Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series SAN and HP StorageWorks 4400 Enterprise Virtual Array

Executive summary

Dell Inc. (Dell) commissioned Principled Technologies (PT) to compare the performance on a heavy Exchange 2007 workload of two mid-range Storage Area Network (SAN) solutions, which we list in alphabetical order:

- Dell EqualLogic PS Series iSCSI SAN with two PS5000XV arrays (Dell EqualLogic SAN)
- HP StorageWorks 4400 4 GB Fibre Channel Enterprise Virtual Array with two disk shelves (HP StorageWorks SAN)

We tested the Dell EqualLogic SAN with Internet Small Computer Systems Interface (iSCSI) protocol. The HP StorageWorks 4400 is a Fibre Channel (FC) array that offers an iSCSI option; we tested it using Fibre Channel.

We configured both SANs with two full shelves of disks, with 16 disks per shelf on the Dell EqualLogic SAN and 12 disks per shelf on the HP StorageWorks SAN.

KEY FINDINGS

- The Dell EqualLogic SAN delivered better performance on our Exchange workload tests. It delivered 86 percent more Achieved IOPS per disk at 208.4 Achieved IOPS per disk compared to the HP StorageWorks SAN at 111.9 Achieved IOPS per disk. (See Figure 1.)
- The Dell EqualLogic SAN delivered 45 percent more Log IOPS per disk, at 54.1 Log IOPS per disk compared to the HP StorageWorks SAN at 37.2 Log IOPS per disk. (See Figure 2.)
- The Dell EqualLogic SAN delivered 77 percent greater throughput, at 1.98 MB per second per disk compared to the HP StorageWorks SAN at 1.12 MB per second per disk. (See Figure 3.)

For this comparison, we selected the primary storage performance tests in the Microsoft Exchange Server Jetstress tool. Jetstress reports the database disk read and write I/O operations per second (Achieved IOPS), log disk write I/O operations per second (Log IOPS), and the megabytes per second throughput that a given Microsoft Exchange 2007 storage solution provides while maintaining satisfactory responsiveness.

Our goal was to find the maximum I/O operations per second (IOPS) each platform could deliver while providing a satisfactory user experience. We configured the simulation to demand maximum IOPS by
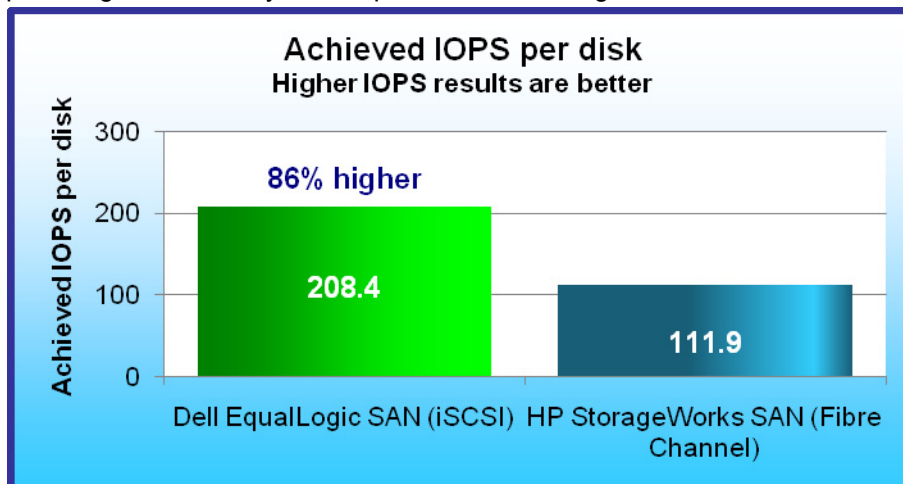

Figure 1: Jetstress performance results, in Achieved IOPS per disk, for two mid-range SAN storage solutions. Results are the Achieved IOPS divided by the number of disks; 32 disks for the Dell EqualLogic SAN and 24 for the HP StorageWorks SAN.

