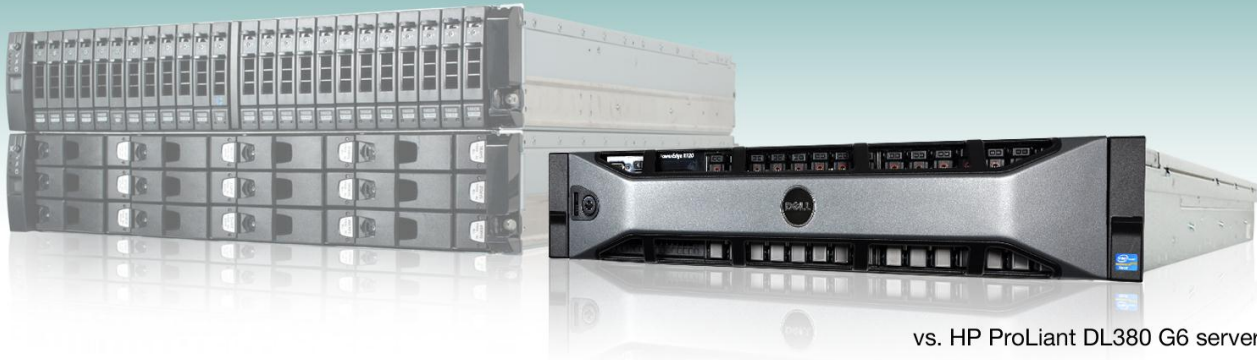# Dell™ PowerEdge™ R720 server with VMware® vSphere® 5

> **4x** consolidation

vs. HP ProLiant DL380 G6 server

While your Exchange server infrastructure can handle your current load, what will happen when you need to add users? Adding more users as your business grows could degrade performance.

Upgrading to a more powerful, virtualized solution, such as the new Dell PowerEdge R720 server coupled with Dell Compellent storage and VMware® vSphere® 5, has the potential to benefit your business in a number of ways: by consolidating hardware, which means less to store, maintain, and power; by increasing the number of users you can support; and by using less energy to power and cool your hardware.

We looked at an older HP ProLiant DL380 G6 server with HP StorageWorks EVA4400 storage by running a mid-range example workload of 2,000 mail users, and found that the new Dell PowerEdge R720 with Compellent storage was able to support four of the same workloads, for a total of 8,000 users. We found that consolidating four of the older servers into virtual machines (VMs) on the PowerEdge R720 using the VMware vSphere 5 hypervisor saved on power and cooling costs by powering only one new server instead of four of the older servers. The savings in hardware, maintenance, and power and cooling costs make the Dell PowerEdge R720 a smart solution for any business, as it can pay back its investment in a little as 18 months.

A PRINCIPLED TECHNOLOGIES TEST REPORT

CONSOLIDATE AND SAVE

Upgrading your current servers that run only one application instance to a new server and storage solution with multiple application instances in virtual machines has the potential not only to increase your performance and server utilization, but also to save you money. Furthermore, selecting the latest mail server software, Microsoft Exchange Server 2010, also lets you benefit from the latest features available for your mail server.

Four times the mailboxes, more users per watt

As Figure 1 shows, one Dell PowerEdge R720 running Microsoft Exchange Server 2010 can run four of the same 2,000-user workloads of the existing HP ProLiant DL380 G6 servers running Microsoft Exchange Server 2010.

Figure 1: The superior performance that the Dell PowerEdge R720 delivers means that you can consolidate four 2,000-user workloads into just one server and support the same number of users.
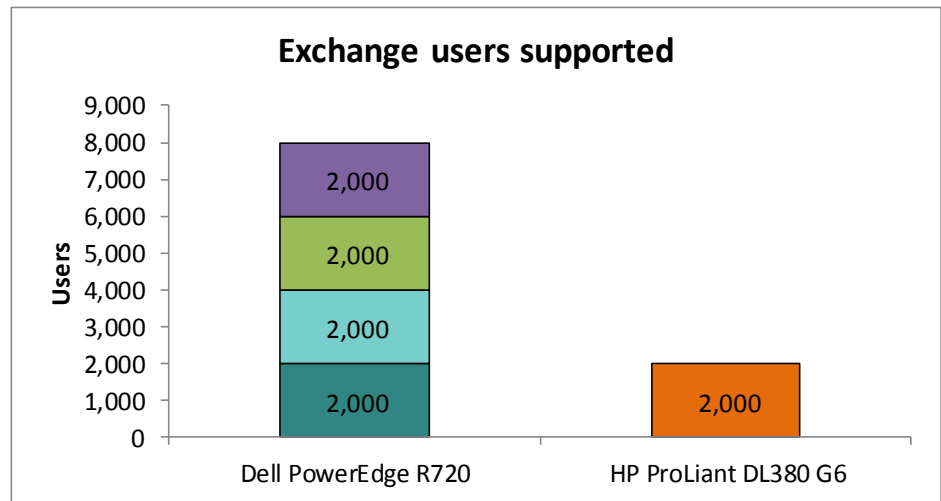
Supporting a large number of users is important, but so is the response time the server provides for those users. Not only was the Dell PowerEdge R720 able to support the additional users, it also provided as good or better response times than the HP ProLiant DL380 G6. Figure 2 shows the average response time (MSExchangeIS\RPC Average Latency counter), in milliseconds for the two servers. (It is worth noting that Microsoft recommends that for best performance the MSExchangeIS\RPC Average Latency counter stay below 10 milliseconds on Exchange 2010.)

	Dell PowerEdge R720 server				HP ProLiant DL380 G6 server
	VM 1	VM 2	VM 3	VM 4	
Response time (ms)	2.33	3.88	2.17	3.61	3.20

Figure 2: Response times, in milliseconds, for the two servers. Lower times are better.

Figure 3 shows the calculated power consumption for each server, both idle (though the Dell PowerEdge R720 was supporting VMs) at peak workload. The Dell PowerEdge R720 server supported 116.0 percent more users per watt than the HP ProLiant DL380 G6.

	Power (W)		Users/watt	Users/watt percentage win
	Instances running no workloads	All instances running workloads		
Dell PowerEdge R720	141.01	243.27	32.89	116.0%
HP ProLiant DL380 G6	109.67	131.30	15.23	

Figure 3: Power statistics for the two servers.

Our premise for testing is that a customer has a set of existing older Exchange servers and plans to replace them with a new Dell server running a virtualized solution. We look at the 2,000-user workload that the older server supported and examine how many of these workloads the new server can run. The point is to show the consolidation possibilities in your environment that the newer solution offers.

In the real world, your individual VMs and individual servers will host one or several of the many different Exchange roles. Because we are using LoadGen to emulate all Exchange-like work, we configured the HP ProLiant DL380 G6 and each VM on Dell PowerEdge R720 as a standalone Exchange server. This representative test is only an approximation of what you might expect to see in your environment. Your actual configuration will differ greatly from this implementation and will include role separation, high-availability considerations, and other choices.

ACHIEVE PAYBACK IN AS LITTLE AS 18 MONTHS BY CONSOLIDATING WITH THE DELL POWEREDGE R720

Tests in our labs using the LoadGen benchmark show that one Dell PowerEdge R720 running Microsoft Exchange Server 2010 can run four of the same 2,000-user workloads of four existing HP ProLiant DL380 G6 servers running Microsoft Exchange Server 2010 and still maintain room for growth.

