Principled Technologies®

TEST REPORT
MARCH 2009

Virtualized OLTP workload performance comparison of end-to-end solutions: Dell PowerEdge R710 with Dell EqualLogic storage vs. HP ProLiant DL385 G5 with HP StorageWorks EVA 4400 storage

Executive summary

Dell Inc. (Dell) commissioned Principled Technologies (PT) to compare virtualized online transaction processing (OLTP) performance of two server-and-storage solutions:

- Dell PowerEdge R710 server and Dell EqualLogic storage
- HP ProLiant DL385 G5p server and HP StorageWorks EVA 4400 storage

KEY FINDINGS

- The Dell PowerEdge R710 server and Dell EqualLogic storage supported 22.2 percent more virtual machines than did the HP ProLiant DL385 G5 server and HP StorageWorks EVA 4400 storage. (See Figure 1.)
- The Dell PowerEdge R710 server and Dell EqualLogic storage had a 21.4 percent performance-per-watt advantage over the HP ProLiant DL385 G5 server and HP StorageWorks EVA 4400 storage. (See Figure 2.)

The Dell PowerEdge R710 solution had two 2.4GHz Intel Xeon E5530 processors and 72 GB of RAM while the HP ProLiant DL385 G5 solution had two 2.7GHZ AMD Opteron 2384 processors and 64 GB of RAM. (The Dell PowerEdge R710 currently supports up to the 2.93GHz Xeon X5570 processor.) The difference in the quantity and speed of RAM in the systems was due to the difference in system architectures and was not a factor in performance as each virtual machine (VM) was limited to 4 GB of RAM. We connected the Dell PowerEdge R710 to the EqualLogic storage via iSCSI and connected the HP ProLiant DL385 G5 to the EVA 4400 storage via Fibre Channel. We installed build 148592 of a version of ESX still under development as the hypervisor for each server. ESX build 148592 supports the new virtualization technologies such as Intel VT Extended Page Tables (EPT).

For this comparison, we selected the DVD Store Version 2 (DS2) test tool. DS2 is an open-source simulation of an online e-commerce DVD store, where customers login, browse, and order products. Each server under test ran multiple Microsoft SQL Server 2008 workloads, one per VM. One copy of the DS2 database was on each VM, with a 20GB database per VM. By combining multiple virtual machines, all running a CPU, memory, and disk intensive workload, the test placed a heavy load on both the server and the storage. Thus, it measured the performance of the overall solution—server and storage, especially as it relates to an active OLTP environment. The main DS2 metric is orders per minute (OPM). We report OPM results from a 300-second period of steady activity and heavy load during the DS2 test run. The Workload section explains in more detail the Microsoft SQL Server 2008 database workload.

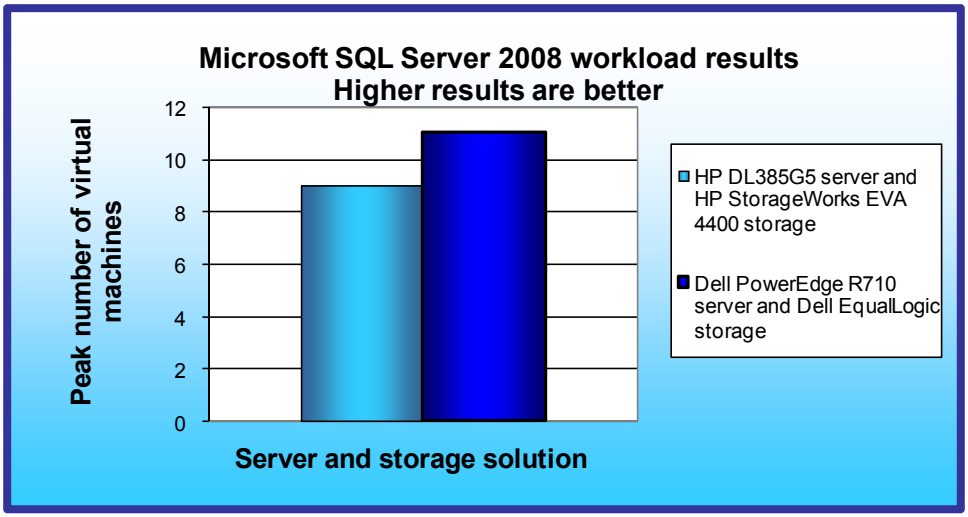

Figure 1: Microsoft SQL Server 2008 workload performance results for the two solutions. Higher numbers are better.

Figure 1 compares the peak number of virtual machines running a Microsoft SQL Server 2008 database workload that each server ran with acceptable performance (all VM scores higher than the baseline). The Dell PowerEdge R710 ran 11 such simultaneous VMs, while the HP ProLiant DL385 G5 ran 9 such simultaneous VMs. Thus, the Dell PowerEdge R710 solution had a 22.2 percent performance advantage over the HP ProLiant DL385 G5

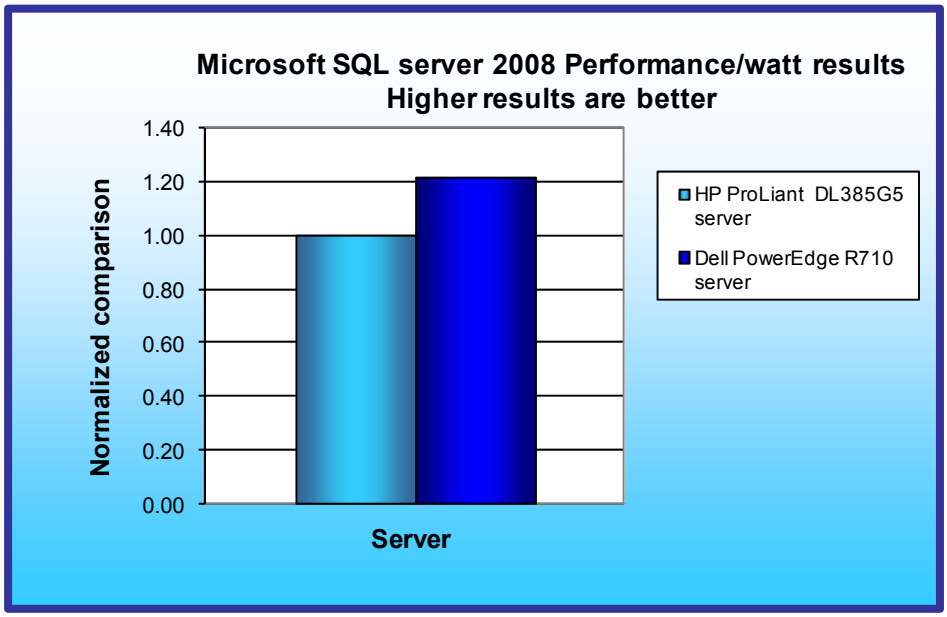

Figure 2: Performance/watt results for the solutions normalized to that of the HP ProLiant DL385 G5 solution. Higher numbers are better.

solution. In addition, the Dell PowerEdge R710 solution had 3.0 percent more average OPMs per VM than did the HP ProLiant DL385 G5 solution.

As Figure 2 shows, the Dell R710 solution delivered 21.4 percent more performance/watt than did the HP DL385 G5 solution. We normalized the results for each workload to those of the server with lower performance/watt. We compute performance/watt by dividing the benchmark's score by the average power consumption, in watts, of the solution during the period the benchmark was delivering peak performance.

