



## Virtualized Exchange workload performance comparison of end-to-end solutions with iSCSI storage connections: Dell PowerEdge 2950 with Dell EqualLogic PS5000 vs. HP ProLiant DL385 with HP StorageWorks EVA 4400

### Executive summary

Dell Inc. (Dell) commissioned Principled Technologies (PT) to compare the virtualized Exchange 2007 workload performance of two server-and-storage solutions with iSCSI connections:

- Dell PowerEdge 2950 server and Dell EqualLogic PS5000 storage array
- HP ProLiant DL385 server and HP StorageWorks EVA 4400 storage array

Both servers contained two processors and 32 GB of RAM, and both connected to their storage with iSCSI. Each server ran multiple Exchange 2007 workloads, one per virtual machine (VM). Each VM's workload used the Microsoft Exchange Load Generator. By combining multiple virtual machines with a 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.

Figure 1 compares the peak number of virtual machines running a Microsoft Exchange 2007 workload that each solution ran with acceptable performance (a response time of a second or less on all tasks). The Dell solution achieved 17 simultaneous virtual machines (VMs), while the HP solution delivered only 14 such VMs. Thus, the Dell solution had a 21.4 percent performance advantage over the HP solution. (The Workload section explains in more detail the virtualized Exchange 2007 workload.)

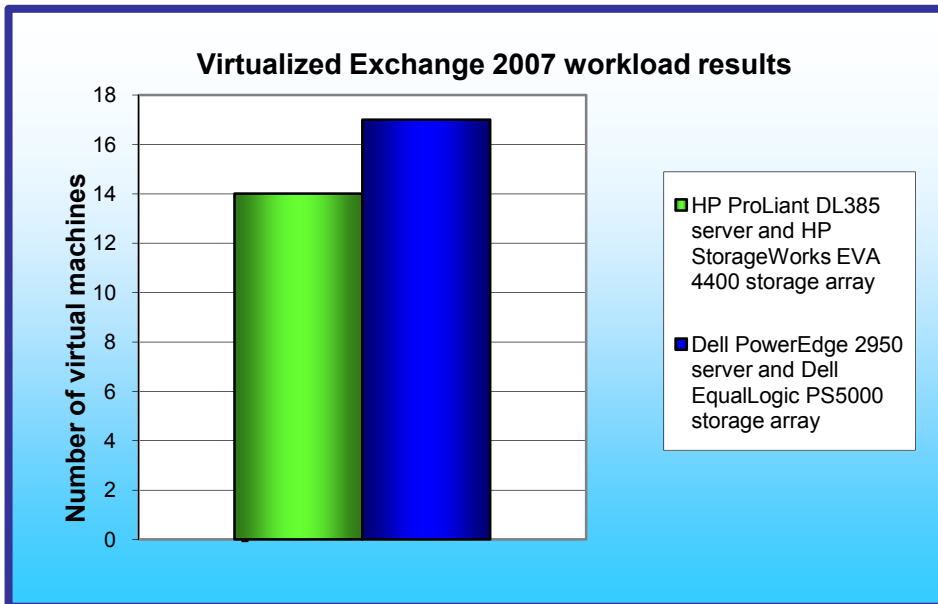


Figure 1: Virtualized Exchange 2007 workload performance results for the two server-and-storage solutions we tested.

### KEY FINDINGS

- The Dell PowerEdge 2950 server and Dell EqualLogic PS5000 storage array delivered 21.4 percent more virtualized Exchange workload performance than the HP ProLiant DL385 server and HP StorageWorks EVA 4400 storage array (see Figure 1).<sup>1</sup>
- The Dell PowerEdge 2950 server and Dell EqualLogic PS5000 storage array delivered 18.2 percent more virtualized Exchange workload performance/watt than the HP ProLiant DL385 server and HP StorageWorks EVA 4400 storage array (see Figure 2).<sup>2</sup>

Figure 2 illustrates the performance/watt for each of the two solutions. In this chart, we normalized the results for each workload to those of the solution 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.

As Figure 2 shows, the Dell solution delivered 18.2 percent more performance/watt than the HP solution.

<sup>1</sup>Principled Technologies, Inc., Virtualized Exchange workload performance comparison of end-to-end solutions with iSCSI storage connections: Dell PowerEdge 2950 with Dell EqualLogic PS5000 vs. HP ProLiant DL385 with HP StorageWorks EVA 4400, October 2008.

<sup>2</sup>Ibid.