using a large number of relatively small mailboxes, running with high thread counts, and simulating users with heavy mailbox activity. To maximize mailbox count, we selected an average mailbox size of 250 MB and used a production-sized Exchange database that filled 60 percent of the available storage on each test storage system. We allocated half the remaining storage, 20 percent of total available storage, for log files.
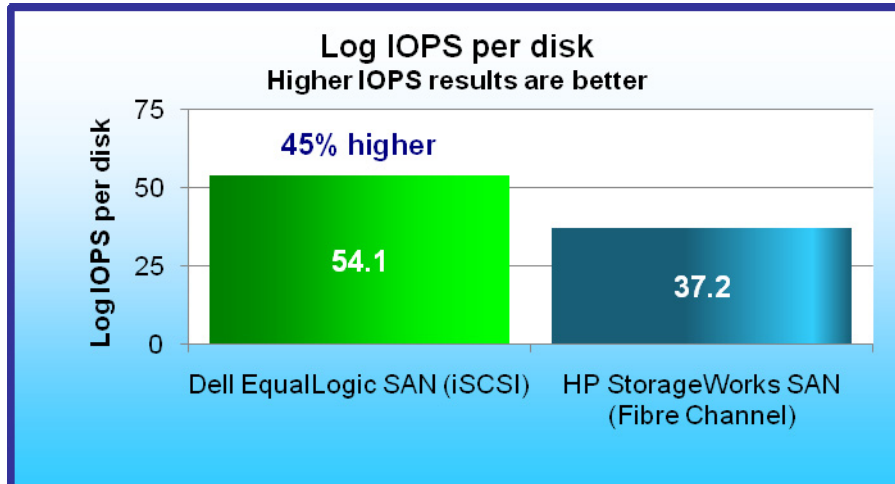
Figure 2: Jetstress performance results, in log write I/O operations per second per disk, for the storage solutions. Results are the log write I/O operations per second divided by the number of disks; 32 disks for the Dell EqualLogic SAN and 24 for the HP StorageWorks SAN.

We tested with the highest thread count each system could support during the tests while still providing latency results within the standard latency thresholds designated in the Jetstress program. We configured the tests to simulate users with very heavy Microsoft Exchange 2007 activity, which Microsoft defines as requiring approximately 0.5 database I/O operations per second per user.

To provide comparable results for the different disk counts of the systems, we divided the Achieved IOPS that Jetstress reports for the tested storage solution by the number of disks in the solution. We show the per-disk results in Figure 1. The disk count includes all disks in both shelves.

As Figure 1 shows, The Dell EqualLogic SAN delivered 86 percent more Achieved IOPS per disk: 208.4 Achieved IOPS per disk compared to the HP StorageWorks SAN at 111.9 Achieved IOPS per disk.

We ran the test three times to ensure repeatability and report the results from the run that produced the median combined database and Log IOPS results.
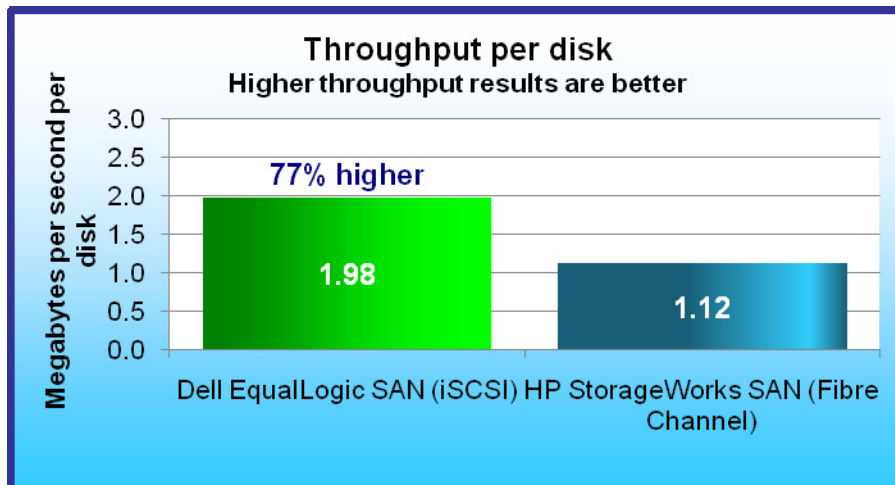