We installed and ran the DS2 client from VMs on a separate ESX 3.5 host with four Intel X7460 2.66Ghz processors and 64 GB of RAM. We ran a single instance of the client per VM, and each client VM targeted only one server VM. We assigned 2 virtual processors and 4 GB of RAM to each client VM.

We defined the peak number of VMs per server as the maximum number of concurrent VMs under load where each VM had at least the performance output in OPM as the baseline. Based on our analysis and experience with DS2, we set the baseline at 2,600 OPM. Each VM on both the PowerEdge R710 and ProLiant DL385 G5 had to score a minimum of 2,600 OPM to be valid. CPU utilization was near 100% on both servers when running at peak VM levels.

Workload

We conducted our testing using DVD Store Version 2, an open-source application with a back-end database component, a front-end Web application layer, and a driver layer that operates as the middle tier and actually executes the workload.

Because our goal was to isolate and test database server storage, we did not use the Web application layer. Instead, we ran the driver application directly via its command-line interface.

DS2 models an online DVD store. Virtual customers log in; browse movies by actor, title, or category; and purchase movies. The workload also creates new customers. Browsing movies involves select operations, some of which use full-text search and some of which do not. The purchase, login, and new customer procedures involve updates and inserts, as well as selects. The workload's main reporting metric is orders per minute (OPM).

For more details about the DS2 tool, see http://www.delltechcenter.com/page/DVD+Store.

Each client VM ran a single instance of DS2, which spawned 32 threads, and used a 15:1 search-to-order ratio, which we implemented via the provided n_searches parameter in DVDStore. This simulated a heavily loaded environment; the load-generating client VMs ran with no think time, blasting requests as quickly as the servers could handle them.

The DS2 driver application creates an orders-per-minute performance counter on the client VM. While the DVDStore client application outputs OPM at 10 second intervals visually, we chose to collect this OPM metric via a Performance Monitor counter on each client VM at one-second intervals.

We ran this workload on all virtual machines simultaneously for 30 minutes. We considered a solution to have delivered acceptable performance if the minimum OPM score on every client VM during the 23 to 28 minute period of the test was above the baseline OPM.

Test results

Figure 3 shows the peak number of virtual machines each solution could handle during testing before dipping below the acceptable threshold and the minimum client score from the median run.

Based on our analysis and experience with DS2, we set the baseline at 2,600 OPM. Each VM on both the PowerEdge R710 and ProLiant DL385 G5 had to score a minimum of 2,600 OPM to be valid.

Server	Peak number of virtual machines	Average OPM Score
Dell PowerEdge R710 and Dell EqualLogic storage	11	3021.05
HP ProLiant DL385 G5 and HP StorageWorks EVA 4400 storage	9	2932.74

Figure 3: The peak number of virtual machines for the two solutions and the average OPM score. Higher numbers are better.

Figure 4 shows the individual VM OPM scores and the minimum OPM score for each run on the Dell PowerEdge R710 solution. Run 3 is the median run.

Dell PowerEdge R710 and Dell EqualLogic storage	Run 1	Run 2	Run 3
VM 1 OPMs	2627.93	2968.20	2900.82
VM 2 OPMs	2961.65	2956.80	2953.60
VM 3 OPMs	3093.94	2989.62	3078.00
VM 4 OPMs	3026.50	2984.10	2978.58
VM 5 OPMs	3083.58	3001.03	3075.71
VM 6 OPMs	2998.23	2975.41	3068.95
VM 7 OPMs	3166.89	3089.09	3014.30
VM 8 OPMs	3048.71	2980.37	2953.25
VM 9 OPMs	3077.71	3053.63	3091.90
VM 10 OPMs	2983.45	2959.00	3067.37
VM 11 OPMs	3063.45	3111.72	3049.10
Minimum OPMs	2627.93	2956.80	2900.82

Figure 4: Individual VM scores and the minimum OPM score from the three runs on the Dell PowerEdge R710 solution. Higher numbers are better.

Figure 5 shows the individual VM OPM scores and the minimum OPM score for each run on the HP ProLiant DL385 G5 server. Run 1 is the median run.

HP ProLiant DL385 G5 and HP StorageWorks EVA 4400 storage	Run 1	Run 2	Run 3
VM 1 OPMs	2666.62	2846.32	2758.78
VM 2 OPMs	3003.99	2777.46	2804.66
VM 3 OPMs	2940.67	2604.99	3099.97
VM 4 OPMs	2790.60	2635.35	2912.25
VM 5 OPMs	3036.82	2979.58	2824.66
VM 6 OPMs	2857.49	2899.64	2896.52
VM 7 OPMs	3075.62	2976.63	3062.64
VM 8 OPMs	3080.72	2871.03	2754.74
VM 9 OPMs	2942.09	3124.97	3015.43
Minimum OPMs	2666.62	2604.99	2754.74

Figure 5: Individual VM scores and minimum OPM score from the three runs on the HP ProLiant DL385 G5 solution. Higher numbers are better.

Figure 6 details the power consumption, in watts, of the servers while idle and during the median run of the Microsoft SQL Server 2008 database workload.

Server	Idle power (watts)	Average power (watts)
Dell PowerEdge R710	195.21	315.03
HP ProLiant DL385 G5	209.74	312.90

Figure 6: Average power usage (in watts) of the two servers while idle and during the median run of Microsoft SQL Server 2008 database workload. Lower numbers are better.

Test methodology

Setting up and configuring the storage

Dell EqualLogic storage configuration

Each of the four Dell EqualLogic arrays has 16 drives, for a total of 64 drives. Each of the five HP StorageWorks EVA 4400 storage trays has 12 drives, for a total of 60 drives. In order to match the drive count of the two storage configurations, we configured two Dell EqualLogic arrays in RAID 10 no-spares mode (16 active drives each) and two Dell EqualLogic arrays in regular RAID 10 mode (14 active drives each), for a total of 60 drives.

We connected the Dell Server to the Dell EqualLogic storage via three 1Gb/s Ethernet cables. We configured the Dell EqualLogic storage into two storage pools. Figure 7 shows the storage layout. The VM operating system and log storage pool (Storage Pool 1) contained one Dell EqualLogic PS6000 Array. The database storage pool (Storage Pool 2) contained three Dell EqualLogic PS5000XV Arrays. We created one 1.28TB volume in the VM operating system and log storage pool. Following VMware's best practices regarding adding storage to ESX, we used vSphere to connect this storage pool to ESX Server as a single data store via the ESX iSCSI initiator using one physical NIC. We created 11 60GB volumes in the database storage pool. We used the Microsoft iSCSI Initiator with the EqualLogic Host Integration Toolkit (HIT) within each VM to connect one 60GB volume to every VM through two virtual NIC's shared between every VM.