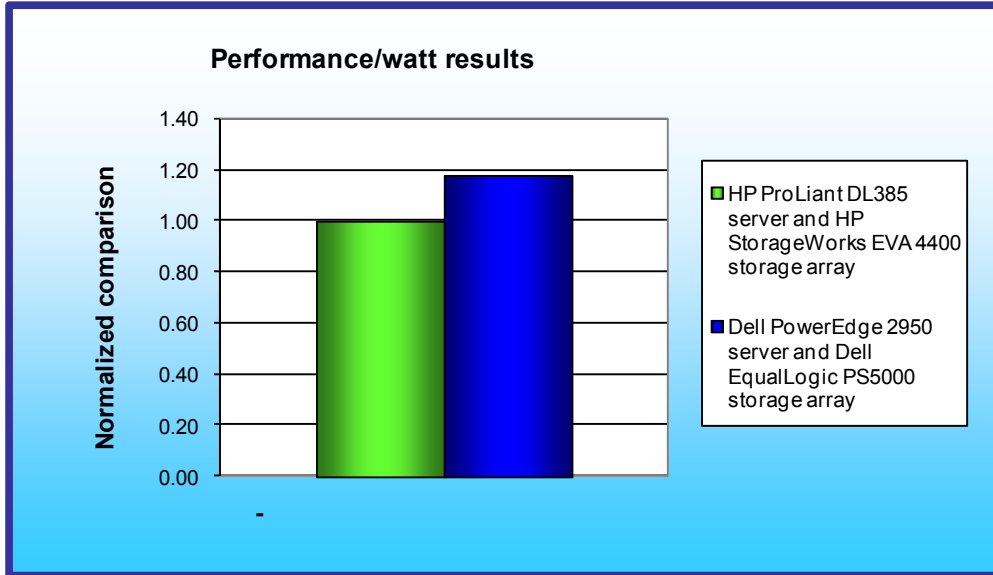


Figure 2: Performance/watt results for the servers normalized to that of the HP ProLiant DL385 server and HP StorageWorks EVA 4400 storage array solution. Higher numbers are better.

## Workload

Our goal was to see how many virtual machines running this workload on Microsoft Server 2008 with Exchange 2007 the server could handle with acceptable performance. To reach that goal, we created a new custom workload that reflected existing standards.

To build that workload, we used Microsoft Exchange LoadGen 2007, an industry-standard tool for benchmarking an Exchange Mail Server. We used as the basis of that workload the LoadGen settings from an industry-standard virtualized mail benchmark that uses the Microsoft Exchange Server 2003 MAPI Messaging Benchmark 3 (MMB3). MMB3 is the previous generation Exchange benchmark, which Microsoft has replaced with LoadGen 2007. We modified the MMB3 workload so it would work on the latest version of LoadGen 2007 by using the Custom feature of that tool. During the tests, LoadGen performs tasks to simulate a standard user generating mail activity. When the workload finishes, LoadGen reports the response time, which is the number of seconds necessary to complete the task.

We ran this workload on all virtual machines simultaneously for 30 minutes. We defined a solution to have delivered acceptable performance if it performed each of the test Exchange operations in less than a second in all of the VMs.

## Test results

Figure 3 shows the total number of virtual machines each solution could handle during testing. For an acceptable score, a solution had to complete all tasks in the LoadGen workload in 1000 ms (1 second), in all virtual machine LoadGen tests.

To determine the maximum number of simultaneous virtual machines each solution could handle, we added virtual machines until one or more of the VMs had a response time on some operations of greater than one second. We then subtracted one VM to identify the total number of VMs the solution could handle. We performed three runs at the total number to verify the response time always remained below 1000ms.

Server	Total number of virtual machines
Dell PowerEdge 2950 server and Dell EqualLogic PS5000 storage array	17
HP ProLiant DL385 server and HP StorageWorks EVA 4400 storage array	14

Figure 3: The total number of virtual machines for the two server-and-storage solutions. Higher numbers are better.

Figure 4 shows the average response time from the median run for each virtual machine.

Server	Dell PowerEdge 2950 server and Dell EqualLogic PS5000 storage array	HP ProLiant DL385 server and HP StorageWorks EVA 4400 storage array
Virtual machine 1	302.50	929.73
Virtual machine 2	385.53	798.80
Virtual machine 3	361.85	580.22
Virtual machine 4	372.87	796.67
Virtual machine 5	373.67	849.42
Virtual machine 6	443.43	461.85
Virtual machine 7	401.00	670.22
Virtual machine 8	352.87	787.83
Virtual machine 9	323.43	813.45
Virtual machine 10	386.38	842.23
Virtual machine 11	451.48	750.32
Virtual machine 12	352.12	503.23
Virtual machine 13	387.00	596.42
Virtual machine 14	356.28	773.05
Virtual machine 15	313.38	N/A
Virtual machine 16	301.33	N/A
Virtual machine 17	435.03	N/A

Figure 4: Average response time from median run for each virtual machine for the two server-and-storage solutions. Lower numbers are better.