To illustrate the cost savings this consolidation can provide, we calculated the costs for a hypothetical enterprise planning this migration and compared those costs to those of retaining the existing servers. We found that, thanks to savings in software and hardware support, server administration, and data center costs for energy, ports, and space, the Dell PowerEdge R720 can pay back the investment in hardware and the migration effort in as little as 18 months. Please note that we do not include the costs associated with the new or older external storage arrays in our analysis, as we assume the organization has or will use existing storage. Figure 4 summarizes the three-year total cost of ownership (TCO) for the two solutions.

Three-year TCO

Figure 4: Despite the initial acquisition cost, the Dell PowerEdge R720 saves on annual operational costs.
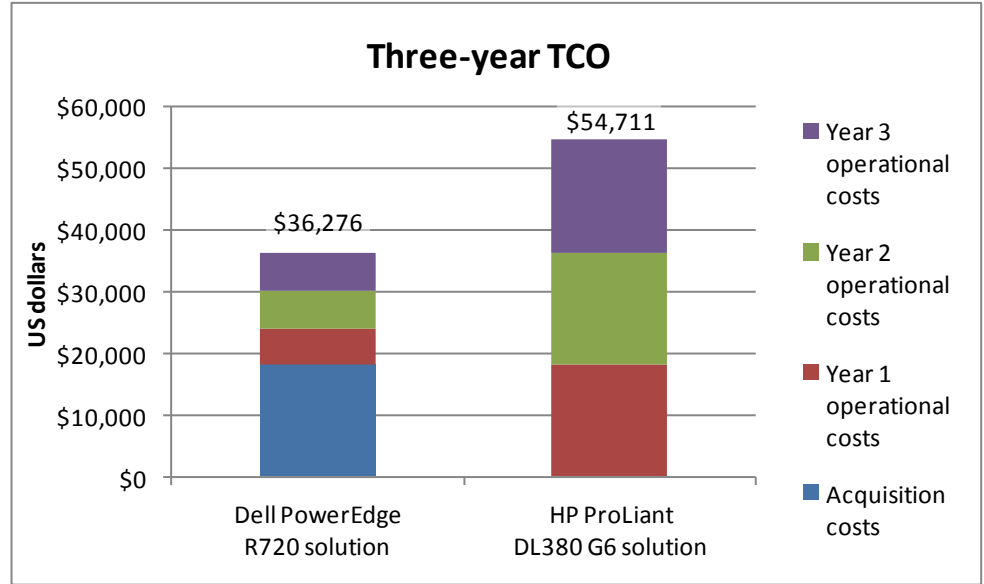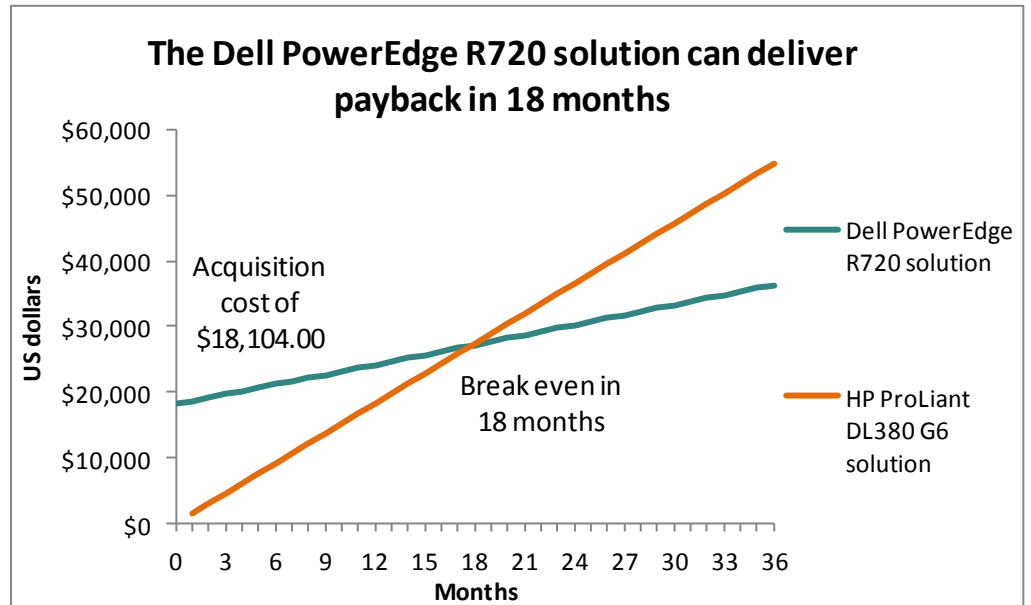
Figure 5 shows that the Dell PowerEdge R720 solution breaks even in as little as 18 months.

The Dell PowerEdge R720 solution can deliver payback in 18 months

Figure 5: The Dell PowerEdge R720 can deliver payback on your investment in just 18 months.

WHAT WE TESTED

To test the configuration's mail server performance, we used the Microsoft Load Generator 2010 (LoadGen) benchmark, which performs tasks to simulate a standard user generating mail activity. We simulated 2,000 users for each bare-metal instance or VM, and used the following settings:

- Mailbox Profile: 100MB mailboxes
- Action Profile: Average
- Client Type: Outlook 2007 Cached

LoadGen simulates the mail activity for the 2,000 users and then reports a PASS/FAIL rating, which is based on acceptable response times.

For more details about LoadGen, see http://www.microsoft.com/downloads/details.aspx?FamilyId=DDEC1642-F6E3-4D66-A82F-8D3062C6FA98&displaylang=en.

Our premise for testing is that a customer has an existing older Exchange sever and plans to replace it with a new Dell server running a virtualized solution. We looked at the 2,000-user workloads that the older server supported and examined how many of these workloads the new server could run. The goal is to show the consolidation possibilities that the new Dell PowerEdge R720 offers for your environment.

In the real world, your individual VMs and individual servers will host one or several of the many different Exchange roles. Because we are using LoadGen to emulate all Exchange work, we configured the HP ProLiant DL380 G6 and each VM on the Dell PowerEdge R720 as standalone Exchange servers. This representative test is only an approximation of what you might expect to see in your environment. Your actual configuration will differ greatly from this implementation and will include role separation, high-availability considerations, and other choices.

The configuration details of our test servers are in Appendix A, the details of our test procedure are in Appendix B and the details of our TCO analysis are in Appendix C.

About the Dell PowerEdge R720

The new Intel Xeon processor E5-2680-powered Dell PowerEdge R720 2U rack server incorporates many improvements and features designed to improve performance, lower power consumption, and make maintenance easier. The PowerEdge R720 is engineered to handle complex workloads, with I/O and internal data management technologies (i.e., NSC, NPAR, CacheCade) to allow faster access to information and GPU accelerators to solve challenges faster than ever.

With power-efficient technology designed to optimize performance while maintaining low power consumption, the Dell PowerEdge R720 comes with the Dell Lifecycle Controller, which simplifies server management by providing a single interface for management functions and by storing critical system information in the system itself. The Dell PowerEdge R720 has an impressive storage capacity and can hold up to 768 GB of RAM to allow flexibility with virtualized solutions .For more information about the Dell PowerEdge R720, visit http://www.dell.com/us/enterprise/p/poweredge-r720/pd.