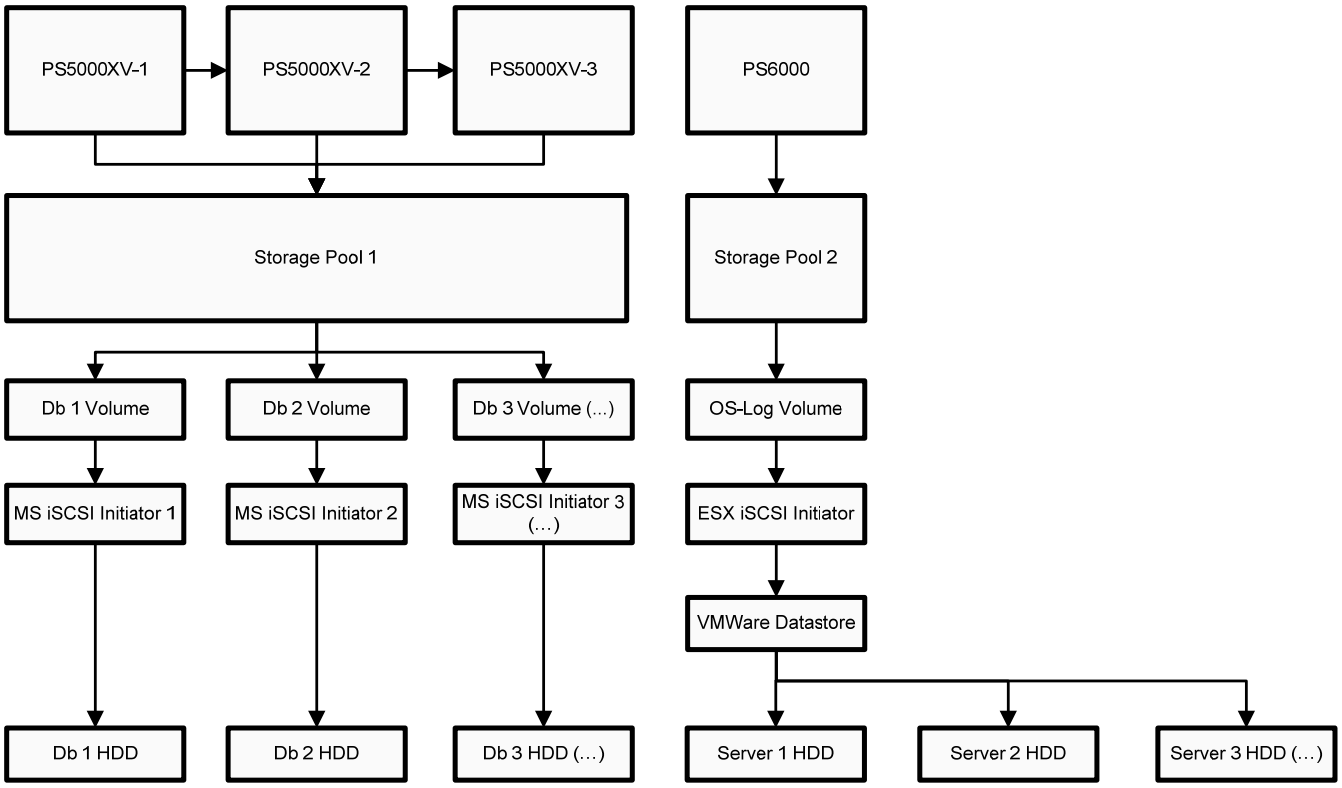

Figure 7: The layout of the Dell EqualLogic storage.

Setting up the storage

1. Using the command line, setup a storage group with the following RAID policies:
    a. PS5000XV-1: RAID-10 (no-spares)
    b. PS5000XV-2: RAID-10
    c. PS5000XV-3: RAID-10 (no-spares)
    d. PS6000: RAID-10
2. Create a storage pool name of `database` with the following members:
    a. PS5000XV-1
    b. PS5000XV-2
    c. PS5000XV-3
3. Create a storage pool name of `OS-Log` with the following member:
    a. PS6000
4. Enable all network connections on each PS5000XV and PS6000 using the following IP address scheme:
    a. IP Address: `192.168.1.##` (## being any number between 10 and 60)
    b. Subnet Mask: `255.255.248.0`
5. Create 11 60GB volumes in the database storage pool with no snapshot reserve, and name them `dvd-store#` (# being 1-11).
6. Create one 1.28TB volume in the database storage pool with no snapshot reserve, and name it `OS-Log`.
7. Enable shared access to the iSCSI target from multiple initiators on every volume.
8. Create an access control record for every volume without specifying any limitations.
9. Create a read-only SNMP community name to use for group monitoring.

HP StorageWorks storage configuration

We connected the HP Server to the HP StorageWorks storage via two 4 Gb/s Fibre Channel cables. We configured the HP StorageWorks storage into two disk groups using RAID 10. Figure 8 shows the storage layout. Our database disk group (Disk Group 1) contained 48 disks. Our VM operating system and log disk group (Disk

Group 2) contained 12 disks. We created one 819GB volume in the operating system and log disk group, which we connected to ESX Server as a single data store and assigned to one fibre channel port. Following VMware best practices, we used the vSphere client to connect the storage to ESX to ensure proper alignment. We created two 1,569GB volumes in the database disk group, which we connected to ESX Server as two data stores and assigned to one fibre channel port.

