installation.
15. At the Feature Selection screen, select Database Engine Services, Full-Text Search, Client Tools Connectivity, Client Tools Backwards Compatibility, Management Tools –Basic, and Management Tools – Complete. Click Next.
16. At the Installation Rules screen, click Next when the check completes.
17. At the Instance configuration screen, leave the default selection of default instance, and click Next.
18. At the Disk space requirements screen, click Next.
19. At the Server configuration screen, choose NT AUTHORITY\SYSTEM for SQL Server Agent, and choose NT AUTHORITY\SYSTEM for SQL Server Database Engine. Click Next.
20. At the Database Engine Configuration screen, select Mixed Mode.
21. Enter and confirm a password for the system administrator account.
22. Click Add Current user. This may take several seconds.
23. Click Next.
24. At the Error and usage reporting screen, click Next.
25. At the Installation Configuration rules screen, check that there are no failures or relevant warnings, and click Next.
26. At the Ready to Install screen, click Install.
27. After installation completes, click Next.
28. Click Close.
29. Create a SQL Server login for the ds2user (see the [Configuring the database \(DVD Store\) section](#) for the specific script to use).
30. Click Start→All Programs→Microsoft SQL Server 2008 R2→Configuration Tools, and click SQL Server Configuration Manager.
31. Expand SQL Server Network Configuration, and click Protocols for MSSQLSERVER.
32. Right-click TCP/IP, and select Enable.
33. Restart the SQL Server service.
34. Download and install Microsoft SQL Server 2008 R2 SP1.

Configuring additional VMs on Microsoft Hyper-V R2 SP1

Copying the VMs

1. Right-click the first VM, and choose Settings.
2. Remove all VHDs from the first VM.
3. Create additional “shell” VMs as necessary with the same settings as the first.

4. Copy all four VHD files from the first VM's LUNs to each additional VM's respective LUNs. We used a round-robin approach to spread our VM files to the eight hypervisor-specific LUNs. For example, VM 1 files were placed on LUN 1 (storage pool 1) and 5 (storage pool 2). VM 2 files were placed on LUN 2 (storage pool 1) and 6 (storage pool 2).
5. Reattach all newly copied VHDs to their respective VMs.
6. Start each VM, rename the computer name of each VM, and reboot each VM.
7. Assign IP addresses as needed for each VM.
8. Modify the SQL Server hostname of each VM using the instructions provided by Microsoft (<http://msdn.microsoft.com/en-us/library/ms143799.aspx>).
9. Bring each VHD online in each VM, using the Server Management utility.
10. Depending on the number of VMs you wish to auto-start, ensure the automatic start action is set for each VM.
11. Shutdown each VM, then edit the memory settings: Click memory and adjust the RAM settings to be dynamic, with a minimum of 1,024MB, maximum of 4,096MB, 8,192MB, or 16,384MB depending on the SQL database size for each VM. Assign a 10% buffer on each VM's dynamic memory setting.

Reconfiguring the automatic start action for each virtual machine

1. In Hyper-V Manager, right-click the first VM, and click Settings.
2. In the left pane, click Automatic Start Action.
3. Under What do you want this virtual machine to do when the physical computer starts?, select Nothing.
4. Click Apply.

Configuring the VMs for high availability

1. Click Start→Administrator Tools→Failover Cluster Manager.
2. Right-click Failover Cluster Manager, and click Manage a Cluster.
3. Select the cluster created in previous steps.
4. Expand the cluster in the left pane.
5. Click Services and Applications.
6. In the Action pane, click Configure a Service or Application.
7. On the Before You Begin page, click Next.
8. On the Select Service or Application page, select Virtual Machine, and click Next.
9. On the Select Virtual Machine page, check the box for all 30 VMs created in the previous sections.
10. On the Confirmation page, click Next.
11. When the task completes, click Finish.