About Dell Compellent storage

The Dell Compellent is an enterprise-class storage system providing a mix of SSD, Fibre Channel (FC), and SAS drives. Dell Compellent Fluid Data storage technology dynamically moves enterprise data to the optimal storage tier based on actual use. The most active data blocks reside on higher-performance drives, while the system automatically moves less frequently accessed data is to lower-cost, high-capacity drives. Our test configuration consisted of a dual controller with 10 GbE iSCSI connections with two shelves of storage, one with 24 146GB SAS drives and one with a combination of 600 GB SAS and 1 TB near-line SAS drives. Dell Compellent storage is available in various configuration options. For more information about Dell Compellent storage, visit http://www.dell.com/us/business/p/dell-compellent.

IN CONCLUSION

Better performance and lower costs are driving factors in the hardware you choose for your data center. In choosing a newer server and storage solution, you can acquire enough processing power to virtualize older servers and consolidate them onto the new solution, which can increase performance dramatically while keeping costs down.

In our tests, the Dell PowerEdge R720 server with Compellent storage was able to take the place of four older HP ProLiant DL380 G6 servers by supporting the same 2,000-user Exchange Server 2010 workload as the older four combined. In addition to supporting four workloads, the Dell PowerEdge R720 was also more power efficient, supporting 116.0 percent more users per watt than the HP ProLiant DL380 G6. With such increases in performance and decreases in power consumption, the Dell PowerEdge R720 can deliver payback in as little as 18 months, providing an affordable consolidation platform for your business.

APPENDIX A – SERVER CONFIGURATION INFORMATION

Figure 6 provides detailed configuration information for the test servers, and Figure 7 provides configuration information for the storage arrays.

System	Dell PowerEdge R720	HP ProLiant DL380 G6
Power supplies		
Total number	2	2
Vendor and model number	Dell D750E-S1	HP HSTNS-PL14
Wattage of each (W)	750	460
Cooling fans		
Total number	6	6
Vendor and model number	AVC DBTC0638B2V	Nidec® UltraFlo™
Dimensions (h x w) of each	2.5" x 2.5"	2-3/8" x 2-5/8"
Volts	12	12
Amps	1.2	2.45
General		
Number of processor packages	2	2
Number of cores per processor	8	4
Number of hardware threads per core	2	2
System power management policy	Balanced Power	Balanced Power
CPU		
Vendor	Intel	Intel
Name	Xeon	Xeon
Model number	E5-2680	X5540
Stepping	6	D0
Socket type	LGA2011	LGA1366
Core frequency (GHz)	2.70	2.53
Bus frequency	8.0 GT/s	6.4 GT/s
L1 cache	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 cache	256 KB (per core)	256 KB (per core)
L3 cache (MB)	20	8
Platform		
Vendor and model number	Dell PowerEdge R720	HP ProLiant DL380 G6
Motherboard model number	00W9X3	HP PADAB0G9VXC1CQ
BIOS name and version	Dell 0.3.37	HP P62
BIOS settings	Maximum Performance	Maximum Performance
Memory module(s)		
Total RAM in system (GB)	64	12
Vendor and model number	Hynix HMT31GR7BFR4A-H9	Kingston KVR1333D3D8R9S/2G
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	7-7-7-20

System	Dell PowerEdge R720	HP ProLiant DL380 G6
Size (GB)	8	2
Number of RAM module(s)	8	6
Chip organization	Double-sided	Double-sided
Rank	Dual	Dual
Operating system		
Name	VMware ESXi 5.0.0	Windows Server 2008 R2 SP1
Build number	515841	7601
File system	EXT3	NTFS
Kernel	5.0.0	ACPI x64-based PC
Language	English	English
Graphics		
Vendor and model number	Matrox® G200e	ATI ES1000
Graphics memory (MB)	8	64
RAID controller		
Vendor and model number	PERC H710P Mini	HP Smart Array P410i
Firmware version	3.130.05-1311	5.14
Cache size	1 GB	256 MB
Hard drive		
Vendor and model number	No hard drives installed[1]	HP MBC2073RC
Number of disks in system	N/A	2
Size (GB)	N/A	73
Buffer size (MB)	N/A	16
RPM	N/A	15K
Type	N/A	SAS
Ethernet adapters		
First network adapter		
Vendor and model number	Intel I350 Gigabit Controller	Broadcom® NetXtreme™ II BCM5709
Type	Integrated	Integrated
Second network adapter		
Vendor and model number	Intel X450-AT2 10 Gigabit Controller	N/A
Type	Integrated	N/A
Optical drive(s)		
Vendor and model number	TEAC DV-28SW	GDR-D20N
Type	DVD-ROM	SATA DVD-ROM
USB ports		
Number	4 external, 1 internal	4 external, 1 internal
Type	2.0	2.0

Figure 6: Configuration information for the servers we tested.

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[1] In our tests, we booted VMware ESXi from an internal SD card, and did not require internal hard drives.

Storage array	Dell Compellent	HP StorageWorks EVA4400
Number of active storage controllers	1	2
Number of active storage ports	4	4
Firmware revision	05.05.03.114.03	10001000
Model/firmware/type	PowerConnect 8024F/ 3.1.4.5 /10GbE	PowerConnect 8024F/ 3.1.4.5 /10GbE
Tray 1		
Number of disks	24	12
Disk vendor and model number	Seagate ST9146852SS	HP BF146DA47AA
Disk size (GB)	146	146
Disk buffer size (MB)	16	16
Disk RPM	15,000	15,000
Disk type	SAS	SCSI
Firmware revision	XRB4	HP01
Tray 2		
Disk type 1		
Number of disks	6	12
Disk vendor and model number	Seagate ST3600057SS	HP BF146DA47AA
Disk size (GB)	600	146
Disk buffer size (MB)	16	16
Disk RPM	15,000	15,000
Disk type	SAS	SCSI
Firmware revision	XREC	HP01
Disk type 2		
Number of disks	6	N/A
Disk vendor and model number	Seagate ST31000424SS	N/A
Disk size (TB)	1	N/A
Disk buffer size (MB)	16	N/A
Disk RPM	7,200	N/A
Disk type	SAS	N/A
Firmware revision	XRMA	N/A

Figure 7: Detailed configuration information for the storage arrays.

APPENDIX B - HOW WE TESTED

Configuring the Dell PowerEdge R720

Figure 8 illustrates our Dell test bed setup. For comparison purposes, we configured each VM as a standalone Exchange server 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. We used a separate server for Active Directory on each VM configuration. In Figure 8, VM1 connects to AD1 and uses client 1, VM2 connects to AD2 and uses client 2, and so forth.