Figure 5 details the power consumption, in watts, of the server-and-storage solutions while idle and during the median run of the virtualized Exchange 2007 workload.

Server	Idle power (watts)	Average power (watts)
Dell PowerEdge 2950 server and Dell EqualLogic PS5000 storage array	1,068.46	1,178.58
HP ProLiant DL385 server and HP StorageWorks EVA 4400 storage array	1,020.88	1,146.76

Figure 5: Average power usage (in watts) of the server-and-storage solutions while idle and during the median run of virtualized Exchange 2007 workload. Lower numbers are better.

## Test methodology

Each server arrived with ESX 3i hypervisor installed on an internal USB key.

### Booting to VMware ESX Server 3i 3.5.0

We performed the following steps in order to boot to VMware ESX Server 3i 3.5.0 build 82664 on the server under test:

1. Power on the server.
2. Enter the Bios.
3. Enable the internal USB port.
4. Place the internal USB port at the top of the boot order.
5. Save and restart the server.

### Installing Virtual Infrastructure Client on the controller

We managed VMware ESX Server with a separate system we call the controller. We ran Microsoft Windows Server 2003, Enterprise Edition on this system and connected it to the VMware ESX Server with a network switch. We performed the following steps to install the necessary VMware Infrastructure Client software on this system:

1. Insert the Virtual Infrastructure install CD into the CD drive.
2. In the Choose Language window, leave the default English selected, and click OK.
3. At the Welcome screen, click Next.
4. At the Introduction screen, click Next.
5. At the License Agreement screen, check the I accept the terms in the license agreement radio button, and click Next.
6. At the Customer Information screen, enter `tester` in the User name field, and click Next.
7. At the Installation Type screen, select the VMware Infrastructure Client radio button, and click Next.
8. At the Ready to Install screen, click Install.
9. At the InstallShield Wizard Completed screen, click Finish.
10. Before you can properly use the VMware ESX Server, you must first install a license file. You can deploy that file with either host-based or server-based licensing. For our testing, we used the host-based license method by following these steps:
  - a. To install the license, click the Configuration tab in the Virtual Infrastructure Client.
  - b. Under the Software section on the left side of the screen, click Licensed Features.
  - c. Make sure the license file (which VMware should have provided with the copy of VMware ESX Server) is on the controller.
  - d. Click Edit next to the License Sources.
  - e. In the pop-up window, select Use Host License File.
  - f. Click Browse, and browse to the location of the license file on the server.
  - g. Click Open to select the file.
  - h. Click Edit next to VMware ESX Server License Type.
  - i. Select VMware ESX Server Standard, and click OK.

### Configuring network adapters with Virtual Infrastructure Client

Before we set up the VMs, we had to configure the network adapters on the VMware ESX Server. To accommodate all the network traffic the test required, we used two network ports on the VMware ESX Server.

We assigned the external network port the IP address of 192.168.0.100 during the VMware ESX Server installation, because the Virtual Infrastructure Client uses this port to communicate.

We performed the following steps to configure the VMware ESX Server for the network adapters:

1. Within the Virtual Infrastructure Client window, select the configuration tab for the VMware ESX Server.
2. In the hardware section, select Networking to view the network setup.
3. Click Properties for Virtual Switch vSwitch0.
4. In the vSwitch0 Properties window, highlight the Virtual Machine Network, and click Edit.
5. Rename the Network Label to External Network.
6. Click OK to close the window.

7. Click Close to close the Properties window.
8. On the Networking configuration tab, click Add Networking.
9. Select Virtual Machine for the connection type, and click Next.
10. Under Create a virtual switch, select vmnic1, and click Next.
11. Change the Network Label to Mail Network, and click Next.
12. At the summary page, click Finish.

### Creating a virtual machine

The steps below describe how we created a base virtual machine. We performed the following basic steps to create each of the VMs the test required. We list the exact parameters we specified for each VM in the section below on installing and configuring that VM.

1. In Virtual Infrastructure Client, highlight the VMware ESX Server (localhost.localdomain).
2. Select File→New→Virtual Machine.
3. Select Custom on the Select the Appropriate Configuration screen, and click Next.
4. Enter the Virtual Machine Name, and click Next.
5. Select the Storage that will hold the VM, and click Next.
6. Select the Operating System for the VM, and click Next.
7. Use the drop-down box to select the number of virtual processors for the VM, and click Next.
8. Select the amount of memory for the VM, and click Next.
9. Select the Network Connection for the VM, and click Next.
10. Accept the default option for the SCSI Adapter, and click Next.
11. Leave the default option to create a new virtual disk on the Select a Disk screen, and click Next.
12. Enter the virtual disk size, and click Next.
13. Leave the default options for the Specify Advanced Options, and click Next.
14. Review the virtual machine summary, and click Finish to create the virtual machine.