Configuring additional VMs on VMware vSphere 5

1. Log into the vCenter Server, which manages the hosts.
2. Right-click the first VM, and choose Clone.
3. Name the new VM.
4. Choose the cluster, and select the host.
5. For the storage screen, choose advanced and direct the new virtual disks to the applicable data stores. Again, we used a round-robin approach to spread our VM files to the 8 hypervisor-specific LUNs. For example, VM 1 files were placed on LUN 1 (storage pool 1) and 5 (storage pool 2). VM 2 files were placed on LUN 2 (storage pool 1) and 6 (storage pool 2).
6. Choose to customize using the customization wizard. Save the clone details as a new customization specification.
7. Continue cloning each VM, modifying the customization specification as necessary for IP addressing and so on.
8. Ensure in each VM that the necessary virtual disks are all online, the hostname is renamed, and the IP addressing was properly assigned by the customization wizard.

9. Modify the SQL Server hostname of each VM using the instructions provided by Microsoft (<http://msdn.microsoft.com/en-us/library/ms143799.aspx>).
10. To configure automatic start for your specified number of VMs, click the Host configuration tab in the vSphere client, and click Virtual Machine Startup/Shutdown.
11. Shut down each VM, and edit the memory settings: Click memory and adjust the RAM maximum parameter to be 4,096MB, 8,192MB, or 16,384MB depending on the SQL database size for each VM.

APPENDIX F - CONFIGURING THE DATABASE (DVD STORE)

Data generation overview

We generated the data using the Install.pl script included with DVD Store version 2.1 (DS2), providing the parameters for our 4GB, 8GB, and 16GB database sizes and the database platform on which we ran: Microsoft SQL Server. We ran the Install.pl script on a utility system running Linux. The database schema were also generated by the Install.pl script.

After processing the data generation, we transferred the data files and schema creation files to a Windows-based system running SQL Server 2008 R2 SP1. We built the 4GB, 8GB, and 16GB databases in SQL Server 2008 R2 SP1, performed a full backup of each database at each size, and moved those backup files to their assigned VMs. We used that backup file to restore on all VMs between test runs. We performed this data generation and schema creation procedure once, and used the same SQL Server backup files for both VMware vSphere 5 and Hyper-V R2 SP1 virtual machines.

The only modification we made to the schema creation scripts were the specified file sizes for our database, which we note in Figure 9. We explicitly set the file sizes higher than necessary to ensure that no file-growth activity would affect the outputs of the test. Besides this file size modification, we created and loaded the database schema according to the DVD Store documentation. Specifically, we followed the steps below:

1. We generated the data and created the database and file structure using database creation scripts in the DS2 download. We made size modifications specific to our 4GB, 8GB, or 16GB databases and the appropriate changes to drive letters.
2. We transferred the files from our Linux data generation system to a Windows system running SQL Server.
3. For each database, we created database tables, stored procedures, and objects using the provided DVD Store scripts.
4. For each database, we set the database recovery model to bulk-logged to prevent excess logging.
5. For each database, we loaded the data we generated into the database. For data loading, we used the import wizard in SQL Server Management Studio. Where necessary, we retained options from the original scripts, such as Enable Identity Insert.
6. For each database, we created indices, full-text catalogs, primary keys, and foreign keys using the database-creation scripts.
7. For each database, we updated statistics on each table according to database-creation scripts, which sample 18 percent of the table data.
8. On the SQL Server instance, we created a ds2user SQL Server login using the following Transact SQL (TSQL) script:

```
USE [master]
GO
CREATE LOGIN [ds2user] WITH PASSWORD=N'',
           DEFAULT_DATABASE=[master],
           DEFAULT_LANGUAGE=[us_english],
           CHECK_EXPIRATION=OFF,
           CHECK_POLICY=OFF
GO
```

9. For each database, we set the database recovery model back to full.

10. For each database, we created the necessary full text index using SQL Server Management Studio.
11. For each database, we created a database user and mapped this user to the SQL Server login.
12. For each database, we then performed a full backup of the database. This backup allowed us to restore the databases to a pristine state relatively quickly between tests.

Figure 9 shows our initial file size modifications.

