PERFORMANCE AND TCO: DELL POWEREDGE R820 VS. HP PROLIANT DL585 G7

Making the most out of your virtualized infrastructure is important to your organization's bottom line. Selecting servers with the power to host a large number of virtual machines (VMs), that provide competitive performance per watt, performance per dollar, and maximize performance per U of rack space, can save your business a great deal of capital.

In the labs at Principled Technologies, we tested the database performance of two servers running VMware® vSphere® 5 VMs: the Dell PowerEdge R820 powered by the Intel Xeon processor E5-4650, and the AMD processor-based HP ProLiant DL585 G7. We found that the Dell PowerEdge R820 not only provided 13.9 percent better overall performance than the HP ProLiant DL585 G7, but also did so while providing 117.3 percent better performance/watt, and 127.8 percent better performance/U of rack space than the HP server. A single Dell PowerEdge R820 fits in just 2U of rack space, so a typical rack can house 21 PowerEdge R820 servers compared to just 10 4U HP ProLiant DL585 G7 servers, letting you pack more power into a smaller space to reduce data center costs. In our TCO analysis, we found that selecting the Dell PowerEdge R820 could reduce three-year total cost of ownership (TCO) compared to the HP ProLiant DL585 G7 by as much as 27.7 percent.

MAY 2012
A PRINCIPLED TECHNOLOGIES TEST REPORT
Commissioned by Dell Inc.

INCREASE PERFORMANCE WHILE SAVING MONEY

The ultimate goal of every business is the same: provide great products or services while making money for employees and investors. Outfitting your data center with servers that deliver top-of-the-line performance is a smart way to meet these business objectives. High-performing servers reduce the pieces of hardware you need to purchase to get the performance level you desire, which saves in not only hardware and maintenance costs, but can also maximize performance/watt and performance/rack space.

Get more for your dollar

To test the database performance of the two servers, we set up 16 VMware vSphere ESXi 5 VMs, each containing a Microsoft SQL Server® 2012 database, on both servers. Database performance is the number of orders per minute (OPM) the server could handle. As Figure 1 shows, we found that the Intel Xeon processor E5-4650-powered Dell PowerEdge R820 provided 13.9 percent greater database performance than the HP ProLiant DL585 G7.

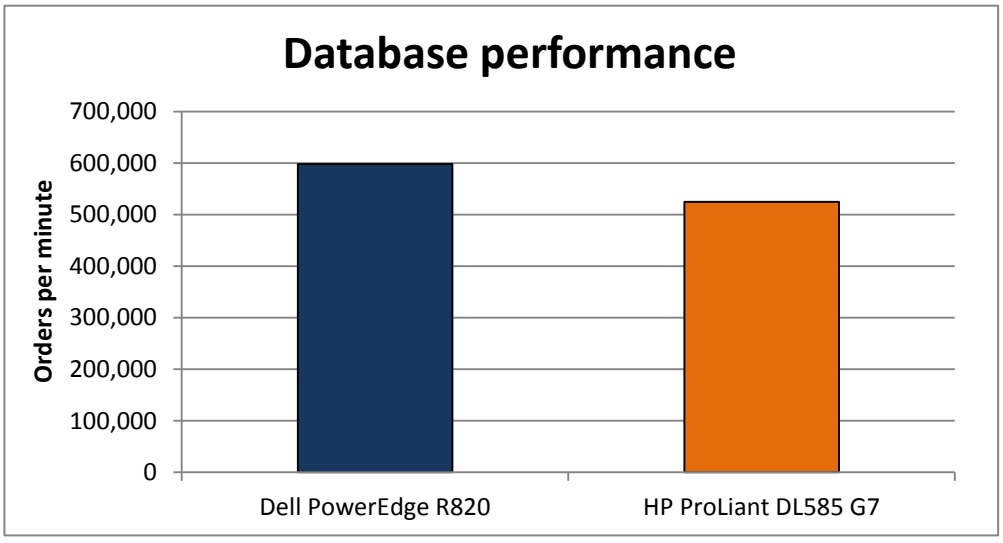

Figure 1: The Dell PowerEdge R820 increased performance over the HP ProLiant DL585 G7 by 13.9 percent.