### Installing and configuring the mail server

To set up this server, you must install several software components. The following subsections detail the necessary installation processes. Before following these instructions, make sure to statically assign an IP address for the server under test, and then plug that port into another system or router. This allows the server to correctly add the domain server function. We recommend making the IP address 192.168.x.250, where x is the VM number. For example, the first mail server would have an IP address 192.168.1.250.

1. Follow the steps in the earlier Creating a virtual machine section using the following VM specifications:
  - a. Name: MailServer
  - b. Virtual processors: 1
  - c. Virtual memory: 2048 MB
  - d. Virtual Disk Size: 40 GB
  - e. Virtual Network: Mail Network (keep the default Windows Network DHCP settings)
2. Install Microsoft Windows Server 2008, Enterprise x64 Edition in the VM.
3. When asked to choose a partition to install the OS to, click New.
4. Enter 24,576 for the size of the partition and click Create.
5. Highlight the newly created partition, and click Format.
6. When formatting completes, click New.
7. Enter 8,192 for the size of the partition and click Create.
8. Highlight the newly created partition, and click Format.
9. When formatting completes, click New.
10. Enter 8,190 for the size of the partition and click Create.
11. Highlight the newly created partition, and click Format.
12. When formatting completes, highlight the 24 GB partition and click Install.
13. Finish the installation procedure using default settings.
14. Right-click the VM in the Virtual Infrastructure Client window, and select Install VMware tools.
15. Reboot the VM.
16. Right-click the desktop, and select Personalize.
17. Click the Screen Saver link.
18. Click the Screen saver drop-down menu, and select (None).

19. Click Apply.
20. Click Change power settings.
21. Click Change plan settings under Balanced.
22. Change the Turn off monitor drop-down menu to Never.
23. Click Save changes and close the Power Options, Screen Saver Settings, and Personalization windows.
24. Open the Start menu, type `regedit` in the search field and press Enter.
25. To allow the VM to automatically log into the OS after a system reboot, change the following Registry key to have the values shown here:
  - [HKEY\_LOCAL\_MACHINE\SOFTWARE\Microsoft\Windows NT\CurrentVersion\Winlogon]
    - DefaultPassword=Password1
    - AutoAdminLogon=1
    - DefaultUsername=administrator
26. Restart the VM.

### Installing the domain controller

1. Set a static IP address using the following steps:
  - a. Right-click the network icon in the quick-launch bar, and choose Network and Sharing Center.
  - b. Click Manage network connections.
  - c. Right-click the local area connection, and choose Properties.
  - d. Select Internet Protocol Version (TCP/IPv4), and click Properties.
  - e. Select the Use the following IP address radio button and enter `192.168.0.250` in the IP address field.
  - f. Press Tab to auto-fill `255.255.255.0` in the Subnet mask field.
  - g. In the Preferred DNS server field, enter `127.0.0.1` and click OK to close the IPv4 properties window.
  - h. Click Close.
2. Give the computer a name using the following steps:
  - a. Click Start then right-click Computer and select Properties.
  - b. Click Change Settings.
  - c. Click Change.
  - d. Enter `mailserver` in the Computer name field, and click OK.
  - e. In the Computer Name/Domain Changes pop-up window, click OK.
  - f. Click OK.
  - g. In the Microsoft pop-up window, click Restart Now.
3. Promote the mailserver to domain controller by following these steps:
  - a. Select Start→Command Prompt.
  - b. Type `dcpromo`.
  - c. At the Welcome pop-up window, click Next.
  - d. At the Operating System Compatibility screen, click Next.
  - e. At the Choose a Deployment Configuration screen select the Create a new domain in a new forest radio button, and click Next.
  - f. At the Name the Forest Root Domain screen, type a domain name (`mailserver.com`), and click Next.
  - g. At the Set Forest Functional Level screen, choose Windows Server 2008 from the drop-down menu, and click Next.
  - h. At the Additional Domain Controller Options screen, accept the defaults, and click Next.
  - i. When the Static IP assignment window pops up, click Yes, the computer will use a dynamically assigned IP address.
  - j. When the Active Directory domain Services Installation Wizard window pops up, click Yes.
  - k. At the Location for Database, Log Files, and SYSVOL screen, click Browse next to the Database folder field and choose the D:\ drive. Click Next.
  - l. At the Directory Services Restore Mode Administrator Password screen, enter a password, and click Next.
  - m. At the Summary screen review the selections, and click Next.
  - n. When the installation software prompts you to do so, insert the OS CD, and click OK.