Logical name	Filegroup	Initial size (MB) Database sizes 4GB/8GB/16GB
Database files		
primary	PRIMARY	3/3/3
cust1	DS_CUST_FG	2,048/5,120/7,168
cust2	DS_CUST_FG	2,048/5,120/7,168
ind1	DS_IND_FG	1,024/2,048/4,096
ind2	DS_IND_FG	1,024/2,048/4,096
ds_misc	DS_MISC_FG	1,024/2,048/2,048
orders1	DS_ORDERS	1,024/2,560/5,120
orders2	DS_ORDERS	1,024/2,560/5,120
Log files		
ds_log	Not Applicable	10,240/12,288/18,432

Figure 9. Our initial file size modifications.

Editing the workload script – ds2xdriver.cs module

A new feature of DVD Store Version 2.1 uses the ability to target multiple targets from one source client. We used this functionality, and in order to record the orders per minute output from each specific database target, we modified the ds2xdriver to output this information to log files on each client system. To do this, we used the StreamWriter method to create a new text file on the client system, and the WriteLine and Flush methods to write the relevant outputs to the files during the tests.

Specifically for this testing, we also modified the DVD Store ds2xdriver to output not only orders per minute, but also orders per second, output at every second. Whereas the orders per minute output is a running average over the duration of the test, the orders per second output shows actual number of orders completed in the prior second.

After making these changes, we recompiled the ds2xdriver.cs and ds2sqlserverfns.cs module in Windows by following the instructions in the DVD Store documentation. Because the DS2 instructions were for compiling from the command line, we used the following steps on a system with Visual Studio installed:

1. Open a command prompt.
2. Use the `cd` command to change to the directory containing our sources.
3. Execute the following command:

```
csc /out:ds2sqlserverdriver.exe ds2xdriver.cs ds2sqlserverfns.cs
/d:USE_WIN32_TIMER /d:GEN_PERF_CTRS
```

Running the DVD Store tests

We created a series of batch files, SQL scripts, and shell scripts to automate the complete test cycle. Our newly compiled version of DVD Store outputs an orders-per-minute metric and orders-per-second metric. In this report, we

focused on the orders-per-second metric, as the vMotion and live migration windows were small enough to warrant that.

Each complete test cycle consisted of the general steps listed below. For each scenario, we ran three test cycles, and chose the median time outcome.

1. Clean up prior outputs from the host system and all client driver VMs.
2. Drop all databases from all target VMs.
3. Restore all databases on all target VMs.
4. Shut down all VMs.
5. Reboot the host systems and all client VMs.
6. Wait for a ping response from the server under test (the hypervisor system), all client systems, and all VMs.
7. For the large mixed VM test, we let the test server idle for one hour. For the single VM test, we let the test server idle for ten minutes.
8. To allow the database to adequately utilize memory pages for each VM, we ran a light mix of warm-up DVD Store runs for 5 minutes, then a heavy mix of warm-up DVD Store runs with zero think time for 15 minutes. For the large VM testing we ran a heavy mix (zero think time) warm-up run for 10 minutes.
9. We then stopped the warm-up run.
10. We then began collecting esxtop and performance monitor data.
11. We started the DVD Store driver mix on all respective clients, targeting the relevant VMs with the mixed think time profiles. See Figures 1 and 2 for the exact size and think time mix we used on all 30 VMs for the large mixed VM test and the single VM test.

We used the following DVD Store parameters for testing the virtual machines in this study (target_IP, threads, size, and think time parameters varied; see Figures 1 and 2 for details):

```
ds2sqlserverdriver.exe --target=<target_IP> --ramp_rate=10 --run_time=30 --  
n_threads=<threads> --db_size=<size> --think_time=<thinktime> --  
detailed_view=Y --warmup_time=1 --pct_newcustomers=5
```

12. For both test scenarios, we waited until 6 minutes into the final mix and set one of the test servers in maintenance mode. To do so, we used the maintenance mode feature in both the vSphere client and the SCVMM Administrator console. Both platforms then migrated all the VMs located on the host, entering maintenance mode using the vMotion or Live Migrate feature. We monitored the job logs and DVD Store tests, recording the time it took for all the VMs to evacuate the server and for the server to completely enter maintenance mode.
13. We then transferred the output and performance files from each host to the controller machine.