While such a performance boost is impressive by itself, the Dell PowerEdge R820 provided additional advantages in our testing compared to the HP ProLiant DL585 G7. We measured the power each server used over the course of our test, and found that the Dell PowerEdge R820 had greater performance per watt of power it used. Figure 2 shows that the Dell PowerEdge R820 had 117.3 percent greater performance/watt than the HP ProLiant DL585 G7.

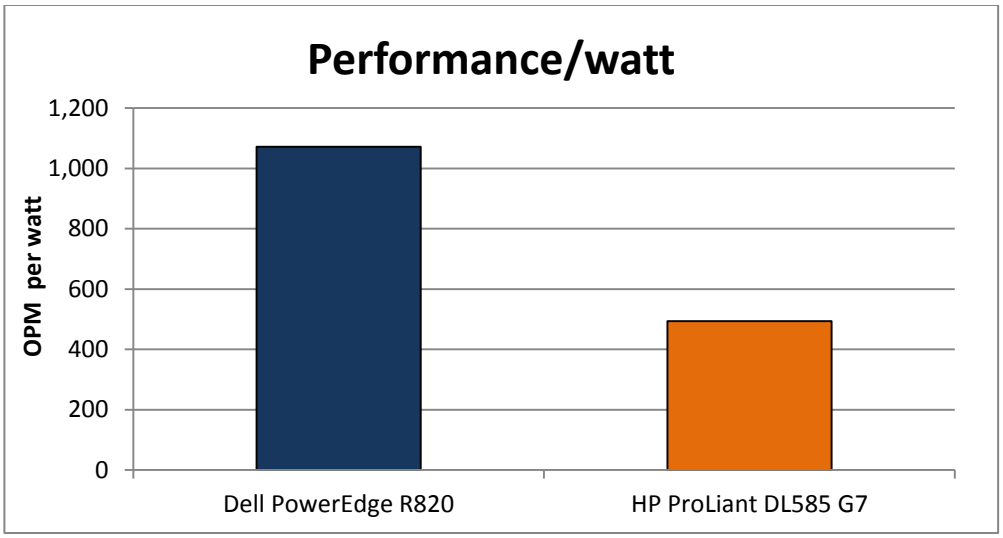

Figure 2: The Dell PowerEdge R820 delivered 117.3 percent greater performance/watt compared to the HP ProLiant DL585 G7.

Performance density is another important factor to consider when planning your data center. How much performance does each server provide for each U of rack space? Using performance data from our testing, we found that the 2U Dell PowerEdge R820, powered by the Intel Xeon processor E5-4650, packed in 127.8 percent more performance per U than the 4U HP ProLiant DL585 G7 server did. (See Figure 3.)

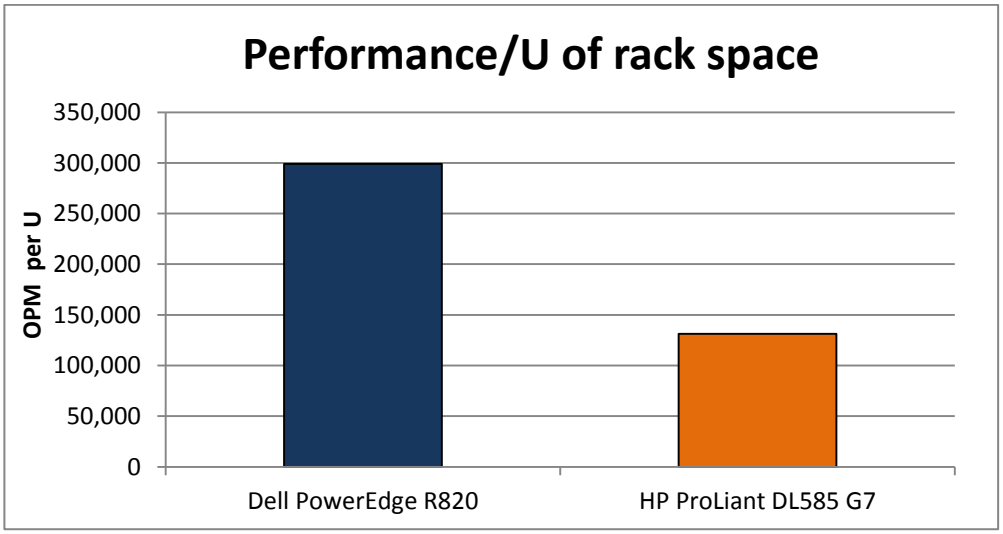

Figure 3: The comparatively sleek 2U Dell PowerEdge R820 more than doubled the performance/U of the HP ProLiant DL585 G7.