- o. At the Completing the Active Directory Installation Wizard screen, click Finish.
- p. When the system prompts you to reboot the server, click Restart Now.
- q. After the server reboots, log in to the system.

### Installing Internet Information Services 6.0

1. Select Start→Administrative Tools→Server Manager.
2. Click Add Roles.
3. At the Select Server Roles screen click Web Server (IIS).
4. In the pop up Add features required for Web Server (IIS) window, click Add Required Features.
5. Click Next.
6. At the Web Server (IIS) screen, click Next.
7. At the Select Role Services screen select the IIS 6 Metabase Compatibility, IIS 6 Management Console, Basic Authentication, Windows Authentication, Digest Authentication, and Dynamic content Compression checkboxes, and click Next.
8. At the Confirm Installation Selections screen, click Install.
9. At the Installation Results screen, click Close.

### Installing Exchange Server 2007

1. Insert the Microsoft Exchange Server 2007 CD.
2. In the pop up AutoPlay window, click Run Setup.EXE.
3. Steps 1 and 2 should already be completed and grayed out.
4. Click Step 3: Install Microsoft Windows PowerShell.
5. Select Start→Command Prompt.
6. In the Command Prompt window type `ServerManagerCmd -I PowerShell` and press Enter.
7. When the installation completes, close the Command Prompt window.
8. Click the link to Step 4: Install Microsoft Exchange Server 2007 SP1.
9. Click Next to go past the introduction screen.
10. Accept the license agreement, and click Next.
11. Select No for error reporting, and click Next.
12. Select Typical Exchange Server Installation, and click Next.
13. Leave the organization name at default (First Organization), and click Next.
14. Select No to the question about client computers running Outlook 2003 and earlier, and click Next.
15. If a warning about a lack of SMTP appears after the check finishes, ignore it.
16. Click Install to start the installation process.
17. Once installation is complete, click Finish. Exchange should automatically open the Exchange Management Console.

### Configuring Exchange Server 2007

1. If Exchange does not automatically open the Exchange Management Console, select Start→All Programs→Microsoft Exchange Server 2007→Exchange Management Console.
2. In the left pane, expand Organization Configuration, and select Hub Transport.
3. In the action pane on the far right, select New Send Connector.
4. Name the send connector SMTP, select the intended use as Internet, and then click Next.
5. In the Address space window, click Add.
6. In the SMTP Address Space window, put \* as the address, make sure Include all subdomains is checked, and click OK.
7. Click Next.
8. Accept defaults for the next two pages by clicking Next.
9. At the New Connector page, click New to create the connector.
10. Click Finish to close the New SMTP Send Connector wizard.
11. In the left pane of the Exchange Management Console window, expand Server Configuration, and select Mailbox.
12. In the Database Management tab, right-click First Storage Group, and select New Public Folder Database.
13. Name the new public folder database Public Folder Database, and click New.

14. In the Completion page, click Finish to close the New Public Folder Database window.
15. Close the Exchange Management Console, and reboot the server.
16. Once the server successfully reboots, log in, and select Start→All Programs→Administrative Tools→Active Directory Users and Computers.
17. In the Active Directory Users and Computers window, select test.com in the left pane, and open Users in the right pane.
18. Right-click a blank area in the Users folder, and select New→User.
19. In the New Object - User window, complete the name fields as you wish (we used first name: test, last name: tester, logon name: tester), and select Next.
20. Enter a secure password (we used Password1), and check Password never expires.
21. In the pop-up information window, click Accept.
22. Select Next to close the New Object – User window.
23. Double-click the new user to bring up the Properties window.
24. Under the Member Of tab, click Add.
25. In the Enter the object names to select dialog box, type Domain Admins; Exchange Organization Administrators, select Check Names to verify, and then click OK.
26. Click OK to close the user Properties window and close Active Directory Users and Computers window.
27. Select Start→All Programs→Microsoft Exchange Server 2007→Exchange Management Console.
28. In the left pane of the Exchange Management Console window, select Recipient Configuration; and in the right pane, select New Mailbox.
29. In the New Mailbox window, select User Mailbox, and click Next.
30. In the User Type page, select Existing users, and click Add.
31. Select the new account you created earlier, and click OK to add it to selection box.
32. Click Next.
33. In the Mailbox Settings page, leave the Alias textbox with default settings, and select Browse in the Mailbox database selection spot.
34. In the Select Mailbox database window, select Mailbox Database, and click OK.
35. Click through the next screens to create the new mailbox, and close when you have done so.
36. Close the Exchange Management Console.
37. Select Start→All Programs→Microsoft Exchange→System Manager.
38. In the left window pane, expand Server Configuration and Mailbox so the First Storage Group is visible.
39. Right-click First Storage Group, and select Properties.
40. Click Browse, and change the Transaction log and System path location to E:\.
41. Check the Enable circular logging box.
42. Click Apply.
43. When the pop-up message appears asking if you want to perform this task, click Yes.
44. When the message appears saying that all mounted stores are back online, click OK.
45. Right-click First Storage Group and select New Mailbox Database.
46. Under Mailbox database name, write Mailbox Database 2.
47. Click the Browse button and select E:\Mailstore. If there is not a directory called Mailstore, create it.
48. Click the New button to create the database.
49. Right-click Mailbox Store under First Storage Group, and select Properties.
50. Select the Database tab.
51. Click Browse, and move the Exchange database and Exchange streaming database to E:\.
52. Check the box beside This database can be overwritten by a restore.
53. Click Customize next to Maintenance interval.
54. Remove all blue from the boxes so the system will not perform maintenance, and click OK.
55. At the Mailbox Store Properties window, click Apply.
56. When a warning message appears, click Yes.
57. When the message that the database files have been moved appears, click OK.
58. Click OK to close the Mailbox Store Properties window.
59. Right-click Mailbox Store 2 under First Storage Group, and select Properties.
60. Select the Database tab.
61. Click Browse, and move the Exchange database and Exchange streaming database to E:\.
62. Check the box beside This database can be overwritten by a restore.