Figure 3: Average disk transfers (in megabytes per second per disk) for the storage arrays during the Jetstress test. Results are megabytes per second per disk divided by the number of disks; 32 disks for the Dell EqualLogic SAN and 24 for the HP StorageWorks SAN.

The overall Jetstress test result is a pass/fail rating based on whether the system's performance fell within acceptable latency thresholds. All the results we report are from runs that passed. Achieved IOPS is the primary Jetstress throughput result. This result is the sum of the average database disk reads and the database disk writes per second during the test.

Achieved IOPS includes only database disk I/O. Jetstress provides separate results for log disk write I/O. Figure 2 shows the average log disk write I/O operations

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

2

per second (Log IOPS) during the same runs we show in Figure 1. The Dell EqualLogic SAN delivered 54.1 Log IOPS per disk, 45 percent more than the HP StorageWorks SAN with 37.2 Log IOPS per disk.

Figure 3 shows the average throughput. in average disk transfers (in megabytes per second per disk), that the Windows Performance Monitor logged during the same Jetstress runs we show in Figures 1 and 2. The Dell EqualLogic SAN delivered 77 percent higher throughput, at 1.98 average disk transfers (in megabytes per second per disk). The HP StorageWorks SAN delivered 1.12 MB per second per disk.

For more information on test results, see Appendix A, which lists test results, and Appendix G, which includes the Jetstress results files.

For further testing, we conducted a multiple-day Jetstress run on the Dell EqualLogic SAN to show how time and capacity affects overall performance. We used the same initial parameters as in the above testing, including capacity, IOPS per user, thread count, number of users and mailbox size. After 48 hours, the performance difference was only 3.15 percent.

Test environment
To conduct the tests, we configured a test bed for each storage array. (See Figure 4.)
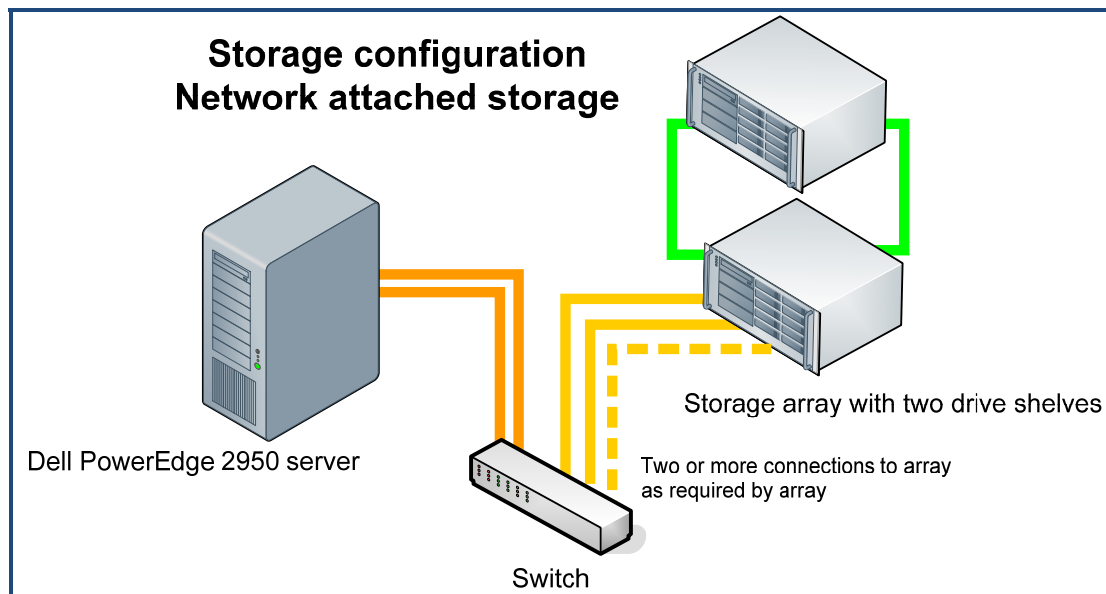
Figure 4: Storage test bed configuration.