A standard 42U rack could hold 21 2UDell PowerEdge R820 servers, for an estimated 12,562,011 OPM per rack, or hold 10 4UHP ProLiant DL585 G7 servers for an estimated 5,251,310 OPM per rack (extrapolating the performance data from our testing). That is an estimated performance increase of 139.2 percent per rack using Dell PowerEdge R820 servers.

In the section that follows, we use our findings to create a hypothetical TCO analysis to show the potential savings of choosing the Dell PowerEdge R820 for your

data center. We discuss our test results in more detail in the What we found section below. For server configuration information, see Appendix A. For details on how we tested, visit Appendix B.

BREAKING DOWN THE SAVINGS

Though no two companies' data center needs will match up exactly, what follows presents one scenario showing the potential savings you could reap by upgrading your data center with new Intel Xeon processor E5-4650-based Dell PowerEdge R820 servers.

For our hypothetical TCO analysis, we compare the acquisition and three-year operational costs of a single Dell PowerEdge R820 server and an HP ProLiant DL585 G7 server each running SQL Server 2012 database workloads.

Figure 4 presents the estimated costs for the two servers over the next three years, including purchasing costs. While the Dell PowerEdge R820 server has a higher acquisition cost, factors such as hardware and software support, licensing costs, data center costs, and administration costs make it a more cost-efficient solution over three years. For detailed information on how we arrived at these costs, see Appendix C.

	Dell PowerEdge R820 solution	HP ProLiant DL585 G7 solution
Acquisition costs		
Hardware cost and 3-year support cost	$43,083.00	$26,448.00
VMware vSphere5 Enterprise Plus	$10,485.00	$10,485.00
Windows Server 2008 DataCenter Edition	$2,405.00	$2,405.00
SQL Server 2012 Enterprise Edition	$219,968.00	$329,952.00
Migration time	$5,000.00	$5,000.00
Total acquisition cost	$275,941.00	$369,290.00
Annual operational costs		
VMware vSphere 5 Standard Production Support and Subscription (licensed per processor)	$2,622.00	$2,622.00
OS Software support Windows Server 2008 R2 DataCenter Edition (per server)	$2,405.00	$2,405.00
SQL Server software support (SQL Server 2012 Enterprise Edition)	$54,992.00	$82,488.00
Administration costs	$2,327.53	$2,327.53
Energy costs	$507.14	$1,248.47
Port costs (1 port each)	$250.00	$250.00
Data center space costs	$197.28	$414.29
Total annual operational costs	$63,300.95	$91,755.29
Total 3-year operational costs	$189,902.85	$275,265.86
Total costs	**$465,843.85**	**$644,555.86**

Figure 4: Three-year acquisition and operating costs for each solution. Lower costs are better.

Figure 5 shows the savings that the Dell PowerEdge R820 server can deliver compared to the HP ProLiant DL585 G7 server over 3 years. Savings equal as much as $178,712, or 27.7 percent less than the HP ProLiant DL585 G7 solution.