We connected the R720 to the 10 GbE through iSCSI using a PowerConnect M8024F switch. We configured the Dell Compellent storage with one RAID 10 disk group with 30 disks. We created four 10GB volumes for Exchange logs, which we connected using iSCSI connection assigned in ESX. We created four 500GB volumes in the same disk group, which we connected to the ESX server and assigned to each VM in ESX.
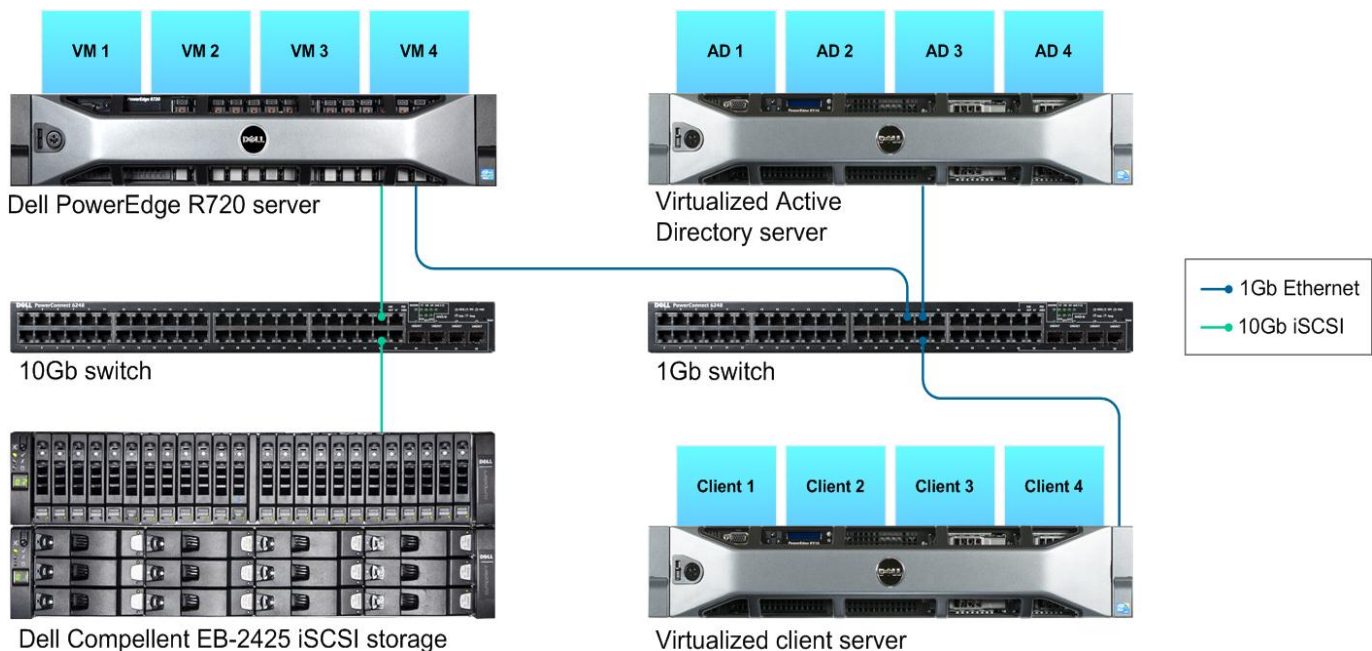

Figure 8: The Dell PowerEdge R720 test bed we used.

Adjusting BIOS settings

We used the latest released BIOS updates on all systems, and adjusted the default BIOS settings. We changed the power profile to OS Control on the Dell system, and Balanced Power and Performance with OS Control for Power Regulation on the HP system. This ensured that the systems used the same power settings.

Installing VMware vSphere 5 (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.

Exchange server consolidation

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 the changes, press Y.

Updating ESXi to the latest build

1. Download the latest ESXi build from VMware.
2. Using the vSphere client from another machine, connect to the ESXi server.
3. Select the Configuration tab, and select Storage under the Hardware heading.
4. Right-click the OS datastore, and select Browse Datastore.
5. Click the upload button, and select the build update ZIP file.
6. Using a telnet/ssh client from another machine, connect to the ESXi server using root credentials.
7. Run the following command using the path and name of the ESXi update:

```
esxcli software vib update –d /vmfs/volumes/OS/ESXi500-201112001.zip
```

8. Repeat steps 6 and 7 for any subsequent systems.

Configuring iSCSI networking

We followed the steps from VMware's 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 the ESXi server.
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 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 second 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 both VMkernel adapters 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 for each of the remaining three NICs dedicated to iSCSI traffic.
6. Access provisioned Dell Compellent storage:
    a. In the vSphere client, click the host, click the Configuration tab, and click Storage adapters.
    b. Right-click the iSCSI software storage adapter.
    c. Click Dynamic discovery.
    d. Click Add.
    e. Enter the Dell EqualLogic group IP address.
    f. Click Close.
    g. Click Yes when prompted to rescan the HBA.

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 LoadGen 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 external volumes

1. In the vSphere client, select the 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.

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, and choose Microsoft Windows Server 2008 R2 (64-bit), and click Next.
9. Choose 1 virtual socket, and 8 virtual processors per core, and click Next.
10. Choose 12GB RAM, and click Next.
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 30 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 30GB 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 SCSI Controller 1, and choose Change Type.
29. Choose VMware Paravirtual, and click OK.
30. Click Finish, and click OK.
31. Start the VM.
32. Attach the Windows Server 2008 R2 SP1 ISO image to the VM and install Windows Server 2008 R2 on your VM.

Installing the operating system on the 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.
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. Repeat steps 1 through 17 to install the operating system on the other VMs.

Adding the external volumes to the VMs in VMware vSphere 5

1. In the vSphere client, right-click the first VM.
2. Click Edit Settings.
3. Select the Hardware tab and click Add…
4. Choose Hard Disk from the Device Type list, and click Next.
5. Choose Raw Device Mapping, and click Next.
6. Select the LUN and click Next.
7. At the Select a datastore screen select Store with Virtual Machine radio and click Next.
8. Select the compatibly to Physical and click Next.
9. At the advanced options select SCSI (1:0) from the Virtual Device Node drop-down box, and click Next.
10. Review the Ready to Complete summary, and click Finish.
11. Repeat steps 1 through 10 for the remaining volumes.
12. In the VM, add the iSCSI storage:
    a. Start the VM, and 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 Online.
    d. Right-click the first volume, and choose Initialize Disk.
    e. Select GPT (GUID Partition Table) for the partition style, and click OK.
    f. In the right pane, right-click the volume and choose New Simple Volume…
    g. At the Welcome screen, click Next.
    h. At the Specify Volume Size screen, leave the default selection, and click Next.
    i. At the Assign Drive Letter or Path screen, choose a drive letter, and click Next.
    j. At the Format Partition screen, leave the default selection, and click Next.
    k. At the Completing the New Simple Volume Wizard screen, click Finish.
    l. Repeat steps c through k for the remaining VM volumes.
13. Repeat steps 1-12 for the remaining VMs and attach the appropriate volumes.

Installing Exchange 2010 SP2 prerequisites on VM1

After completing the following steps for VM1, repeat them for VM2, VM3, and VM4.

1. Select Start→Administrative Tools→Server Manager.
2. Click Add Roles.
3. At the Before You Begin screen, click Next.
4. At the Select Server Roles screen, click Web Server (IIS).