Each test bed included the following components:

- One Dell PowerEdge 2950 server; Figure 5 shows its configuration. We attached each storage array to a server via two discrete NICs (for the iSCSI tests) or two discrete FC HBAs (for the Fibre Channel tests). We ran Jetstress from the server.
- One Dell PowerConnect 5448 switch (for the iSCSI tests) or one Brocade 200E Fibre Channel switch (for the Fibre Channel tests)
- Storage system under test:
  - o Dell EqualLogic PS Series SAN with two PS5000XV iSCSI arrays
  - o HP StorageWorks 4400 Enterprise Virtual Array with two full shelves of disks

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

3

Component	Details
Server	Dell PowerEdge 2950 server
Processors	Two quad-core Intel Xeon E5405 processors at 2.0 GHz
Memory	16 GB of FB-DDR2 PC5300 memory
Internal disk	One 80GB, 7,200 RPM Western Digital WD800AAJS-18SATA 3.0Gb drive
NIC (for iSCSI connections)	Two Intel PRO/1000PT NICs
HBA (for FC connections)	Two QLogic QLE2460 FC HBAs
OS	Windows Server 2003 R2 Enterprise x64 Edition SP2
Test software	Jetstress 08.02.0060, and Ese .08.01.0240.005

Figure 5: Dell PowerEdge 2950 server configuration.

Appendix B provides more detailed information on the test environment.

Storage arrays under test

The storage arrays we tested each included two full shelves of disks, with 16 disks per shelf on the Dell EqualLogic SAN and 12 disks per shelf on the HP StorageWorks SAN. We configured the storage arrays with disks of similar speed and size. Disks were 146 GB or the closest available size, and 15K RPM.

Figure 6 identifies the systems we tested, their disk counts, the amount of useable storage, RAID technology, and whether we tested with them iSCSI or Fibre Channel connections.

PT tested both storage arrays using all disks to hold Exchange databases and log files. We followed best practices in choosing RAID technologies for the test systems. The Microsoft Exchange Server 2007 *Planning Your Server and Storage Architecture* instructions on the Microsoft TechNet site (http://technet.microsoft.com/en-us/library/bb738146.aspx) recommend RAID 10 for its speed and performance. We followed these recommendations and configured each array as RAID 10. Formatted storage capacity in Figure 7 shows the amount of usable space that remained.
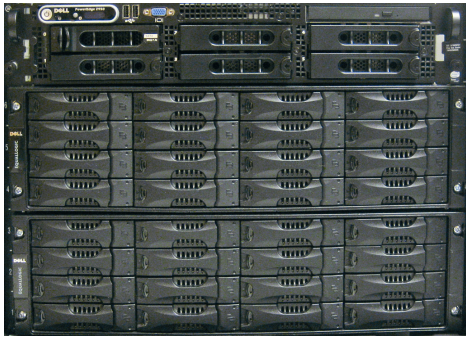
	Dell EqualLogic SAN	HP StorageWorks SAN
Arrays	Dell EqualLogic PS Series SAN with two PS5000XV arrays	HP StorageWorks 4400 Enterprise Virtual Array with two full disk shelves
Disks	32 146GB 15K RPM SAS disks total for the two shelves	24 146GB 15K RPM FC disks total for the two shelves
Formatted storage capacity	2,089 GB. We used all disks and enabled the RAID 10-no spares mode.	1,630 GB
Connection	iSCSI	Fibre Channel
RAID technology	RAID 10	RAID 10

Figure 6: The SANs we tested. Photos include the test server.