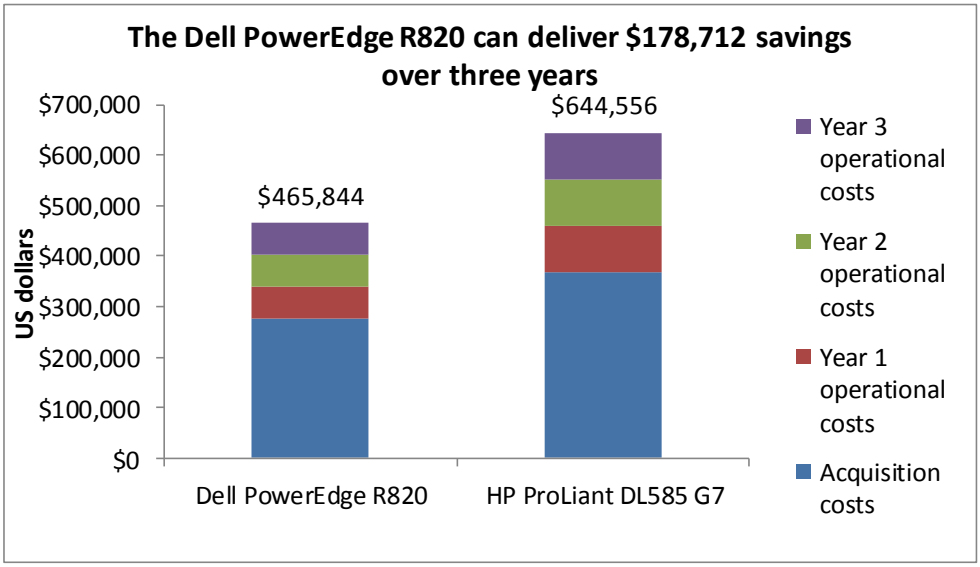

Figure 5: The Dell PowerEdge R820 can deliver savings of $178,712, or 27.7 percent, over three years compared to the HP ProLiant DL585 G7.

WHAT WE FOUND

Figure 6 shows the DS2 orders per minute results, by VM, for each server. The Intel Xeon processor E5-4650-powered Dell PowerEdge R820 server handled 13.9 percent more orders per minute than the HP ProLiant DL585 G7. We performed three runs on both servers. The results in Figure 6 are the median of those three runs.

VM	Dell PowerEdge R820	HP ProLiant DL585 G7
VM 1	37,124	33,147
VM 2	37,042	32,098
VM 3	37,007	29,740
VM 4	37,747	33,660
VM 5	37,818	34,053
VM 6	37,639	32,121
VM 7	37,206	34,458
VM 8	37,182	35,012
VM 9	35,900	33,593
VM 10	37,550	29,569
VM 11	36,738	33,088
VM 12	37,264	34,121
VM 13	36,298	32,607
VM 14	37,666	29,722
VM 15	38,271	30,334
VM 16	39,739	37,808
Total OPM	**598,191**	**525,131**

Figure 6: Orders per minute that each server handled in our DS2 test, broken down by VM.

Figure 7 presents CPU utilization and power statistics during our testing. The power results with VMs running no workloads show the power for the servers with no workloads actively running; the servers still host VMs, which uses more power than completely idle servers running no VMs. We recorded power and CPU utilization statistics with all VMs running workloads when our database tests were running.

	VMs running no workloads		All VMs running workloads		Performance /watt	Performance/watt percentage win
	Power (W)	% CPU utilization	Power (W)	% CPU utilization		
Dell PowerEdge R820	248.1	7.1	557.8	96.3	1,072.5	117.3
HP ProLiant DL585 G7	607.0	7.9	1,064.0	87.0	493.5	

Figure 7: CPU utilization, power, and performance/watt statistics for the two servers.

WHAT WE TESTED

To test the database performance of the servers, we set up 16 VMs on each server. We configured each VM with 4 vCPU, 12GB of memory and a virtual NIC. Each VM ran Windows Server 2008 R2 with its own 5GB SQL Server 2012 database. We used the DVD Store Version 2.1 benchmark to create our workload.

About DVD Store Version 2.1

To create our real-world ecommerce workload, we used the DVD Store Version 2.1 (DS2) benchmarking tool. DS2 models an online DVD store, where customers log in, search for movies, and make purchases. DS2 reports these actions in orders per minute (OPM) that the system could handle, to show what kind of performance you could expect for your customers. The DS2 workload also performs other actions, such as adding new customers, to exercise the wide range of database functions you would need to run your ecommerce environment. For more information about the DS2 tool, see http://www.delltechcenter.com/page/DVD+Store.

IN CONCLUSION

Populating your data center with servers with powerful processors can do more than just deliver excellent performance for your applications. In our tests, we found that the Intel Xeon processor E5-4650-based Dell PowerEdge R820 server outperformed the HP ProLiant DL585 G7 by 13.9 percent. The power-efficient PowerEdge R820 also provided 117.3 percent better performance/watt, and delivered 127.8 percent more performance per U on an individual server, for an estimated 139.2 percent more performance when filling a 42U rack.

With more performance and the potential to save you up to 27.7 percent in TCO over three years, the Dell PowerEdge R820 is a smart solution for your data center.

APPENDIX A – SERVER CONFIGURATION INFORMATION

Figure 8 provides detailed configuration information for the test servers.