63. Click Customize next to Maintenance interval.
64. Remove all blue from the boxes so the system will not perform maintenance, and click OK.
65. At the Mailbox Store 2 Properties window, click Apply.
66. When a warning message appears, click Yes.
67. When the message that the database files have been moved appears, click OK.
68. Click OK to close the Mailbox Store 2 Properties window.
69. Right-click Public Store under First Storage Group, and select Properties.
70. Select the Database tab.
71. Click Browse, and move the Exchange database and Exchange streaming database to E:\.
72. Check the box beside This database can be overwritten by a restore.
73. Click Customize next to Maintenance interval.
74. Remove all blue from the boxes so the system will not perform maintenance, and click OK.
75. At the Public Store Properties window, click Apply.
76. When a warning message appears, click Yes.
77. When the message that the database files have been moved appears, click OK.
78. Click OK to close the Public Store Properties window.
79. In the left pane of the Virtual Infrastructure Client, right-click the MailServer1 VM, and select Install VMware Tools.
80. At the Install Tools pop-up window, click OK.
81. Click Next through the Installation Wizard to install the VMware Tools. This process accepts all defaults.
82. When the installation completes, click Finish.
83. Click Yes to reboot the virtual machine.

## Cloning the VMs

We followed the steps below to copy a VM with VMware Converter. They assume you have installed the VMware Converter on the same machine as the VMware Virtual Infrastructure Client.

1. Open VMware Converter, and click Import Machine.
2. At the Welcome screen, click Next.
3. At the Source screen, click Next.
4. Select VMware ESX Server for the Source, and click Next.
5. Enter the IP address, user name, and password of the VMware ESX Server, and click Next.
6. Select the virtual machine that you want to copy (for example: Base32), and click Next.
7. For the Source Data, leave the default (Import all disks and maintain size), and click Next.
8. At the Destination screen, keep the default, and click Next.
9. For Destination Type, select VMware ESX server, and click Next.
10. Enter the IP address, user name, and password of the VMware ESX Server, and click Next.
11. Enter the virtual machine name (for example, if you are copying Base32, the server you are configuring could be IdleServer1, MailServer1, or WebServer1), and click Next.
12. Select the host system, and click Next.
13. Select the Datastore, and click Next.
14. Select the Network connection for the virtual machine, and click Next.
15. Leave the default Customization settings, and click Next.
16. Review the summary, and click Finish to begin copying the virtual machine.

## Installing and configuring the mail client

We used a separate ESX Server running virtual clients for all mail clients. To create the mail client, you must install several software components. Before following these instructions, make sure to statically assign an IP address for the client, and then plug that port into the system under test. This allows the client to correctly join the domain. 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: MailClient
  - b. Virtual processors: 1
  - c. Virtual memory: 512 MB
  - d. Virtual Disk Size: 8 GB
  - e. Virtual network: External Network (keep the default Windows Network DHCP settings)
2. Install Microsoft Windows Server 2003 R2 Enterprise x64 Edition Service Pack 2 on the VM.

3. Assign a computer name of "Clientx" for the mail 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. Use "Testbed" for the workgroup.

To set up this server, we had to install several additional software components. The following subsections detail the necessary installation processes.