5. If prompted by an Add features required for Web Server (IIS) pop-up window, click Add Required Features.
1. Click Next.
2. At the Web Server (IIS) screen, click Next.
3. At the Select Role Services screen, select the IIS 6 Metabase Compatibility, IIS WMI Compatibility, HTTP Errors, HTTP Redirection, IIS 6 Management Console, Basic Authentication, Windows Authentication, Tracing, Digest Authentication, and Dynamic and Static content Compression checkboxes, and click Next.
4. At the Confirm Installation Selections screen, click Install.
5. At the Installation Results screen, click Close.
6. Select Start→Administrative Tools→Server Manager.
7. Click Features.
8. Click Add Features.
9. Select .NET Framework 3.5.1 Features.
10. When the Add Features Wizard pop-up window prompts you, click Add Required Role Services.
11. Click Next.
12. At the Introduction to Web Server (IIS) screen, click Next.
13. At the Select Role Services screen, click Next.
14. Click Install.
15. At the Installation Results screen, click Close.
16. Download the Microsoft Filter Pack 2.0. (http://www.microsoft.com/downloads/en/details.aspx?FamilyID=5cd4dcd7-d3e6-4970-875e-aba93459fbee)
17. Run FilterPackx64.EXE.
18. Click Next.
19. Click I accept the terms in the License Agreement, and click Next.
20. Click OK once installation is complete.
21. Click Start→Administrative Tools→Services.
22. Right-click the Net.Tcp Port Sharing service, and click Properties.
23. Change the Net.Tcp Port Sharing startup type to Automatic, and click OK.
24. Open command prompt, type `ServerManagerCmd –i RSAT-ADDS`, and press Enter.
25. Reboot the server.

Installing Exchange Server 2010 SP2

After completing the following steps for VM1, repeat them for the other VMs.

1. Insert the Exchange Server 2010 installation DVD, and capture the DVD drive in the VM session. When the Autoplay window appears, click Run Setup.EXE.
2. The installer should consider steps 1 and 2 to be complete (they appear grayed out). Click the link to Step 3: Choose Exchange Language Option.
3. Click Install only languages from the DVD.
4. Click the link to Step 4: Install Microsoft Exchange Server.
5. To go past the introduction screen, click Next.
6. Accept the license agreement, and click Next.
7. Select No for error reporting, and click Next.
8. Select Typical Exchange Server Installation, and click Next.
9. Leave the organization name at default (First Organization), and click Next.
10. At the question about client computers running Outlook 2003 or Entourage, select No, and click Next.
11. To accept defaults for Configure Client Access server external domain, click Next.
12. At the Customer Experience Improvement Program screen, select I don't wish to join the program at this time, and click Next.
13. Click Install to start the installation process.

14. Once the installation has completed, click Finish. Exchange should automatically open the Exchange Management Console.

Enabling circular logging

1. Click Start→All Programs→Microsoft Exchange Server 2010→Exchange Management Console.
2. Expand Organization Configuration, and click Mailbox.
3. Right-click DB1, and click Properties.
4. Click the Maintenance tab, and check the box next to Enable circular logging, and click OK.

Disabling Maintenance Schedule

5. Click Start→All Programs→Microsoft Exchange Server 2010→Exchange Management Console.
6. Expand Organization Configuration, and click Mailbox.
7. Right-click Mailbox Database, and click Properties.
8. Click Maintenance.
9. Click Customize and Double-click the empty gray box above Sunday.
10. Ensure that all cells on the graph turn white, and click OK.
11. Click OK.

Disabling Microsoft Search Indexer Service

1. Click Start→Administrator Tools→Services.
2. Select Microsoft Exchange Search Indexer, and right-click Properties.
3. On the properties screen Startup Type change to Disabled, and click Stop.
4. Click OK, and close the Services screen.

Changing the default Mailbox Database drive location

1. Click Start, and click Exchange Management Console.
2. Right-click Mailbox Database.
3. Select Move Database Path.
4. Click Browse, navigate to E:\Database, and click Save.
5. Click Move.
6. When the application prompts you to dismount the mailbox database, click Yes.
7. Click Finish.

Configuring LoadGen 2010 clients

We installed Windows Server 2008 R2 SP1 on all clients. We installed the latest updates on as of 1/17/2012.

Configuring client 1

1. Change the Computer name to Client 1
2. Set NIC to the following:
   - IP address: 192.168.10.120
   - Subnet mask: 255.255.255.0
   - Default Gateway: 192.168.10.110
3. Join the domain Dell.troilus.com.
4. Reboot when necessary.

Installing .Net 3.5.1

A prerequisite for LoadGen is that you have .NET 3.5.1 Installed on the client. Repeat these steps for each client after joining the domain.

1. On Client1, click Server Manager.
2. On Server Manager, expand Features.
3. At Features, click Add.

4. At the Features screen, check .Net Framework 3.5.1.
5. At the Add Features Wizard, click Add Required Role Services.
6. At the Select Features screen, click Next.
7. At the Web Server (ISS), screen click Next.
8. At the Select Role Services screen, click Next.
9. At the Confirm Installation Selections screen, click Install.

Installing LoadGen 2010

Repeat this for each client after joining the domain.

1. Double click loadgen2010.exe.
2. At the Welcome screen, click Next.
3. At the EULA screen, accept, and click Next.
4. At the Select Installation Folder screen, click Next.
5. At the Confirm Installation screen, click Next
6. At the Installation Complete screen, click Close.
7. At the Restart Your System prompt, click Yes.

Configuring client 2

1. Change the Computer name to Client 2.
2. Set a NIC to the following:
   - IP address: `192.168.20.120`
   - Subnet mask: `255.255.255.0`
   - Default Gateway: `192.168.20.110`
3. Join the domain Dell2.troilus2.com.

Configuring client 3

1. Change the Computer name to Client 3.
2. Set a NIC to the following:
   - IP address: `192.168.30.120`
   - Subnet mask: `255.255.255.0`
   - Default Gateway: `192.168.30.110`
3. Join the domain Dell3.troilus.com.

Configuring client 4

1. Change the Computer name to Client 4.
2. Set a NIC to the following:
   - IP address: `192.168.40.120`
   - Subnet mask: `255.255.255.0`
   - Default Gateway: `192.168.40.110`
3. Join the domain Dell4.troilus.com.

Preparing LoadGen on the clients

1. Select Start→All Programs→Microsoft Exchange→Exchange Load Generator.
2. When the Load Generator window appears, select Start a new test.
3. Select Create a new test configuration, and click Continue.
4. In the Specify test settings window, type Password1 as the Directory Access Password and Mailbox Account Master Password, and click Continue with recipient management.
5. Make 2,000 users in the Mailbox Database, and click Continue.
6. To accept defaults for Advanced recipient settings, click Continue.
7. In the Specify test user groups window, select the plus sign (+) to add a user group.

8. Change the Client Type to Outlook 2007 Cached and the Action Profile to Average, 100MB and click Continue.
9. Leave defaults in Remote configurations, and click Continue.
10. Click Save the configuration file as, and name it 100x2000.cfg
11. Click Start the initialization phase (recommended before running the test) to start initialization. The initialization process might take a few hours.