System	Dell PowerEdge R820	HP ProLiant DL585 G7
Power supplies		
Total number	2	4
Vendor and model number	Dell E1100E-S0	HP DPS-1200FB-1 A
Wattage of each (W)	1,100	1,200
Cooling fans		
Total number	6	4
Vendor and model number	San Ace 60 9GA0612P1J611	DC BRUSHLESS PFC0912DE
Dimensions (h x w) of each	2.5" x 2.5"	3.5" x 3.5"
Volts	12	12
Amps	1.50	4.32
General		
Number of processor packages	4	4
Number of cores per processor	8	16
Number of hardware threads per core	2	1
System power management policy	Balanced	Balanced
CPU		
Vendor	Intel	AMD
Name	Xeon	Opteron™
Model number	E5-4650	6282 SE
Stepping	7	B2
Socket type	LGA2011	G34
Core frequency (GHz)	2.70	2.60
Bus frequency (GT/s)	8.0	6.4
L1 cache	32 KB	8 x 64 KB, 16 x 16 KB
L2 cache	256 KB	8 x 2 MB
L3 cache (MB)	20	16
Platform		
Vendor and model number	Dell PowerEdge R820	HP DL585 G7
Motherboard model number	Dell UL94V-0	HP 604046-001
BIOS name and version	Dell 1.0.0	ProLiant System BIOS A16
BIOS settings	Default	Default
Memory module(s)		
Total RAM in system (GB)	256	256
Vendor and model number	Samsung M393B2G70BH0-YH9	Samsung M393B1K70BH1-CH9
Type	PC3L-10600R	PC3-10600R
Speed (MHz)	1,333	1,333
Speed running in the system (MHz)	1,333	1,333
Timing/Latency (tCL-tRCD-tRP-tRASmin)	9-9-9-36	9-9-9-24
Size (GB)	16	8

System	Dell PowerEdge R820	HP ProLiant DL585 G7
Number of RAM module(s)	16	32
Chip organization	Double-sided	Double-sided
Rank	Dual	Dual
Operating system		
Name	VMware ESXi 5.0 Update 1	VMware ESXi 5.0 Update 1
Build number	623860	623860
File system	EXT3	EXT3
Kernel	5.0.0U1	5.0.0U1
Language	English	English
Graphics		
Vendor and model number	Matrox® G200eR	ATI ES1000
Graphics memory (MB)	16	16
RAID controller		
Vendor and model number	Dell PERC H710P Adapter	HP Smart Array P410i
Firmware version	21.0.1-0130	3.66
Cache size	1 GB	512 MB
Hard drives		
Vendor and model number	Seagate ST9300653SS	Seagate ST9300653SS
Number of drives	8	8
Size (GB)	300	300
RPM	15,000	15,000
Type	SAS	SAS
Ethernet adapter		
Vendor and model number	Intel Gigabit 4P I350-t	HP NC375i
Type	Integrated	Integrated
Optical drive(s)		
Vendor and model number	PLDS DVD+-RW DS-8A5SH	None
Type	Internal	N/A
USB ports		
Number	4 external, 1 internal	4 external, 1 internal
Type	2.0	2.0

Figure 8: System configuration information for the test servers.

APPENDIX B - HOW WE TESTED

Figure 9 illustrates our test bed setup. For comparison purposes, we configured each VM as a standalone SQL Server 2012 environment with all roles included on each. This approach allowed us a modular method to determine an exact increase in identical virtual machines. Results in your specific environment will vary. In Figure 9, VM1 uses client 1, VM2 uses client 2, and so forth.

Note: The diagram below shows the Dell PowerEdge R820 server and the Dell PowerEdge R900 server running virtual clients. We configured the HP test bed identically, using the same virtual client server and switch, but with the HP ProLiant DL575 G7 in place of the Dell PowerEdge R820 server.