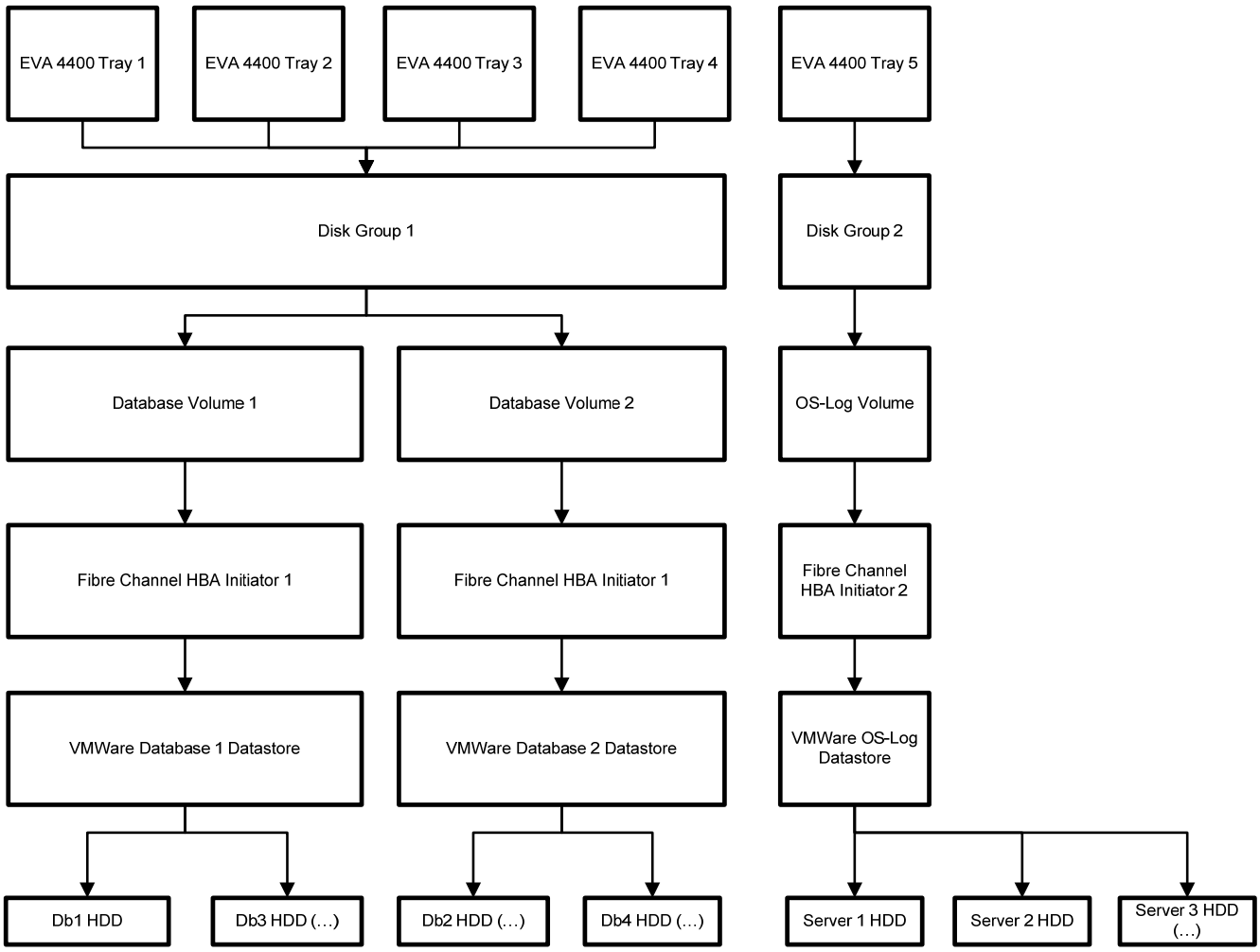

Figure 8: The layout of the HP StorageWorks storage.

Setting up the storage

1. Create a disk group with the following parameters:
    a. Name: Database
    b. Disks: 1-48
    c. Disk drive failure protection: None
    d. Alarm Level: 100%
2. Create a disk group with the following parameters:
    a. Name: OS-Log
    b. Disks: 49-60
    c. Disk drive failure protection: None
    d. Alarm Level: 100%
3. Create a new vDisk with the following parameters:
    a. Name: Database1

   b. Size: 1,569 GB
   c. Disk Group: Database
   d. Redundancy: Vraid 1
4. Create a new vDisk with the following parameters:
   a. Name: Database2
   b. Size: 1,569 GB
   c. Disk Group: Database
   d. Redundancy: Vraid 1
5. Create a new vDisk with the following parameters
   a. Name: OS-Log
   b. Size: 819 GB
   c. Disk Group: OS-Log
   d. Redundancy: Vraid 1
6. Create a Host, and add the world wide name for both Fibre Channel adapters on each server under test.

Adjusting BIOS settings

To maximize performance for each server, we adjusted the BIOS settings as follows:

- Dell PowerEdge R710 system: We enabled virtualization.
- HP ProLiant DL385 G5 system: We enabled virtualization and enabled No-Execute Page-Protection.

Setting up the host server

We installed build 148592 of a version of ESX still under development on the host server. ESX build 148592 supports the new virtualization technologies such as EPT. We also installed the vSphere client tool on a management workstation, which was an Intel Pentium 4, 630 3.00GHz running Windows Vista Ultimate SP1 (6001) with 2GB RAM.

Installing ESX Build 148592

1. Insert ESX Build 148592 DVD, and restart the computer.
2. While booting, press F11 to enter Boot Menu.
3. Press the down arrow to navigate to the appropriate boot device, and press Enter.
4. To start ESX in graphical mode, press Enter.
5. On the Welcome screen, click Next.
6. Click the checkbox to accept the terms of the license agreement, and click Next.
7. Accept the default keyboard layout, and click Next.
8. On the Custom Drivers screen, choose No to install custom drivers, and click Next.
9. You will receive a warning if you chose No. Click Yes to proceed. Drivers will load at this point.
10. Click Next.
11. Enter your serial number now, or choose to enter one later. Click Next.
12. On the Network Configuration screen, choose the NIC that you will use for system tasks. Click Next.
13. On the next Network Configuration screen, set your IP addressing information, subnet mask, DNS, and hostname. Click Next.
14. On the Setup Type screen, choose standard setup.
15. Select the virtual disk you wish to install ESX on, and click Next.
16. On the Data Loss warning screen, click OK.
17. On the Time Zone Settings screen, choose your appropriate time zone, and click Next.
18. On the Date and Time screen, modify the date and time as you wish, and click Next.
19. Assign a root password for ESX. Optionally, add additional users if you wish, and click Next.
20. On the Summary screen, click Next to install.
21. When the installation is complete, click Next.
22. Click Finish to reboot the system.

Enabling secure shell (ssh) access for the root user

1. Using Putty, Cygwin, or another terminal, ssh to the ESX Server.
2. Type the following command to switch to the root user:

```
# su -
```
3. Enter the root user password.
4. Type the following command to change to the appropriate directory:
```
# cd /etc/ssh
```
5. Edit the sshd_config file using vi. Use the following command:
```
# vi sshd_config
```
6. Press the down arrow key to move the cursor to the PermitRootLogin line, and then move the cursor to the word no. Press the i key to insert text.
7. Type the word `yes` and delete the word no.
8. Press the Escape key to return to command mode.
9. Type the following command to save and exit the file:
```
:wq
```
10. Type the following command to reboot the server:
```
# init 6
```

Installing vSphere on a management workstation

1. Navigate to the IP address of your ESX Server.
2. Accept certificate warnings, and continue.
3. Click vSphere to download the vSphere client.
4. Choose Run to install.
5. Choose your language, and click OK.
6. On the Welcome screen, click Next.
7. Accept the license terms, and click Next.
8. Enter user and organization details, and click next.
9. Optionally, click the checkbox to install the update utility. Click Next.
10. On the Destination Folder screen, click Next.
11. Click Install.
12. Click OK.

Connecting the storage to the host

On the Dell EqualLogic storage, we connected the OS-Log volume to the ESX Server VMkernel using one physical 1Gb NIC. We presented each virtual machine with two 1Gb virtual NIC's connected to two physical NIC's that we used to connect the Microsoft iSCSI Initiator within the Virtual Machine to its individual iSCSI database volume.

On the HP StorageWorks storage, we connected the OS-Log volume to ESX Server using the first Fibre Channel adapter. We connected the two database volumes to ESX Server using the second Fibre Channel Adapter.

We connected an additional virtual NIC to a physical 1Gb NIC for DVD Store client to server communications.

Adding the iSCSI storage adapter in ESX (Dell only)

1. Click Start, All Programs, VMware, VMware vSphere client.
2. Click the Configuration tab.
3. Click Networking.
4. Click Add Networking…
5. Select the VMkernel radio button, and click Next.
6. Deselect any selected NICs that vSphere shows as "down". Select the first of the available four NICs that vSphere does not show as "down" in the Speed column. Click Next.
7. Assign a label to the network. Click Next.
8. Enter a valid IP address and subnet. Click Next.
9. Click Finish.
10. Click No when the application prompts you to enter a default gateway.
11. Click the Configuration tab.
12. Click Storage Adapters under Hardware pane.
13. Click iSCSI Software Adapter. Then, click Properties.

14. Click Configure.
15. Click Enabled.
16. Click OK.
17. After the application disables the device, click the Dynamic Discovery tab.
18. Click Add.
19. Enter the IP address of the storage group.
20. Click Close.
21. Click Yes when the application prompts you to rescan for changes.

Adding the storage volumes to ESX storage

1. In vSphere, click the Configuration tab
2. Click Storage in the Hardware pane.
3. Click Add Storage…
4. Choose Disk/LUN. Click Next.
5. Select the appropriate LUN. Click Next.
6. Click Next.
7. Enter a name for the datastore. Click Next.
8. Click Next to accept the defaults for block size.
9. Click Finish to complete the addition of the LUN.
10. Repeat steps 1 through 9 two more times (HP only).