### Backing up the mail database on clients

On the test server, once you have set up LoadGen and created its initial mail database, you need to back up that database and logs so you can have clean copies for each test. Use this process to back up that database:

1. Select Start→All Programs→Microsoft Exchange Server 2010→Exchange Management Console in the mail server.
2. In the left pane, under Server Configuration, click Mailbox.
3. In the right pane, right-click Mailbox Database, and select Dismount Database from the menu.
4. At the Do you want to continue? pop-up message, click Yes.
5. Right-click Public Folder Database, and select Dismount Database from the menu.
6. At the Do you want to continue? pop-up message, click Yes. The red arrow appears when you have dismounted the Public Folder Store.
7. Using Windows Explorer, create two new folders: C:\backup\mailstore and C:\backup\publicstore.
8. With Windows Explorer, copy all files from D:\DB\Mailbox\First Storage Group to D:\backup. This process may take several minutes.
9. Close Windows Explorer.
10. In Exchange Management Console, right-click Mailbox Database, and select Mount Database from the menu.
11. Right-click the Public Folder Database, and select Mount Database from the menu.
12. Close Exchange System Manager.

Configuring the HP ProLiant DL380 G6

Figure 8 illustrates our HP test bed setup. We configured the HP ProLiant DL380 G6 as a standalone Exchange server environment with all roles included. We used separate virtualized servers for Active Directory and LoadGen client.

We connected the HP server to the HP StorageWorks Storage via two 4 Gb/s Fibre Channel cables. We configured the storage with one RAID 10 disk group with 24 disks. We created one 10GB volume for the Exchange logs, which we connected to the HP and assigned to one FC port. We created one 1TB volume in the same disk group, which we connected to the HP server and assigned to another FC port.
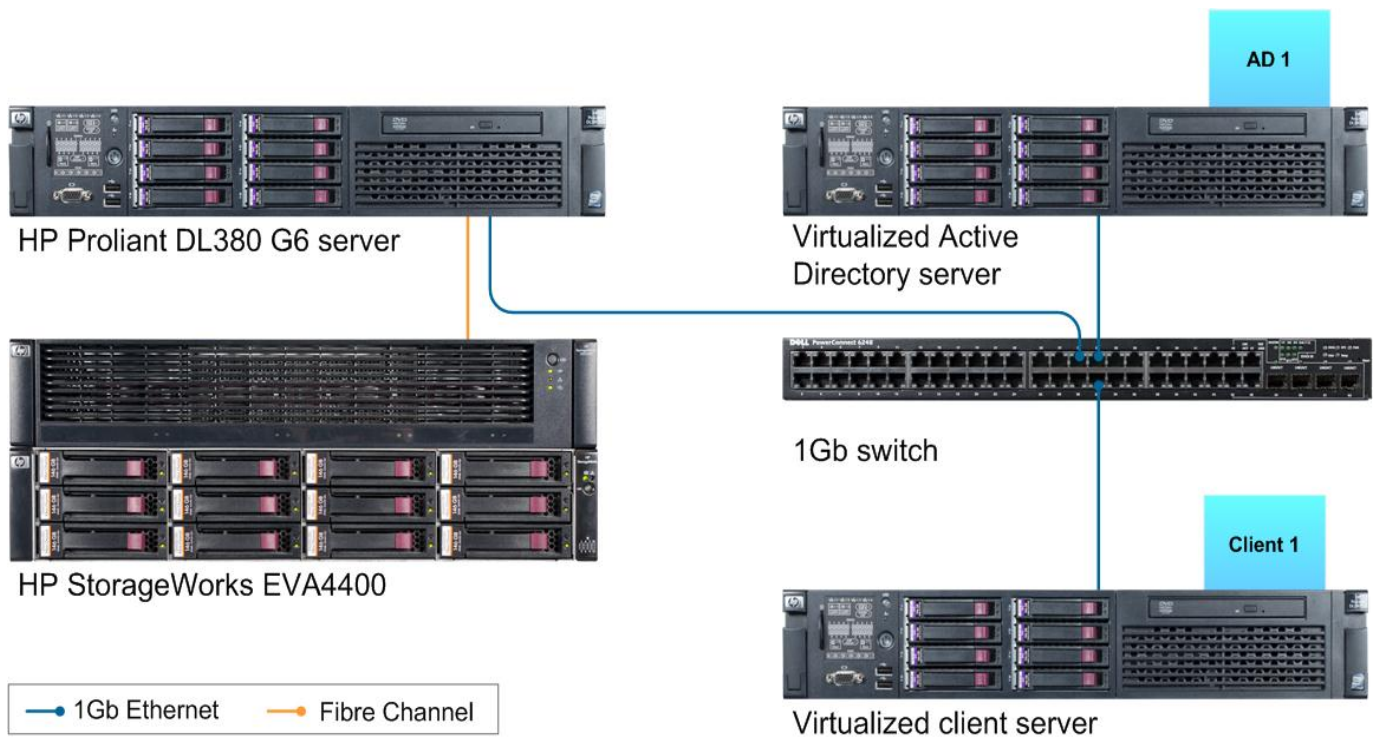
Figure 9: The HP ProLiant DL380 G6 test bed we used.

We used the BIOS RAID configuration utility to create one two-disk RAID 1 for the operating system and external storage for the LoadGen databases. We installed Windows Server 2008 R2 SP1 with the latest updates as of 1/9/2012.

Setting the computer name

1. Click Start→Administrative Tools→Server Manager.
2. In the right pane, click Change System Properties.
3. Under the Computer Name tab, click Change…
4. Change the Computer name to `DL380 G6`
5. Reboot the system.

Adding DB drives to Windows

1. Click Start→ right-click My Computer, and select Manage.
2. Expand Storage, and select disk management.
3. Select the Offline Drive, and right-click and select Online
4. Right-click the volume, and select New Simple Volume.
5. Name the new volume DB and click OK.

Setting up the network configuration on the server

1. Click Start→Network.
2. Click Network and Sharing Center.
3. Click Manage Network Connections.
4. Right-click Local Area Connection.
5. Click Properties.
6. Click Internet Protocol Version 4 (TCP/IPv4), and click Properties.

7. Select Use the following IP Address, and input the following numbers:
   - IP address: `192.168.5.105`
   - Subnet mask: `255.255.255.0`
8. Click OK to close the window.
9. At the Local Area Connection Properties window, click Close.
10. Close the Network Connection window.

Joining the domain

1. Click Start→right-click My Computer→Properties.
2. Click Change settings.
3. On the System Properties screen, click Change.
4. On the Computer Name/domain changes screen, click Domain radio, and type `HP.troilus`
5. Enter in the credentials to the AD machine.
6. At the welcome prompt, click OK.
7. Close the computer Name/Domain Changes screen.
8. At the reboot prompt, click Yes.