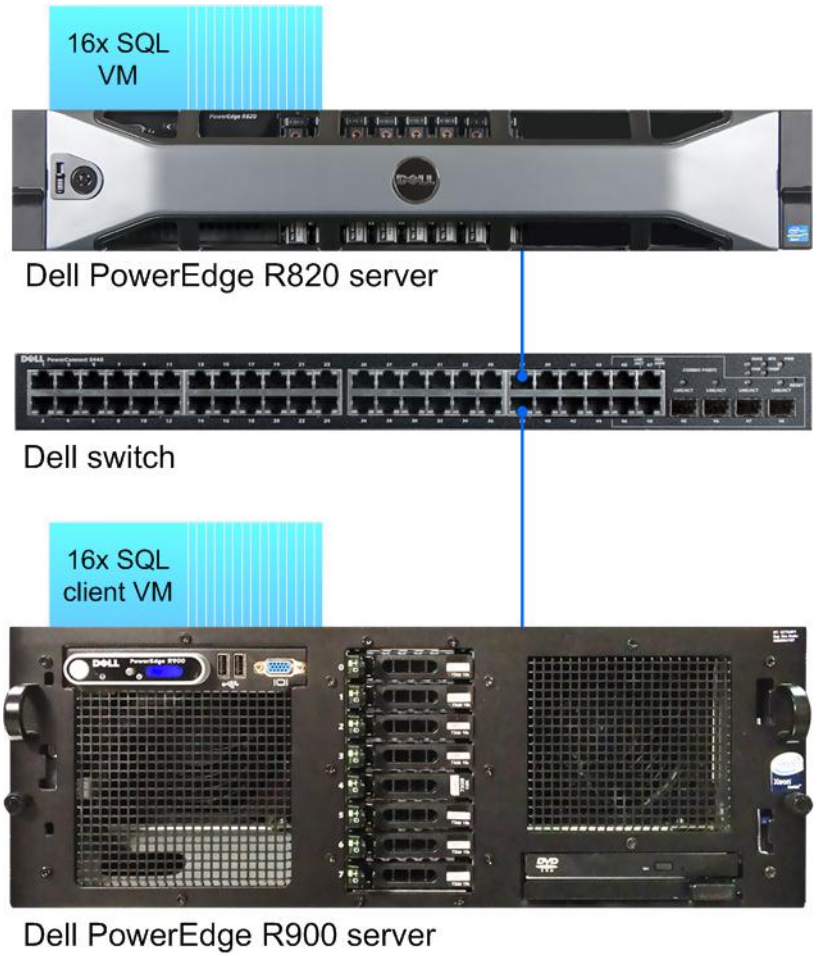

Figure 9: The test bed we used.

Setting up the server

We used the latest released firmware and software updates on all systems and used the default BIOS settings. The steps below show how we configured both servers.

Installing VMware vSphere 5.0 Update 1 (ESXi)

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.

Configuring ESXi after Installation

1. On the 5.0.0 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:
    a. Select Enable ESXi Shell, and press Enter.
    b. Select Enable SSH, press Enter, and press ESC.
4. On the System Customization screen, select Configure Management Network.
5. On the Configure Management Network screen, select IP Configuration.
6. On the IP Configuration screen, select set static IP, enter an IP address, subnet mask, and default gateway, and press Enter.
7. On the Configure Management Network screen, press Esc. When asked if you want to apply changes, press Y.

Configuring VM networking

1. Using the vSphere client from another machine, connect to the ESXi server.
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 internal RAID volume

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

Creating the first VM

1. In the vSphere client, connect to the ESXi host.
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, choose Microsoft Windows Server 2008 R2 (64-bit), and click Next.
9. Choose 1 virtual socket, and 4 virtual processors per core, and click Next.
10. Choose 12GB RAM, and click Next.
11. Click 1 for the number of NICs, 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 30 GB, choose thick-provisioned lazy zeroed, specify the datastore, 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 13GB for the virtual disk size, choose thick-provisioned lazy zeroed, and specify the DB datastore.
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 30GB for the virtual disk size, choose thick-provisioned lazy zeroed, and specify the Logs datastore.
27. Choose SCSI (1:1) for the device node, and click Next.
28. Click Finish, and click OK.
29. Start the VM.
30. Attach the Windows Server 2008 R2 SP1 ISO image to the VM and install Windows Server 2008 R2 on your VM.

Configuring the VMs

See the above sections regarding the initial creation of the virtual machine. We provide steps below for installing the operating system, Microsoft SQL Server, and configurations of the VMs.

Installing the VM operating system on the first VM

1. Connect to the ISO image of the installation DVD for Windows Server 2008 R2 SP1 Enterprise from the VM console. If the ISO image is not stored on the host, start the VM first and then connect to the ISO image.
2. Start the VM.
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. Install the latest VMware Tools package on the VM. Restart as necessary.
13. Connect the machine to the Internet, and install all available Windows updates. Restart as necessary.
14. Enable remote desktop access.
15. Change the hostname and reboot when the installation prompts you.
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.