### Joining the domain

1. Select Start→Control Panel→Network Connections→Local Area Connection.
2. Click Properties.
3. Highlight Internet Protocol (TCP/IP), and click Properties.
4. Select the Use the following DNS server addresses radio button and enter the IP of the DNS server in the Preferred DNS server field. Click OK.
5. Right-click My Computer, and select Properties.
6. Under the Computer Name tab, click Change.
7. In the Computer Name Changes window, under the Member of section, select the Domain radial box, and type `test.com`.
8. Select OK to start joining the domain.
9. When the window appears asking for a person qualified on the domain, enter `Tester` as the username and `Password1` as the password.
10. Click OK at the welcome pop-up window and the window warning that you must reset the computer for the changes to take effect.
11. Click OK in the System Properties window.
12. When a pop-up appears asking if you want to restart now, click Yes to restart your computer.

### Installing Internet Information Services 6.0

1. Select Start→Control Panel→Add or Remove Programs.
2. Click Add/Remove Windows Components.
3. Select Application Servers, and click Details.
4. Click ASP.NET, and make sure a check appears in the check box.
5. Select Internet Information Services (IIS), and click Details.
6. Click OK to close the Application Server window.
7. At the Windows Components Wizard, click Next to begin the installation.
8. When the system prompts you to do so, insert the OS CD, and click OK.
9. At the Completing the Windows Components Wizard window, click Finish.
10. Close the Add or Remove Programs window.

### Installing Exchange Server 2007 and Load Generator

1. Insert the Microsoft Exchange Server 2007 CD. The CD should automatically launch the installation software.
2. Click the link to Step 1: Install .NET Framework 2.0.
3. When you arrive at the download link, download the x64 version of the .NET Framework, and install.
4. Click the link to Step 3: Install Microsoft Windows PowerShell; this takes you to the download link.
5. When you arrive at the download link, download Microsoft Windows PowerShell, and install with defaults.
6. Search for and download SP1 for .NET Framework 2.0.
7. Install SP1 with all defaults.
8. Click the link to Step 4: Install Microsoft Exchange Server 2007 SP1.
9. Click Next to go past the introduction screen.
10. Accept the license agreement, and click Next.
11. Select No for error reporting, and click Next.
12. Select Custom Exchange Server Installation, and click Next.
13. Check Management Tools, and click Next.
14. After the check finishes, click Install to start the installation process.

15. Once installation is complete, click Finish.
16. Download and install Load Generator using all defaults.

### Preparing Load Generator

1. Log into the MailClient using the tester account.
2. Select Start→All Programs→Microsoft Exchange→Exchange Load Generator.
3. When the Load Generator window appears, select Start a new test.
4. Select Create a new test configuration, and click Continue.
5. Enter `tester` as the account name.
6. In the Specify test settings window, type `Password1` as the Directory Access Password and Mailbox Account Master Password, and click Continue with recipient management.
7. Make 500 users in each Mailbox Database, and click Continue.
8. To accept defaults for Advanced recipient settings, click Continue.
9. In the Specify test user groups window, select the plus sign to add a user group.
10. Change the Client Type to Outlook 2007 Online and the Action Profile to Custom, and click Continue.
11. Leave defaults in Remote configurations, and click Continue.
12. Click Save the configuration file as, and name it `Loadgencfg`.
13. Click Start the initialization phase (recommended before running the test) to start initialization. The initialization process might take a few hours.

### Power measurement procedure

To record each server's power consumption during each test, we used an Extech Instruments ([www.extech.com](http://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 2 minutes while each system was running ESX Server 3i but otherwise idle, meaning no VMs were powered on.

We then recorded the power usage (in watts) for each system during the testing at 1-second intervals. To compute the average power usage, we averaged the power usage during the time the system was producing its peak performance results. Since 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 5 (idle and average peak power) for the results of these measurements.

### Testing procedure

To perform the test, we used a series of batch files. First, we powered on all virtual machines. We made each wait for the controller to copy a file to begin the test. Before beginning the test, we let all equipment sit for 1 hour and 30 minutes to ensure the virtual machines were idle and had finished running any background tasks. Then we executed the start batch file on our controller, which copied a file to all virtual machines to start LoadGen. After LoadGen finished, we used another batch file to copy the results from all virtual machines. The batch files simply used the copy command and referred to all virtual machines by their IP addresses. Once a run finished, we used a restore batch file, which restored the mailstore to the original state. This allowed us to always start from the same point in testing.