APPENDIX G –SERVER AND STORAGE CONFIGURATION INFORMATION

Figure 10 provides detailed configuration information for the Dell PowerEdge R710 servers, and Figure 11 provides configuration information for the Dell EqualLogic PS5000XV storage arrays.

System	3 x Dell PowerEdge R710 servers
Power supplies	
Total number	2
Vendor and model number	Dell Inc. N870P-S0
Wattage of each (W)	870
Cooling fans	
Total number	5
Vendor and model number	Nidec UltraFlo™ RK385-A00
Dimensions (h x w) of each	2.5 x2.5
Volts	12
Amps	1.68
General	
Number of processor packages	2
Number of cores per processor	6
Number of hardware threads per core	2
CPU	
Vendor	Intel®
Name	Xeon®
Model number	X5670
Stepping	B1
Socket type	FCLGA 1366
Core frequency (GHz)	2.93
Bus frequency	6.4 GT/s
L1 cache	32 KB + 32 KB (per core)
L2 cache	6 x 256 KB (per core)
L3 cache	12 MB (shared)
Platform	
Vendor and model number	Dell PowerEdge R710
Motherboard model number	OYDJK3
BIOS name and version	Dell Inc. 3.0.0
BIOS settings	Default
Memory module(s)	
Total RAM in system (GB)	96
Vendor and model number	M393B1K70BH1-CH9
Type	PC3-10600
Speed (MHz)	1,333
Speed running in the system (MHz)	1,333
Timing/Latency (tCL-tRCD-tRP-tRASmin)	9-9-9-24
Size (GB)	8
Number of RAM module(s)	12
Chip organization	Double-sided

System	3 x Dell PowerEdge R710 servers
Rank	Dual
Microsoft OS	
Name	Windows Server 2008 R2 SP1
Build number	7601
File system	NTFS
Kernel	ACPI x64-based PC
Language	English
VMware OS	
Name	VMware vSphere 5.0.0
Build number	441354
File system	VMFS
Kernel	5.0.0
Language	English
Graphics	
Vendor and model number	Matrox® MGA-G200ew
Graphics memory (MB)	8
RAID controller	
Vendor and model number	PERC 6/i
Firmware version	6.3.0-0001
Cache size (MB)	256
Hard Drives	
Vendor and model number	Dell ST9146852SS
Number of drives	4
Size (GB)	146
RPM	15,000
Type	SAS
Onboard Ethernet adapter	
Vendor and model number	Broadcom NetXtreme® II BCM5709 Gigabit Ethernet
Type	Integrated
Discrete 10Gb fibre adapter	
Vendor and model number	Intel Ethernet Server Adapter X520-SR1
Type	Discrete
Optical drive(s)	
Vendor and model number	TEAC DV28SV
Type	DVD-ROM
USB ports	
Number	6
Type	2.0

Figure 10. Detailed configuration information for our test servers.

Storage array	Dell EqualLogic PS5000XV storage array
Arrays	3
Number of active storage controllers	1
Number of active storage ports	3
Firmware revision	5.0.7
Switch number/type/model	Dell PowerConnect 6248
Disk vendor and model number	Dell ST3600057SS/ST3450856SS/ST3600002SS
Disk size (GB)	600/450/600
Disk buffer size (MB)	16
Disk RPM	15,000
Disk type	6.0 Gbps SAS / 3.0 Gbps SAS/ 6.0 Gbps SAS
EqualLogic Host Software for Windows	Dell EqualLogic Host Integration Tools 3.5.1
EqualLogic Host Software for VMware	Dell EqualLogic Multipathing Extension Module (MEM) 1.1 Beta

Figure 11. Detailed configuration information for the storage array.

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Principled Technologies, Inc.
1007 Slater Road, Suite 300
Durham, NC, 27703
www.principledtechnologies.com

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