Installing SQL Server 2012 RC0 on the first VM

1. Open the vSphere console for the VM or connect to the VM with RDP.
2. Log into the virtual machine.
3. Connect to the ISO image of the installation DVD for SQL Server 2012 RC0 Enterprise from the VM console or the menu in the vSphere Client.
4. Click Run SETUP.EXE. If Autoplay does not begin the installation, navigate to the SQL Server 2012 RC0 DVD, and double-click.
5. If the installer prompts you with a .NET installation prompt, click Yes to enable the .NET Framework Core role.
6. In the left pane, click Installation.
7. Click New installation or add features to an existing installation.
8. At the Setup Support Rules screen, wait for the check to complete. If there are no failures or relevant warnings, click OK.
9. Select the Enter the product key radio button, and enter the product key. Click Next.
10. Click the checkbox to accept the license terms, and click Next.
11. Click Install to install the setup support files.
12. 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.
13. At the Setup Role screen, choose SQL Server Feature Installation.
14. 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.
15. At the Installation Rules screen, click Next once the check completes.
16. At the Instance configuration screen, leave the default selection of default instance, and click Next.
17. At the Disk space requirements screen, click Next.
18. At the Server configuration screen, click Next.
19. At the Database Engine Configuration screen, select Mixed Mode.
20. Enter and confirm a password for the system administrator account.
21. Click Add Current user. This may take several seconds.
22. Click Next.
23. At the Error and usage-reporting screen, click Next.
24. At the Installation Configuration rules screen, check that there are no failures or relevant warnings, and click Next.
25. At the Ready to Install screen, click Install.

26. After installation completes, click Next.
27. Click Close.
28. Create a SQL Server login for the ds2user (see the Configuring the database (DVD Store) section for the specific script to use).
29. Copy the pre-created DVD Store backup to the specified backup VHD volume.
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 if it is disabled.

Configuring additional VMs on VMware vSphere 5.0

1. Log into the vCenter Server, which manages the host.
2. Right-click the first VM, and choose Clone.
3. Name the new VM.
4. Choose the cluster, and select the host.
5. At the Storage screen, click Next.
6. At the Summary screen, click Finish.
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 addresses are properly assigned.
9. 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.

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 5GB database size and the database platform on which we ran: Microsoft SQL Server. We ran the Install.pl script on a utility system running Linux. The Install.pl script also generated the database schema.

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 5GB database in SQL Server 2008 R2 SP1, and then performed a full backup, storing the backup file on the C: drive for quick access. We used that backup file to restore the original database on the servers between test runs. We also updated the compatibility level of the database to SQL Server 2012 RC0.

The only modification we made to the schema creation scripts were the specified file sizes for our database. 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, the database schema was created and loaded 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 5GB database 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. We created database tables, stored procedures, and objects using the provided DVD Store scripts.
4. We set the database recovery model to bulk-logged to prevent excess logging.

5. 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. We created indices, full-text catalogs, primary keys, and foreign keys using the database-creation scripts.
7. 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. We set the database recovery model back to full.
10. We created the necessary full text index using SQL Server Management Studio.
11. We created a database user, and mapped this user to the SQL Server login.
12. 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 10 shows our initial file size modifications.

Logical name	File group	Initial size (MB)
Database files		
primary	PRIMARY	3
cust1	DS_CUST_FG	2,560
cust2	DS_CUST_FG	2,560
ind1	DS_IND_FG	1,536
ind2	DS_IND_FG	1,536
ds_misc	DS_MISC_FG	1,536
orders1	DS_ORDERS	1,536
orders2	DS_ORDERS	1,536
Log files		
ds_log	Not Applicable	10,240

Figure 10: Our initial file size modifications.

Editing the workload script – ds2xdriver.cs module

A new feature of DVD Store version 2.1 is 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.

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. DVD Store outputs an orders-per-minute metric, which is a running average calculated through the test. In this report, we report the last OPM reported by each client/target pair.