## Appendix A – Server configuration information

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

Server	Dell PowerEdge 2950	HP ProLiant DL385
<b>General dimension information</b>		
Height (inches)	3.5	3.5
Width (inches)	19	19
Depth (inches)	27	26.5
U size in server rack	2	2
<b>Power supplies</b>		
Total number	2	2
Wattage of each	750	800
<b>Cooling fans</b>		
Total number	4	6
Dimensions (H x W) of each	2.5 x 2.5	2.5 x 2.5
Voltage	12	12
Amps	2.10	1.80
<b>General processor setup</b>		
Number of processor packages	2	2
Number of cores per processor package	4	4
Number of hardware threads per core	1	1
System Power Management Policy	Always On	Always On
<b>CPU</b>		
Vendor	Intel	AMD
Name	Quad-Core Intel Xeon E5440	Third Generation AMD Opteron 2356
Stepping	C0	B3
Socket type	LGA 771	Socket F (1207)
Core frequency (GHz)	2.83	2.30
Front-side bus frequency (MHz)	1,333	1,000
L1 cache	32 KB + 32 KB (per core)	64 KB + 64 KB (per core)
L2 cache	2 x 6 MB (each 6 MBs shared by 2 cores)	2 MB (512 KB per core)
L3 cache	NA	2 MB (shared)
<b>Platform</b>		
Vendor and model number	Dell PowerEdge 2950	HP ProLiant DL385 G5
Motherboard model number	CN-0WW126-13740-86H-0285	PACEN0D9VVZ1FA
Motherboard revision number	A02	0D
BIOS name and version	Dell BIOS Version 2.3.1	HP BIOS A09 (v2.10)
BIOS settings	Enabled Virtualization Technology, Enabled USB 2.0 Controller	Enabled AMD Virtualization, Enabled USB 2.0 Controller
<b>Memory module(s)</b>		
Vendor and model number	Samsung M393T5160QZA-CE6Q0	Samsung M395T5160QZ4-CE65
Type	PC2-5300	PC2-5300
Speed (MHz)	667	667

Server	Dell PowerEdge 2950	HP ProLiant DL385
Speed in the system currently running @ (MHz)	667	667
Timing/Latency (tCL-tRCD-iRP-tRASmin)	5-5-5-15	5-5-5-15
Size	32 GB (8 x 4 GB)	32 GB (8 x 4 GB)
Number of RAM modules	8	8
Chip organization	Dual-sided	Dual-sided
<b>Hard disk</b>		
Vendor and model number	Seagate ST973451SS	HP DH072BB978
Number of disks in system	2	2
Size	73 GB	72 GB
Buffer size	16 MB	16 MB
RPM	15,000	15,000
Type	SAS	SAS
Controller	LSI SAS 1068E	HP Smart Array P400 Controller
Controller driver	mptscsi_2xx	cciss
<b>Operating system</b>		
Name	VMware ESX Server 3i v3.5	VMware ESX Server 3i v3.5
Build number	82664	82664
File system	ext3 (server) Vmfs3 (virtual machines)	ext3 (server) Vmfs3 (virtual machines)
Kernel	2.4.2147.0.1.ELvmnix	2.4.2147.0.1.ELvmnix
Language	English	English
<b>Graphics</b>		
Vendor and model number	ATI ES1000	ATI ES1000
Chipset	ATI ES1000	ATI ES1000
Type	Integrated	Integrated
Memory size	32 MB	32 MB
Resolution	1,024 x 768	1,024 x 768
<b>Network card/subsystem</b>		
Vendor and model number	Broadcom Corporation NetXtreme II 5708 Gigabit Ethernet	Broadcom Corporation NetXtreme II 5708 Gigabit Ethernet
Type	Integrated	Integrated
Driver	bnx2	bnx2
<b>Optical drive</b>		
Vendor and model number	TEAC CD-224E CD-ROM	HP DVD-ROM
<b>USB ports</b>		
Number	5 (1 internal)	5 (1 internal)
Type	USB 2.0	USB 2.0

Figure 6: 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.

Enclosure	Dell Equal Logic PS5000XV	HP EVA 4400
<b>General dimension information</b>		
Height (inches)	5.5	3.5
Width (inches)	19.0	19.0
Depth (inches)	21.5	22.0
U size in server rack	3	2
<b>Power supplies</b>		
Total number	2	2
Wattage of each	450	575
<b>Cooling fans</b>		
Total number	4	4
Dimensions (H x W) of each	4 x 4	2.5 x 2.5
Voltage	12 volts	12 volts
Amps	1.8 amps	1.68 amps
<b>Hard disk</b>		
Vendor and model number	Seagate ST3146855SS	HP BF146DA47C and HP BF146DA47A
Number of disks in system	32	19 x HP BF146DA47C and 13 HP BF146DA47A
Size	146 GB	146 GB
Buffer Size	16 MB	16 MB
RPM	15,000	15,000
Type	SAS	Fibre Channel

Figure 7: Detailed system configuration information for the two array systems.



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