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

4

Appendix C provides additional details about the tested storage arrays, and Appendix D shows the data and log file layouts for each.

Test workload

The purpose of the Jetstress primary storage performance tests is to exercise the storage arrays using the maximum sustainable Exchange type of I/O. The tests produce results that show how long it takes the storage under load to respond to an I/O request. The test does not have a single workload; instead, testers create a simulated Exchange mailbox profile that defines the Jetstress workload. We calculated values for three Jetstress test parameters that define the simulated Exchange mailbox profile: targeted database IOPS per user, average mailbox size, and number of mailboxes.

- **Database IOPS per user.** We based our tested user profile for this report on the Microsoft profile for very heavy Exchange 2007 cached mode users. These users average 30 sent and 120 received messages per day. This load averages 0.5 database IOPS for each user. We used this average as our targeted database IOPS per user.
- **Mailbox size.** We assumed an average mailbox size of 250 MB. We selected this relatively small size because we wanted a large number of mailboxes against which to measure I/O performance.
- **Number of mailboxes.** We formatted each disk and set up the RAID technology for each. We then calculated the mailbox count for each system by determining the number of 250 MB mailboxes that would use 60 percent of the remaining disk space on each test system. We selected the 60 percent capacity figure to provide a production-sized database that left room for log files and growth. We rounded the number of mailboxes down to the nearest multiple of 50.

Appendix E provides further details about the Jetstress tests.

Test procedures

We first ran the Jetstress disk subsystem test with automatic tuning to identify a thread count, and then ran the initial performance test using that thread count. If the system passed the initial performance test run, we continued to retest using higher thread counts to push IOPS to the maximum, stopping when Jetstress reported a failing user experience rating. If the system failed the initial performance test run, we retested using lower thread counts until Jetstress reported a passing user experience rating. If the test failed using just a single thread, we reduced the number of mailboxes until Jetstress gave a passing user experience rating. This process identified the highest IOPS score that the system could achieve while receiving a passing user experience rating. We then did two more runs using the settings from the run that produced those results. We ran each test for 2 hours. Jetstress reports results in I/O operations per second. We gathered the following results from the Jetstress report:

- Database disk reads per second
- Database disk writes per second
- Log writes per second (Log IOPS)
- Achieved IOPS (sum of the database disk reads and writes per second)
- IOPS (calculated by summing the Achieved IOPS and the Log IOPS)

To find the amount of data moved in those operations, Jetstress provides Windows Performance Monitor logs of server performance. We gathered the following results from those logs:

- Average disk transfers per second
- Average disk read MB per second
- Average disk write MB per second
- Average disk transfers MB per second

The results we report in Figures 1 through 4 are the results from the run that produced the median IOPS.

Appendix F provides further details of the test procedures.

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

5

Appendix A: Test results

Figure 7 provides test results for the storage arrays, as well as information about the simulated exchange configuration that defines the test workload. We ran the Jetstress primary storage performance test three times for each test system. We summed the disk read, disk write, and log write IOPS, and report that sum as the IOPS value for each run. We report the median of the IOPS values for the three runs in the Median IOPS row. We report the Achieved IOPS and other results from that same run. The body of this report displays the results from that median run.