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

1. Clean up prior outputs from the host system and all client driver systems.
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 system and all client systems.
6. Wait for a ping response from the server under test (the hypervisor system), all client systems, and all VMs.
7. Let the test server idle for one hour.
8. Start the DVD Store driver on all respective clients.
   We used the following DVD Store parameters for testing the virtual machines in this study:

```
ds2sqlserverdriver.exe --target=<target_IP> --ramp_rate=10 --run_time=30 --
n_threads=32 --db_size=5GB --think_time=0 --detailed_view=Y --warmup_time=5
```

Measuring power usage

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.

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 hypervisor and all 16 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. We call this time the power measurement interval.

APPENDIX C – TCO CALCULATIONS AND ASSUMPTIONS

TCO scenario and model

For our TCO analysis, we compare the costs of purchasing a single Dell PowerEdge R820 server or HP ProLiant DL585 G7 server and operating them over the next three years. The TCO analysis includes acquisition costs and three-year operating costs for the two solutions. We include costs for servers only, not storage. We assume charges for data center are on a per-port basis.

TCO assumptions

Acquisition costs

Hardware purchase and support

- We configured the servers as we tested them (see Appendix A) on the vendor's respective Web sites (as of 5/16/2012) to obtain pricing information.
- We include support costs for the two servers. Dell 3-Year ProSupport and Mission Critical 4HR Onsite Pack costs $3,299 for the Dell PowerEdge R820, and HP Care Pack with 3 Years 6-hour 24x7 CTR, Defective Media Retention Hardware Support costs $1,393.

Software purchase

- We include the cost of purchasing VMware vSphere 5 Enterprise Plus, Windows Server 2008 DataCenter Edition, and SQL Server 2012 Enterprise Edition. Only the SQL Server 2012 cost differs between the two solutions, because SQL Server is licensed per core. This costs $219,968 for the Dell PowerEdge R820 and $329,952 for the HP ProLiant DL585 G7.

Other acquisition costs

- We include 100 hours of planning and setup time at $50 an hour for both solutions, a total of $5,000. We base this figure on our experience.

Ongoing costs

Software support

- We include vSphere 5 Enterprise Plus with Production support and subscription (SaS) (licensed per processor), OS Software Support for Windows Server 2008 DataCenter Edition (licensed per server), and SQL Server 2012 Enterprise Edition Software support (licensed per core). Only the SQL Server 2012 cost differs between the two solutions, because SQL Server is licensed per core. This costs $54,992 for the Dell PowerEdge R820 and $82,488 for the HP ProLiant DL585 G7.

Data center costs

- We estimate rack space costs at $4,142.90 per rack. The 2U Dell PowerEdge R820 costs 1/21 of a rack, or $197.28 to store, and rack space for the 4U HP ProLiant DL585 G7 costs 1/10 of a rack, or $414.29. We assume 10 4u servers per rack or 21 2 u servers.

Energy costs

- We measured the power of each server model while running a workload and while idle. We assume the servers run around the clock and are active 25 percent of the time.

Figure 11 shows the measured power for the servers in the two solutions. We assume that energy costs for cooling equal energy costs for powering the HP ProLiant DL585 G7 and that the energy efficiencies of the Dell PowerEdge R820 drop energy costs for cooling to 80 percent of cost of power.

Power utilization	Dell PowerEdge R820 solution	HP ProLiant DL585 G7solution
Power usage per server (watts-active)	557.8	1,064.0
Power usage per server (watts-idle)	248.1	607.0

Figure 11: Power utilization numbers, in watts, for each solution. Lower numbers are better.

- We estimate energy costs using active power for that percentage of time and the idle power measurement for the remaining time. We assume a power rate of 9.88 cents per KWH.

Figure 12 shows our estimate of energy costs for power and cooling for the two solutions each year.

Energy costs	Dell PowerEdge R820 solution	HP ProLiant DL585 G7 solution
Annual	$507	$1,248
Three year	$1,521	$3,744

Figure 12: Energy costs for each solution. Lower numbers are better.

Source: Average commercial price for January 2012 at http://www.eia.gov/electricity/monthly/index.cfm (report epmxlfile5_6_b.xls)--Average commercial price for Jan. 2012

Administrative costs

- We assume one FTE administrator can manage 44 servers. We estimate a burdened administrator salary of $102,411.35 based on an administrator salary of $72,200 and a burden rate of 44.04 percent.

ABOUT PRINCIPLED TECHNOLOGIES

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