Setting up the iSCSI NICs with vSphere (Dell only)

1. Click the Configuration tab.
2. Click Networking.
3. Click Add Networking.
4. Click Virtual Machine.
5. Choose to Create a virtual switch. Assign the relevant NIC in the system. Click Next.
6. Assign a network name.
7. Click Finish.
8. Repeat steps 1 through 7 once more.

Creating and configuring the VMs

Creating the virtual machine with vSphere

1. Click Start, All Programs, VMware, VMware vSphere client.
2. Enter the IP address or hostname, user name, and password. Click Login.
3. Click the Virtual Machines tab.
4. Right-click, and choose New Virtual Machine.
5. Choose Custom, and click Next.
6. Assign a name to the virtual machine. Click Next.
7. Select a datastore for the virtual machine files. We chose the OS-Log Datastore. Click Next.
8. Choose Virtual Machine Version 7 to utilize build 148592 of ESX. Click Next.
9. Choose Microsoft Windows, then Microsoft Windows Server 2008 (64-bit). Click Next.
10. Choose two virtual processors. Click Next.
11. Choose 4GB RAM. Click Next.
12. Click None for the number of NICs. Click Next.
13. Choose LSI Logic SAS as the SCSI controller. Click Next.
14. Choose to create a new virtual disk. Click Next.
15. Make the OS virtual disk size 50 GB, and click Next.
16. Keep the default virtual device node, and click Next.
17. Click Finish.
18. Right-click the VM, and choose Edit Settings.
19. On the Hardware tab, click Add…
20. Choose Ethernet Adapter, and click Next.
21. Choose VMXNet 3, and Click Next.
22. Click Finish then OK.

Installing the guest operating system

1. Insert the installation DVD for Windows Server 2008 x64 into the DVD drive.
2. In vSphere, right-click the virtual machine, and choose CD/DVD drive.
3. Click the Host Device radio button, and choose the appropriate drive.
4. Click OK.
5. Right-click the machine, and choose Power, Power On.
6. Right-click the machine, and choose Open console.
7. Choose the language, time and currency, and keyboard input. Click Next.
8. Click Install Now.
9. Choose Windows Server Enterprise (Full Installation). Click Next.
10. Accept the license terms, and click Next.
11. Click Custom.
12. Click the Disk, and click Drive options (advanced).
13. Click New, Apply, Format, and then click Next.
14. Let the installation process continue. The VM will reboot several times.
15. After the installation completes, click OK to set the Administrator password.
16. Enter the administrator password twice, and click OK.
17. When the operating systems finishes booting, choose VM, Guest, Install/Upgrade VMware Tools.
18. On the information Install VMware Tools screen, click OK.
19. On the autoplay menu, click Run setup.exe.
20. On the Welcome screen, click Next.
21. On the Setup Type screen, choose Typical, and click Next.
22. Click Install.
23. On the various Windows Security screens, click Install each time.
24. Click Finish to complete the installation.
25. Click Yes to reboot the VM.
26. Log into the VM after reboot.
27. Click Start, Control Panel, then double-click System.
28. Click Change Settings.
29. Click Change.
30. Enter the new computer name, and click OK.
31. Click OK to restart, click Close, and click Restart Now.

Configuring networking in the VM

1. Power on the VM, and open the console.
2. Click Start, Control Panel, Network Connections, then click Manage Network Connections.
3. Right-click the NIC, and choose properties.
4. Select TCP/IP (v4), and choose properties.
5. Set the IP address, subnet, gateway, and DNS server for this NIC, which will handle outgoing server traffic (i.e., the public IP). Click OK, then click Close.
6. On the Dell server, repeat steps 2 through 5 twice, but these NIC's should be on the same network segment as the Dell EqualLogic storage.

Installing the Host Integration toolkit on the VM (Dell only)

1. Download the host integration toolkit (Setup64.exe).
2. Double click Setup64.exe.
3. Accept the security warnings, and choose to run the exe.
4. Click Next.
5. Click Accept, then Next.
6. Click Typical, then Next.
7. You will see a Windows Firewall warning; leave it open for a minute.
8. Click the Start button, then choose Administrative Tools→Windows Firewall with Advanced Security.
9. In the left panel, click Inbound Rules.
10. In the center Inbound Rules panel, right-click iSCSI Service (TCP-In), and choose Enable Rule.
11. In the center Outbound Rules panel, right-click iSCSI Service (TCP-In), and choose Enable Rule.

12. Close the Windows Firewall dialog.
13. Clear the message box.
14. Click Install.
15. Click Yes to install multipath software automatically.
16. Choose to restart the computer when the application prompts you to do so.

Installing Windows updates

1. Power on the VM, and open the console.
2. Log into the VM.
3. Click Start, Windows Update.
4. Click View Advanced Options.
5. Click Never Check for Updates.
6. Click OK.
7. Click Check for Updates.
8. Click Install Now when the application prompts you to install an update for Windows update.
9. Click View available updates to ensure you install the necessary updates.
   Note: We installed the following updates:
   - Hotfix for Windows(KB942288)
   - Security Update for Windows Server 2008 x64 Edition (KB958687)
   - Update for Windows Server 2008 x64 Edition (KB957388)
   - Security Update for Windows Server 2008 x64-based Systems (KB938464)
   - Security Updates for Windows Server 2008 x64 Edition (KB955069)
   - Cumulative Security Update for Internet Explorer 7 for Windows Server 2008 x64 Edition (KB961260)
   - Security Updates for Windows Server 2008 x64 Edition (KB954459)
   - Security Updates for Windows Server 2008 x64 Edition (KB957097)
   - Security Updates for Windows Server 2008 x64 Edition (KB958623)
   - Security Updates for Windows Server 2008 x64 Edition (KB953733)
   - Security Updates for Windows Server 2008 x64 Edition (KB950762)
   - Update for Windows Server 2008 x64 Edition (KB955839)
   - Security Updates for Windows Server 2008 x64 Edition (KB958624)
   - Security Updates for Windows Server 2008 x64 Edition (KB950974)
   - Update for Windows Server 2008 x64 Edition (KB951978)
   - Microsoft .NET Framework 3.5 Service Pack1 and .NET Framework 3.5 Family Update (KB951847) x64
   - Security Updates for Windows Server 2008 x64 Edition (KB954211)
   - Security Update for Windows Mail for Windows Server 2008 x64 Edition (KB951066)
   - Update Rollup for ActiveX Killbits for Windows Server 2008 x64 Edition (KB960715)
   - Security Updates for Windows Server 2008 x64 Edition (KB956841)
   - Security Updates for Windows Server 2008 x64 Edition (KB956802)
   - Update for Windows Server 2008 x64 Edition (KB957321)
   - Update for Windows Server 2008 x64 Edition (KB952287)
   - Windows Malicious Software Removal Tool x64 – Febuary 2009 (KB890830)
   - Security Updates for Windows Server 2008 x64 Edition (KB958644)
   - Security Updates for Windows Server 2008 x64 Edition (KB958644)
   - Update for Windows Server 2008 x64 Edition (KB950050)
   - Cumulative Security Update for ActiveX Killbits for Windows Server2008 x64 Edition (KB950760)
   - Update for Windows Server 2008 x64 Edition (KB955302)
   - Windows Update software 7.2.6001.788
10. Click Install.
11. Agree to the license terms, and click Finish.
12. Reboot the VM when the application requests you do so.
13. After reboot, check Windows update again for further updates. Click Start, Windows Update.