	Dell EqualLogic SAN (iSCSI)	HP StorageWorks SAN (Fibre Channel)
Test workload		
Number disks tested	32	24
Number of mailboxes	5,100	4,000
Total useable space (GB)	2,089	1,637
Initial database size (GB)	1,245	977
Percentage raw disk storage capacity utilization	45	47
Mailbox size (MB)	250	250
Initial database percentage storage capacity utilization	60	60
Number of storage groups	13	10
Thread count	21	10
Final database size (GB)	1,264	985
IOPS (higher is better). IOPS is sum of disk read, disk write, and log write IOPS.		
IOPS - Run 1	8,595.428	3,623.502
IOPS - Run 2	8,397.621	3,576.421
IOPS - Run 3	8,368.439	3,506.084
Achieved IOPS (higher is better). Achieved IOPS is sum of disk read and disk write IOPS.		
Achieved IOPS - Run 1	6,729.517	2,722.108
Achieved IOPS - Run 2	6,667.510	2,684.535
Achieved IOPS - Run 3	6,632.916	2,634.095
Results from median run (higher is better). Median IOPS and other results are from that same run.		
Median IOPS	8,398	3,576
Median Achieved IOPS	6,668	2,685
Database disk reads per second	2,811	1,282
Database disk writes per second	3,856	1,403
Log writes per second	1,730	892
Average disk transfers per second (from performance logs)	8,249	3,607
Average disk read MB per second	21.824	10.187
Average disk write MB per second	41.549	16.650
Average disk transfers MB per second	63.4	26.8

Figure 7: Results for the storage arrays.

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

6

Appendix B: Test environment

We created a test bed in a climate-controlled room for each storage system. Each test bed included the following components connected with Cat6 cables:

- Microsoft Exchange Server
  - One Dell PowerEdge 2950 server installed with the following software:
    - Microsoft Windows Server 2003 R2 Enterprise Edition x64 SP2
    - Jetstress 08.02.0060
- Switches
  - One Dell PowerConnect 5448 switch (for the iSCSI tests)
  - One Brocade 200E Fibre Channel switch (for the FC tests)
- Storage systems under test:
  - Dell EqualLogic PS Series SAN with two PS5000XV arrays, each with one full shelf of disks
  - HP StorageWorks 4400 Enterprise Virtual Array with two full shelves of disks

Microsoft Exchange Servers

Figure 8 provides detailed configuration information for the server.

Server	Dell PowerEdge 2950
General	
Number of processor packages	2
Number of cores per processor package	4
Number of hardware threads per core	1
System Power Management Policy	Always On
CPU	
Vendor	Intel
Name	Xeon E5405
Stepping	6
Socket type	Socket 771-LGA
Core frequency (GHz)	2.0
Front-side bus frequency (MHz)	1,333
L1 cache	32 KB + 32 KB (per core)
L2 cache	12 MB (2 x 6 MB shared)
Platform	
Vendor	Dell Inc.
Motherboard model number	0M332H
Motherboard chipset	Intel 5000X
Motherboard revision number	12
Motherboard serial number	JD6HWG1
BIOS name and version	Dell 2.3.1 (4/29/2008)
BIOS settings	Default
Chipset INF driver	Intel 7.3.0.1010
Memory module(s)	
Vendor and model number	Samsung M395T5750EZ4-CE66
Type	FB-DDR2 PC5300
Speed (MHz)	667

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance
between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

7

Server	Dell PowerEdge 2950
Speed in the system currently running @ (MHz)	667
Timing/Latency (tCL-tRCD-iRP-tRASmin)	5-5-5-15
Size	16,384 MB
Number of RAM modules	8 x 2,048 MB
Chip organization	Double-sided
Channel	Dual
Hard disk	
Vendor and model number	Western Digital WD800AAJS-18
Number of disks in system	1
Size	80 GB
Buffer size	8 MB
RPM	7,200 RPM
Type	SATA 3.0 Gb
Controller	Intel 6321ESB
Controller driver	Intel 7.3.0.1010 (11/18/2005)
Operating system	
Name	Windows Server 2003 R2 Enterprise x64 Edition
Build number	3790
Service Pack	SP2
Microsoft Windows update date	8/26/2008
File system	NTFS
Language	English
Microsoft DirectX version	9.0c
Graphics	
Vendor and model number	ATI ES1000
Chipset	ATI ES1000
BIOS version	BK-ATI VER008.005.028.000
Type	Integrated
Memory size	16 MB
Resolution	1,024 x 768 x 32-bit
Driver	ATI 8.24.3.0 (4/5/2006)
Network card/subsystem	
Vendor and model number	Intel PRO/1000 PT Server Adapter
Type	Discrete
Driver	9.7.34.0 (2/1/2007)
Optical drive	
Vendor and model number	TEAC CD-224E-N
Type	CD/DVD-ROM
Interface	SATA
Dual/single layer	Dual
USB ports	
Number of ports	4
Type of ports (USB 1.1, USB 2.0)	2.0

Figure 8: Detailed system configuration information for the test server.