Installing Exchange Server 2010 SP2 prerequisites

1. Select Start→Administrative Tools→Server Manager.
2. Click Add Roles.
3. At the Before You Begin screen, click Next.
4. At the Select Server Roles screen, click Web Server (IIS).
5. If prompted by an Add features required for Web Server (IIS) pop-up window, click Add Required Features.
6. Click Next.
7. At the Web Server (IIS) screen, click Next.
8. At the Select Role Services screen, select the IIS 6 Metabase Compatibility, IIS WMI Compatibility, HTTP Errors, HTTP Redirection, IIS 6 Management Console, Basic Authentication, Windows Authentication, Tracing, Digest Authentication, and Dynamic and Static content Compression checkboxes, and click Next.
9. At the Confirm Installation Selections screen, click Install.
10. At the Installation Results screen, click Close.
11. Select Start→Administrative Tools→Server Manager.
12. Click Features.
13. Click Add Features.
14. Select .NET Framework 3.5.1 Features.
15. When the Add Features Wizard pop-up window prompts you, click Add Required Role Services.
16. Click Next.
17. At the Introduction to Web Server (IIS) screen, click Next.
18. At the Select Role Services screen, click Next.
19. Click Install.
20. At the Installation Results screen, click Close.
21. Download the Microsoft Filter Pack 2.0. (http://www.microsoft.com/downloads/en/details.aspx?FamilyID=5cd4dcd7-d3e6-4970-875e-aba93459fbee)
22. Run FilterPackx64.EXE.
23. Click Next.
24. Click I accept the terms in the License Agreement, and click Next.
25. Click OK once installation is complete.
26. Click Start→Administrative Tools→Services.
27. Right-click the Net.Tcp Port Sharing service, and click Properties.

28. Change the Net.Tcp Port Sharing startup type to Automatic, and click OK.
29. Open command prompt, type `ServerManagerCmd –i RSAT-ADDS`, and press Enter.
30. Reboot the server.

Installing Exchange Server 2010 SP2

1. Insert the Exchange Server 2010 installation DVD, and capture the DVD drive in the VM session. When the Autoplay window appears, click Run Setup.EXE.
2. The installer should consider steps 1 and 2 to be complete (they appear grayed out). Click the link to Step 3: Choose Exchange Language Option.
3. Click Install only languages from the DVD.
4. Click the link to Step 4: Install Microsoft Exchange Server.
5. To go past the introduction screen, click Next.
6. Accept the license agreement, and click Next.
7. Select No for error reporting, and click Next.
8. Select Typical Exchange Server Installation, and click Next.
9. Leave the organization name at default (First Organization), and click Next.
10. At the question about client computers running Outlook 2003 or Entourage, select No, and click Next.
11. To accept defaults for Configure Client Access server external domain, click Next.
12. At the Customer Experience Improvement Program screen, select I don't wish to join the program at this time, and click Next.
13. Click Install to start the installation process.
14. Once the installation has completed, click Finish. Exchange should automatically open the Exchange Management Console.

Enabling circular logging

1. Click Start→All Programs→Microsoft Exchange Server 2010→Exchange Management Console.
2. Expand Organization Configuration, and click Mailbox.
3. Right-click DB1, and click Properties.
4. Click the Maintenance tab, and check the box next to Enable circular logging, and click OK.

Disabling Maintenance Schedule

1. Click Start→All Programs→Microsoft Exchange Server 2010→Exchange Management Console.
2. Expand Organization Configuration, and click Mailbox.
3. Right-click Mailbox Database, and click Properties.
4. Click Maintenance.
5. Click Customize and Double-click the empty gray box above Sunday.
6. Ensure that all cells on the graph turn white, and click OK.
7. Click OK.

Disabling Microsoft Search Indexer Service

1. Click Start→Administrator Tools→Services.
2. Select Microsoft Exchange Search Indexer, and right-click Properties.
3. On the properties screen Startup Type change to Disabled, and click Stop.
4. Click OK, and close the Services screen.

Changing the default Mailbox Database drive location

1. Click Start, and click Exchange Management Console.
2. Right-click Mailbox Database.
3. Select Move Database Path.
4. Click Browse, navigate to E:\Database, and click Save.

5. Click Move.
6. When the application prompts you to dismount the mailbox database, click Yes.
7. Click Finish.

Installing LoadGen 2010 on HP client

On a client with Windows Server 2008 R2 SP1 that is already part of the domain, perform the following steps:

1. Select Start→Administrative Tool→Server Manager.
2. Click Features.
3. Click Add Features.
4. Select .NET Framework 3.5.1 Features.
5. When the Add Features Wizard pop-up window prompts you, click Add Required Role Services.
6. Click Next.
7. At the Introduction to Web Server (IIS) screen, click Next.
8. At the Select Role Services screen, click Next.
9. Click Install.
10. At the Installation Results screen, click Close.
11. Select the Loadgen2010 .EXE
12. At the welcome screen, click Next.
13. Accept the EULA, and click Next.
14. On the Select Installation Folder, click Next.
15. At the installation confirmation, click Next.
16. At the Installation complete screen, click Next.
17. On the Restart your systems prompt, click Yes.

Preparing LoadGen

1. Select Start→All Programs→Microsoft Exchange→Exchange Load Generator 2010.
2. When the Load Generator window appears, select Start a new test.
3. Select Create a new test configuration, and click Continue.
4. In the Specify test settings window, type `Password1` as the Directory Access Password and Mailbox Account Master Password, and click Continue with recipient management.
5. Make 2,000 users in the Mailbox Database, and click Continue.
6. To accept defaults for Advanced recipient settings, click Continue.
7. In the Specify test user groups window, select the plus sign (+) to add a user group.
8. Change the Client Type to Outlook 2007 Cached and the Action Profile to Average, 100MB and click Continue.
9. Leave defaults in Remote configurations, and click Continue.
10. Click Save the configuration file as, and name it `100x2000.cfg`
11. Click Start the initialization phase (recommended before running the test) to start initialization. The initialization process might take a few hours.

Backing up the mail database on the HP ProLiant DL360G6

On the test server, once you have set up LoadGen and created its initial mail database, you need to back up that database and log files so you can have clean copies for each test. Use this process to back up that database:

1. Select Start→All Programs→Microsoft Exchange Server 2010→Exchange Management Console in the mail server.
2. In the left pane, expand Organization Configuration, and click Mailbox.
3. In the right pane, right-click Mailbox Database, and select Dismount Database from the menu.
4. At the Do you want to continue? pop-up message, click Yes.
5. Right-click Public Folder Database, and select Dismount Database from the menu.

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6. At the Do you want to continue? pop-up message, click Yes. The red arrow appears when you have dismounted the Public Folder Store.
7. Using Windows Explorer, create two new folders: C:\backup\mailstore and C:\backup\publicstore.
8. With Windows Explorer, copy all files from D:\DB\Mailbox\First Storage Group to D:\backup. This process may take several minutes.
9. Close Windows Explorer.
10. In Exchange Management Console, under Organization Configuration, right-click Mailbox Database, and select Mount Database from the menu.
11. Right-click the Public Folder Database, and select Mount Database from the menu.
12. Close Exchange System Manager.

APPENDIX C - TCO DETAILS

In this section, we detail the assumptions we used to calculate TCO for the two solutions. Figure 10 presents a breakdown of the costs for the two solutions.

	Dell PowerEdge R720 solution	HP ProLiant DL380 G6 solution
Acquisition costs		
Hardware purchase	$11,197.00	
Software cost - VMware vSphere5 Standard	$1,990.00	
Migration (planning and setup)	$4,917.00	
Total acquisition costs	$18,104.00	
Annual operational costs		
OS Software support Windows Server 2008 R2 Enterprise Edition (licensed per server)	$589.50	$2,358.00
VMware vSphere 5 Standard with Basic Support and Subscription (licensed per processor)	$646.00	N/A
Windows Exchange Server 2010 Standard Edition (licensed per instance)	$708.00	$708.00
Hardware support	$833.00	$2,358.68
Administration costs	$2,324.18	$10,226.40
Energy costs	$259.51	$796.80
Port costs (2 ports per server)	$500.00	$1,000.00
Data center space costs	$197.28	$789.12
Total annual operational costs	$6,057.47	$18,237.00
Total 3-year operational costs	$18,172.41	$54,711.00
Total costs	$36,276.41	$54,711.00

Figure 10: Three-year acquisition and operating costs for each solution. Lower costs are better.