14. Click Check for updates.
15. If Windows lists no important updates, then close the updates window.

Installing SQL Server 2008 on the VM

1. Insert the DVD into the physical DVD drive.
2. Right-click the VM, and choose Power, Power On.
3. Right-click the VM, and choose Open Console.
4. Click the Connect CD/DVD button. Choose CD/DVD Drive 1, Connect to host device…
5. Click Run SETUP.EXE on the autoplay menu.
6. When the application prompts you to install the .NET Framework, click OK.
7. Select the Accept radio button, and click Install.
8. When the installation finishes, click Exit.
9. When the application prompts you, click OK to install a hotfix for Windows (KB942288).
10. Click Restart now to restart the VM upon completion.
11. After rebooting, log into the VM.
12. Click Start, Computer.
13. Double-click the CD/DVD drive.
14. Click Installation.
15. Click New SQL Server stand-alone installation.
16. On the Setup support rules screen, click OK.
17. Specify the Enterprise Evaluation free edition. Click Next.
18. Click the checkbox to accept the license terms. Click Next.
19. Click Install to install the setup support files.
20. You may see a Windows Firewall warning. For now, ignore this, and click Next.
21. On the Feature Selection screen, select Database Engine Services, Full-Text Search, Client Tools Connectivity, Client Tools Backward Compatibility, Management Tools –Basic, and Management Tools – Complete. Click Next.
22. On the Instance configuration screen, click Next.
23. On the Disk space requirements screen, click Next.
24. On the Server configuration screen, choose NT AUTHORITY\SYSTEM for SQL Server Agent, and choose NT AUTHORITY\SYSTEM for SQL Server Database Engine. Click Next.
25. On the Database Engine Configuration screen, select Mixed Mode.
26. Enter a password for the system administrator account.
27. Click Add Current user. This may take several seconds.
28. Click Next.
29. On the Error and usage reporting screen, click Next.
30. On the installation rules screen, click Next.
31. On the Ready to Install screen, click Next.
32. After installation is complete, click Start, Administrative Tools,

Adding an additional drive to the VM via the iSCSI initiator (Dell only)

1. Power on the VM, and open the console.
2. Click Start, Control Panel, and double-click iSCSI Initiator.
3. Click the Discovery tab.
4. Click Add Portal…
5. Add the IP address of the Dell EqualLogic storage group.
6. Click OK.
7. Click the Targets tab.
8. Find the relevant SQL Data volume for this VM, and select it. Click Log On…
9. Check the checkbox to allow automatic logon on reboot, and to also enable multipath.
10. Click OK.

Adding an additional virtual drive to the VM via vSphere (HP only)

1. Power off the VM, right-click and choose Edit Settings.
2. Click Add

3. Choose Hard Disk, and click Next.
4. Choose Create a new virtual disk, and click Next.
5. Choose 60GB for the size and select Specify a datastore. Click Browse.
6. Select the appropriate datastore. We alternated database storage between the two datastores available on the HP Storage. Click OK.
7. Click Next.
8. Click Next.
9. Click Finish.
10. Click OK.

Configuring additional drives in Disk Management

1. Power on the VM, and open the console.
2. Click Start, Administrative Tools, Computer Management.
3. Click Disk Management
4. Right click the uninitialized disks (if any), and choose Initialize Disk.
5. Choose MBR.
6. Right-click the volume and choose New Simple Volume. Click Next.
7. Keep the default drive space and click Next.
8. Keep the default drive letter assignment and click Next.
9. Choose NTFS, 64KB allocation unit size, and check the Perform a quick format checkbox. Click Next.
10. Click Finish.
11. Create folders necessary for the database restore. We used <driveletter>:\SQLData.

Creating the additional VMs on the host server

After installing and configuring the initial VM, we created the additional VMs through automated cloning scripts.

Cloning the VMs

We used a shell script on the ESX Server to copy the Virtual Disks, and clone the VMs. This shell script copied the VM definition and virtual disks, and registered the new VM in ESX, using the vmware-cmd utility. Using these automated cloning scripts saved time and let us confirm that we configured all VMs similarly.

Configuring the additional VMs after cloning

1. In vSphere, expand the host, then click the VM.
2. Click the console tab.
3. Start the VM by right-clicking the VM, and choosing Power →Power On.
4. Click Start→Control Panel→Network and Internet→Network Connections, and double-click the Local Area Connection.
5. Select Internet Protocol Version 4 (TCP/IPv4), and click Properties.
6. In the Internet Protocol Version 4 (TCP/IPv4) Properties screen, select the Use the following IP address radio button.
7. Enter a valid static IP address for this new VM, subnet mask, and default gateway.
8. Select the Use the following DNS server addresses radio button, and enter at least one valid DNS server, if the application requires you to do so.
9. Click OK, and click Close to exit.
10. Click Start→Control Panel→System.
11. Click Change Settings to change the computer name.
12. Click the Change button
13. Type the new computer name
14. Click OK, then click OK again.
15. Reboot the VM as prompted.

Creating the virtual client machines

For the DVD Store scripts, we used a number of client virtual machines to simulate a number of users putting a load on the server. To ensure that the accuracy of virtual clients is comparable to physical clients we performed a similar test on physical clients as well. For our client VMs, we installed a fresh copy of ESX 3.5 update 3 on our client host; a Dell PowerEdge R900 server with four 4 Intel X7460 2.66Ghz processors, eight 73GB, 15k SAS drives and 64GB RAM. We created and configured a master client as we describe above, and also installed a fresh copy of Windows Server 2003 R2 x86 w/ SP2 on the initial client and installed Windows Updates available as of Feb. 24, 2009. We created a folder called C:\ClientShare to store workload scripts, and shared this folder for access from our controller machine. We installed the .NET 2.0 framework on each client VM, as the DVD Store test executable requires this. We created a performance counter log on each client machine to track the number of orders per minute (OPM) each virtual database server returns. We used the Windows Server 2003 version of the system preparation tool to prepare the VM for cloning, and then used the cloning shell scripts to create the additional clients. We followed this process for each installation:

1. Follow the steps in the earlier Creating a virtual machine section using the following VM specifications:
    a. Name: SQLClient
    b. Virtual processors: 2
    c. Virtual memory: 4096 MB
    d. Virtual Disk Size: 8 GB
    e. Virtual network: External Network
2. Install Microsoft Windows Server 2003 R2 Enterprise x86 Edition Service Pack 2 on the VM.
3. Assign a computer name of `Clientx` for the database client, where `x` is the client number.
4. For the licensing mode, use the default setting of five concurrent connections.
5. Enter a password for the administrator log on.
6. Select Eastern Time Zone.
7. Use typical settings for the Network installation.
8. Type `Workgroup` for the workgroup.
9. Install Windows Updates, .NET 2.0 framework, and DVDStore client executable

DVD Store setup

Data generation overview

We built the database schema using the scripts in the DS2 distribution package, though we made a few minor modifications. The DS2 stress tool provides options to generate 10MB, 1GB, or 100GB datasets. To get the tool to generate the 20 GB of user data we used in this test, we had to make a few straightforward changes to the source code and to the DVD Store application's scripts. Note: We created our test data on a Linux system to take advantage of the larger RAND MAX.