Hardware costs

Dell provided us with hardware costs for the Dell PowerEdge R720, which had not been released at the time of our testing, which we completed on a pre-release model. Costs do not include discounts, shipping, or taxes. Dell quoted a price of $11,197.00 for the server configuration we tested (see Appendix A). The cost includes basic 3-year hardware support. We include the additional cost of Mission Critical ProSupport with the hardware support costs. We do not include storage array costs in this analysis. Please note that we do not include the cost or power usage of external storage arrays in our analysis, as we assume the organization has or will use existing storage.

Migration costs

We assume that the migration from the existing servers to the Dell PowerEdge R720 will take 100 hours. Migration includes the staff costs of planning the migration, ordering the hardware, setting up the server, and migrating software and databases. We estimate this cost at $4,917.00 based on 100 hours of a server administrator with an hourly cost of $49.17. To calculate the hourly rate, we used the mean annual wage of $72,200 for a network and computer

systems administrator as reported in the Bureau of Labor Statistics Occupational Employment and Wages for May 2010.[2] We added an additional 41.64 percent to cover benefits for total annual salary cost of $102,264.08, which would have an equivalent hourly full time wage equivalent of $49.17. We estimated the benefits rate using data in another Bureau of Labor Statistics report: Employer Costs for Employee Compensation – September 2011.[3]

Software licenses

Windows Server 2008 R2 Enterprise Edition

We assume the both solutions run Windows Server 2008 R2 Enterprise using per-server licensing. This license model requires CAL licenses. We do not include CAL costs in this analysis because the number of users or devices and therefore Windows CALs would be the same for both solutions.

For each solution, we assume the enterprise maintains current Microsoft Software Assurance on the Windows Server software and that their licensing allows them to migrate the software between servers. We also assume they can renew the Software Assurance agreements for the three years in this analysis.

The Dell PowerEdge R720 solution saves the Software Assurance costs of existing licenses that the solution doesn't need. We assume our hypothetical enterprise paid for the original license upfront and makes annual Microsoft Software Assurance payments. We also assume they can either cancel the Software Assurance agreements for licenses that the Dell PowerEdge R720 solution does not need or can use the licenses elsewhere.

The Dell PowerEdge R720 solution requires only one of the four Windows Server 2008 R2 Enterprise Edition licenses of the existing solution. The existing environment needed one license per server, for a total of four. The Dell PowerEdgeR720 solution needs only one of these licenses. One license supports an instance of the server software in one physical and four virtual operating system environments, the exact configuration of the Dell PowerEdge R720 solution in this model.

We used software pricing from the Microsoft License Advisor tool[4] and used the Quick Quote option there to find the single license price for a Microsoft Open License for corporate organizations with No Level pricing. The price quoted there is $2,358 per Windows Server 2008 R2 Enterprise Edition. Annual Software Assurance is one-fourth the license cost.

Microsoft Exchange Server 2010 Standard Edition

Microsoft Exchange Server 2010 Standard Edition supports up to five mail stores and the Enterprise edition supports more. The Standard edition is the choice for the single mail store used by the hypothetical enterprise.

Microsoft Exchange Server is priced on a per-instance basis. We assume the enterprise supports the software under a Microsoft Software Assurance agreement and would migrate the Microsoft Exchange licenses from the existing servers to the Dell PowerEdge R720 server. The four physical instances on the existing solution and the four virtual

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[2] http://www.bls.gov/oes/current/oes151142.htm
[3] http://www.bls.gov/news.release/ecec.t05.htm, Bureau of Labor Statistics report: Employer Costs –September 2011, Table 5. Private industry, by major occupational group and bargaining status, Management, Professional and Related column. That report estimates that salary is 70.6 percent and benefits are 29.4 percent of total compensation for Management, Professional and Related employees in private industry. Using those numbers we calculate benefits as 41.64% of salary.
[4] http://www.microsoft.com/licensing/mla/default.aspx

machine instances on the Dell PowerEdge R720 solution both have the same license count and same ongoing Software Assurance cost.

We used software pricing from the Microsoft License Advisor tool[5] and used the Quick Quote option there to find the single license price for a Microsoft Open License for corporate organizations with No Level pricing. The price quoted there is $708 per Microsoft Exchange Server 2010 Standard Edition. Annual Software Assurance is one-fourth the license cost.

VMware vSphere 5 Standard Edition

The Dell PowerEdge R720 solution requires VMware vSphere 5 Standard Edition licensing for virtualization, which costs $995 per processor, for a total of $1,990 for the two-socket PowerEdge R720. Production Support and Subscription is $323 per year. Each VMware vSphere 5 Standard edition license supports one processor and includes a 32GB vRAM entitlement. Our tested configuration did not exceed the combined 64GB vRAM entitlement of the two processor licenses.

Hardware support

Dell provided a quote of $2,499 for three-year support for the Dell PowerEdge R720 server. We base the HP support estimate on the support for the HP ProLiant DL380 G6 on the three-year support cost listed on the HP Store for the HP ProLiant DL380 G6 models. Figure 11 shows the hardware support costs for each solution.

	3-year	1-year	Annual cost per solution
HP Care Pack, 3 Years, 6-hour 24x7 CTR, Defective Media Retention Hardware Support, ProLiant DL380	$1,769	$589.67	$2,358.68
Dell Support: 3 Year ProSupport and Mission Critical 4HR 7x24 Onsite Pack	$2,499.00	$833.00	$833.00

Figure 11: Hardware support for the two solutions.

Energy costs

Figure 12 shows the calculations for the annual energy cost estimates. We calculate typical watts as 25 percent watts-active and 75 percent watts-idle. We use a cost per KWH of $ 0.0988 based on the average commercial price for electricity reported by the US Energy Information Administration as of January 2012.[6]

Annual costs - Energy costs	Dell PowerEdge R720	HP ProLiant DL380 G6
Power usage per server (watts-active)	243.27	131.30
Power usage per server (watts-idle)	141.01	109.67
Typical watts	166.58	115.08
Annual kWh per server	1,459.24	1,008.10
Multiplier for cooling	1.8	2.0

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[5] http://www.microsoft.com/licensing/mla/default.aspx
[6] http://www.eia.gov/electricity/monthly/index.cfm (report epmxlfile5_6_b.xls)

Annual costs - Energy costs	Dell PowerEdge R720	HP ProLiant DL380 G6
Total kWh for power and cooling one server	2,626.6	2,016.2
Annual energy cost per server	$260	$199
Annual energy cost for solution	**$260**	**$797**

Figure 12: Energy cost calculations for the two solutions.

Rack and space costs

We assume each server has two ports out and that the data center charges an annual per port cost of $250. For data center space, each server uses 2u. Because one u of space costs $98.64, the data center space for each server costs approximately $197.28, or $789.12 for the four servers in the existing configuration.

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