Editing the ds2_create_orders.c module

The module ds2_create_orders.c defines constants that define the maximum values for the customer ID and the product ID. The constants for the 20GB database size did not exist. We added the constants for this size.

On the command line for the ds2_create_orders.c module, we specified the size. The available options were S (small), M (medium), and L (large). We added the case W for the 20GB database. In the switch statement that sets the values for the variables max_cust_id and max_prod_id, we added cases that assigned them the proper values for the 20GB database size.

We recompiled the ds2_create_orders.c module on Linux, following the instructions in the header comments. We used the following command line: `gcc -o ds2_create_orders ds2_create_orders.c -lm`

Editing the ds2_create_cust.c module

We had to make the same changes to the ds2_create_cust.c module that we made to the ds2_create_orders.c module. On the command line for the ds2_create_cust.c module, we specified the size. The available options were S (small), M (medium), and L (large). We added the case W for the 20GB database. In the switch statement

that sets the values for the variables max_cust_id and max_prod_id, we added cases that assigned them the proper values for the 20 GB database size.

We recompiled the ds2_create_cust.c module on Linux, following the instructions in the header comments. We used the following command line: `gcc -o ds2_create_cust ds2_create_cust.c -lm`

Generating the data for the 20GB database

We used shell scripts to run all four of the executables that generate the data. The distribution did not include shell scripts for the 20GB size. We wrote shell scripts based on the ds2_create_cust_large.sh and ds2_create_orders_large.sh scripts. The ds2_create_prod and ds2_create_inv executables did not ship with associated shell scripts, so we created shell scripts using the instructions in the readme files. We ran the shell scripts in the following order to generate the data for the 20GB database:

1. `ds2_create_orders_20gb.sh`
2. `ds2_create_inv_20gb.sh`
3. `ds2_create_prod_20gb.sh`
4. `ds2_create_cust_20gb.sh`

We waited until the processes finished before we moved onto the next step.

Creating the database

We modified the database creation SQL Server scripts in the DVD Store distribution package to build the database schema, which includes the file structure, tables, indices, stored procedures, triggers, and so on. We built a master copy of the 20GB database version for SQL Server 2008, and then used that master copy to restore our test database to each test server VM between each test run. We stored the backup file on the VM C: drive for quick access.
We followed these steps to create the database:

1. We created the database and file structure using database creation scripts provided with DS2. We made size modifications specific to our 20GB database and the appropriate changes to drive letters.
2. We created database tables, stored procedures, and objects.
3. We set the database recovery model to bulk-logged to prevent excess logging.
4. We loaded the data that the database generated. 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.
5. We created indices, full-text catalogs, primary keys, and foreign keys using the database-creation scripts.
6. We updated statistics on each table according to database-creation scripts, which sample 18 percent of the table data.
7. We created ds2user SQL Server login and user for testing 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
```

8. We set the database recovery model back to full.

We made the following changes in the build scripts:

- Because we varied the size of the datasets, we sized the files in our scripts to reflect the database size and the number of files per filegroup. We allowed for approximately 40 percent free space in our database files to ensure that filegrowth activity did not occur during the testing.

- We followed Microsoft's recommendation of having 0.25 to 1 file per filegroup per core. We used two files per filegroup on our 2 virtual processor VMs.
- We did not use the DBCC PINTABLE command for the CATEGORIES and PRODUCTS tables, both because Microsoft recommends against this practice and because the commands do nothing in SQL Server 2008.
- We added the FORCESEEK hint in the BROWSE_BY_ACTOR stored procedure because in initial testing we found that SQL Server 2008 was choosing an index scan instead of the preferred index seek, adding unnecessary overhead.
- We created a SQL Server login called ds2user and mapped a database user to this login. We made each such user a member of the db_owner fixed database role.
- Using the DVD Store scripts as a reference, we created the full-text catalog and index on the PRODUCTS table manually in SQL Server Management Studio.
- In our pre-test experimentation, we found that SQL Server 2008 would occasionally choose an inefficient query plan in the DVD Store workload. To flush the plan cache during these cases, we used the DBCC FREEPROCACHE command.

We then performed a full backup of the database. This backup allowed us to restore each server VM to a pristine state relatively quickly between tests.

Editing the workload script - ds2xdriver.cs module

To use the 20GB database we created earlier, we had to change the following constants:

- In the routine Controller(), we changed the string sizes. We added the W option for the 20GB database size. DS2 uses the sizes string to interpret the db_size_str option.
- In the class Controller, we changed the arrays MAX_CUSTOMER and MAX_PRODUCT. To each, we added values specifying the bounds for the customer and product IDs. The Controller() routine uses these arrays.
- We added a command line parameter for the database name: `–database_name`

Editing the workload script - ds2sqlserverfns.cs module

We changed the connection string to increase the number of available connections, to not use the default administrator ("sa") account, and to include a parameter for the database name. We raised the available connections limit from the default of 100 to 200 to allow room for experimentation. We created a user account called ds2User and used that account.

The ds2connect routine in the ds2sqlserverfns.cs module defines sConnectionString. We used the following string; the changes we made appear in bold.

```
string sConnectionString = "User ID=ds2User;Initial Catalog="+dbname+";Max
Pool Size=200;Connection Timeout=120;Data Source=" + Controller.target;
```

Recompiling the ds2sqlserverdriver.exe executable

We recompiled the ds2xdriver.cs and ds2sqlserverfns.cs module on Windows by following the instructions in the header comments. Because the DS2 instructions were for compiling from the command line, we used the following steps:

1. Open a command prompt.
2. Use the cd command to change to the directory containing our sources.
3. Run the batch file C:\Program Files\Microsoft Visual Studio 9.0\Common7\Tools\vsvars32.bat. This sets up the environment variables for us.
4. Execute the following command:
   ```
   csc /out:ds2sqlserverdriver.exe ds2xdriver.cs ds2sqlserverfns.cs
   /d:USE_WIN32_TIMER /d:GEN_PERF_CTRS
   ```

Testing procedure

To perform the test, we used a series of batch files. We stored batch files respective to each system on that system, either under the C:\ServerShare folder or the C:\ClientShare folder, and we used the psexec, plink, and winscp utilities to coordinate the test procedures amongst the client machine, server machine, and controller. We use simple file sharing, or secure ftp to copy files from machine to machine as we needed.

The testing procedure consisted of the following steps:

1. Execute batch files and shell scripts to clean up prior outputs on client virtual machines, the server physical machine, and the controller.
2. Drop the database on each server VM.
3. Restore the database on each server VM.
4. Pause for 5 minutes to wait for background tasks to complete before server reboot.
5. Reboot the physical machines, and wait for a ping response from the physical machine, as well as from all VMs involved in testing.
6. Wait 10 additional minutes for any background tasks to complete.
7. Record idle power for 2 minutes.
8. Start performance counters on client virtual machines, and start esxtop on the server under test.
9. Start the workload connections.
10. Start the workload ramp up period. Run the DBCC FREEPROCACHE command if necessary (see the Creating the database section).
11. Start the workload.
12. Stop the workload.
13. Copy all output files to the controller.

Power measurement procedure

To record each server's power consumption during each test, we used an Extech Instruments (www.extech.com) 380803 Power Analyzer/Datalogger. We connected the power cord from the server under test to the Power Analyzer's output load power outlet. We then plugged the power cord from the Power Analyzer's input voltage connection into a power outlet. For the storage arrays, which have multiple power cords, we plugged all of the cords for each array into a power strip and then plugged the power strip into the Power Analyzer's output load power outlet.

We used the Power Analyzer's Data Acquisition Software (version 2.11) to capture all recordings. We installed the software on a separate Intel processor-based PC, which we connected to the Power Analyzer via an RS-232 cable. We captured power consumption at one-second intervals.

To gauge the idle power usage, we recorded the power usage for two minutes while each system was running the appropriate number of VMs, but otherwise idle, meaning they were not running any test workload.

We then recorded the power usage (in watts) for each system during the testing at one-second intervals. To compute the average power usage, we averaged the power usage during the time the system was producing its peak performance results. Because we measured the power of the server and storage separately, we added the average power of both together to get the total power. We call this time the power measurement interval. See Figure 6 (idle and average peak power) for the results of these measurements.

Appendix A – Server configuration information

This appendix provides detailed configuration information about the servers, which we present in alphabetical order. Figure 9 provides detailed system configuration information.

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Servers	Dell PowerEdge R710	HP ProLiant DL385 G5p
General dimension information		
Height (inches)	3.50	3.40
Width (inches)	17.50	17.50
Depth (inches)	27.00	27.25
U size in server rack (U)	2	2
Power supplies		
Total number	2	2
Wattage of each (W)	870	800
Cooling fans		
Total number	5	6
Dimensions (h x w) of each	2.5” x 2.5”	2.5” x 2.4”
Voltage (V)	12	12
Amps (A)	1.60	2.45
General processor setup		
Number of processor packages	2	2
Number of cores per processor package	4	4
Number of hardware threads per core	2	1
System power management policy	OS control	HP Dynamic Power Savings Mode
CPU		
Vendor	Intel	AMD
Name	Xeon E5530	Opteron 2384
Stepping	4	2
Socket type	LGA1366	Socket F
Core frequency (GHz)	2.4	2.7
L1 cache	32 KB + 32 KB (per core)	64KB + 64KB (per core)
L2 cache	1 MB (4 x 256 KB)	2 MB (4 x 512 MB)
L3 cache	1 x 8 MB	1 x 6 MB
Platform		
Vendor and model number	Dell PowerEdge R710	HP ProLiant DL385 G5p
Motherboard model number	PWBYN967	488895-001
Motherboard revision number	X08	C
BIOS name and version	Dell 0.2.15	HP BIOS A22

Servers	Dell PowerEdge R710	HP ProLiant DL385 G5p
BIOS settings	Virtualization enabled	AMD Virtualization enabled, No-Execute Page-Protection enabled
Memory modules		
Total RAM in system (GB)	72	64
Number of types of memory modules	2	1
First type of memory modules		
Vendor and model number	Crucial CT51272BB1339	Samsung M393T1K66AZA
Type	PC3-10600 DDR3	PC2-5300 DDR2
Speed (MHz)	1,333	667
Speed in the system currently running @ (MHz)	1,066	667
Timing/latency (tCL-tRCD-iRP-tRASmin)	9-9-9-24	5-5-5-15
Size (GB)	24	64
Number of RAM modules	6 x 4 GB	8 x 8 GB
Chip organization	Double-sided	Double-sided
Second type of memory modules		
Vendor and model number	Samsung M393B1K70BH1	N/A
Type	PC3-8500 DDR3	N/A
Speed (MHz)	1,066	N/A
Speed in the system currently running @ (MHz)	1,066	N/A
Timing/latency (tCL-tRCD-iRP-tRASmin)	8-8-8-24	N/A
Size (GB)	48	N/A
Number of RAM modules	6 x 8GB	N/A
Chip organization	Double-sided	N/A
Hard disk		
Vendor and model number	Seagate ST973451SS	HP DH072BAAKN
Number of disks in system	2	2
Size (GB)	73	72
Buffer size (MB)	16	16
RPM	15,000	15,000
Type	SAS	SAS
Operating system		
Name	VMware ESX	VMware ESX
Build number	148592	148592
File system	ext3 (server) vmfs3 (virtual machines)	ext3 (server) vmfs3 (virtual machines)
Language	English	English
Network card/subsystem		
Vendor and model number	Intel PRO/1000 Dual Port Adapter D33682	Broadcom NetXtreme II 5709 Dual-Port Ethernet
Type	Integrated	Integrated

Servers	Dell PowerEdge R710	HP ProLiant DL385 G5p
Optical drive		
Vendor and model number	TEAC DV-28S-VDB	HP GDR-D20N
USB ports		
Number	4	4
Type	2.0	2.0

Figure 9: Detailed system configuration information for the two test servers.

Appendix B – Storage array configuration information

This appendix provides detailed configuration information about the array systems, which we present in alphabetical order. Figure 10 presents detailed configuration information for the storage arrays.

	Dell EqualLogic iSCSI SAN	HP StorageWorks Fibre Channel SAN
Arrays	Three Dell EqualLogic PS5000XV arrays and one Dell EqualLogic PS6000 Array	HP StorageWorks EVA 4400 Enterprise Virtual Array with five full disk shelves
Disks	60 active 15,000RPM SAS disks total for the four shelves	60 active 15,000RPM FC disks total for the five shelves
Active storage cache	5 GB (1 GB per PS5000XV and 2 GB per PS6000)	4GB
Number of active storage controllers	4 (1 per array)	2
Number of passive storage controllers	4 (1 per array)	0
Number of active storage ports	10 (3 per PS5000XV array; 4 per PS6000)	4
Firmware revision	v4.1.1	XCS v9.00.10
Switch type/ model/firmware revision	Two Dell PowerConnect 6248 v2.2.0.3	Two Brocade 200E Fabric OS v6.0.0b
Disk vendor and model number	32x Seagate ST3146855SS 16x Seagate ST3450856SS 16x Maxtor ATLAS15K2_147SAS	36x HP BDF146DA47A 24x HP BF146DA47A
Disk size	146 GB and 450 GB	146 GB
Disk buffer size (MB)	16	16
Disk RPM	15,000	15,000
Disk type	SAS	Fibre Channel
RAID type	RAID 10	RAID 10

Figure 10: Detailed configuration information for the storage arrays.

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About Principled Technologies

We provide industry-leading technology assessment and fact-based marketing services. We bring to every assignment extensive experience with and expertise in all aspects of technology testing and analysis, from researching new technologies, to developing new methodologies, to testing with existing and new tools.

When the assessment is complete, we know how to present the results to a broad range of target audiences. We provide our clients with the materials they need, from market-focused data to use in their own collateral to custom sales aids, such as test reports, performance assessments, and white papers. Every document reflects the results of our trusted independent analysis.

We provide customized services that focus on our clients' individual requirements. Whether the technology involves hardware, software, Web sites, or services, we offer the experience, expertise, and tools to help you assess how it will fare against its competition, its performance, whether it's ready to go to market, and its quality and reliability.

Our founders, Mark L. Van Name and Bill Catchings, have worked together in technology assessment for over 20 years. As journalists, they published over a thousand articles on a wide array of technology subjects. They created and led the Ziff-Davis Benchmark Operation, which developed such industry-standard benchmarks as Ziff Davis Media's Winstone and WebBench. They founded and led eTesting Labs, and after the acquisition of that company by Lionbridge Technologies were the head and CTO of VeriTest.

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