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

8

Dell PowerConnect 5448 switch

We tested the iSCSI solution using one Dell PowerConnect 5448 switch, as described in Figure 9.

Component	Details
Router	One Dell PowerConnect 5448 switch
Frame size	Jumbo frames enabled on all connected devices. Size set to 9,014 bytes
Flow control	Flow control set to Generate & Respond on all network interface cards
iSCSI optimization	iSCSI optimization disabled
Receive descriptors	Set to 256 on all network interface cards

Figure 9: Dell PowerConnect 5448 switch configuration.

Brocade 200E Fibre Channel switch

We tested the Fibre Channel solution using one Brocade 200E Fibre Channel switch. We tested with the default configuration settings for this switch.

Individual test beds

The remainder of this appendix shows diagrams of the components in each of the test beds and indicates their connections.

Dell EqualLogic SAN

Each of the two Dell EqualLogic PS5000XV arrays has two controllers, with three 1Gb iSCSI ports per controller that also serve as management ports. Only one controller from each array is active simultaneously; the secondary controller on each array is in a passive failover mode in case of controller failure. We used three iSCSI ports per controller to connect the arrays to the iSCSI switch. Figure 10 shows the wiring diagram for the server, switch, and storage for the Dell EqualLogic SAN. This array does not require connections between the two shelves; it uses the iSCSI network connections to communicate between the shelves.
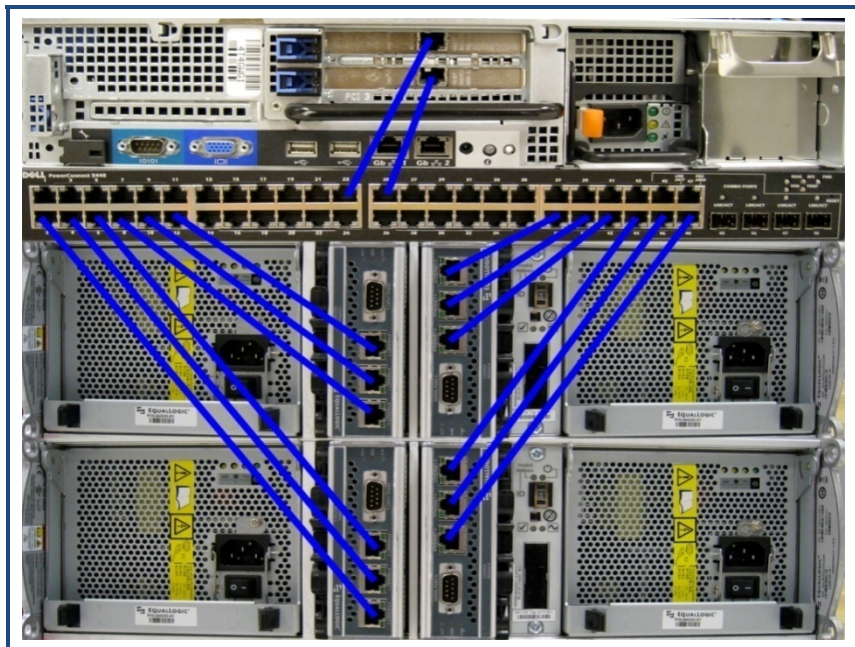

Figure 10: Dell EqualLogic SAN wiring diagram for the server, switch, and storage. Blue lines represent iSCSI or Fibre Channel connections between the server and the switch and the switch and the array.

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

9

HP StorageWorks SAN

The HP StorageWorks 4400 Enterprise Virtual Array has two controllers, with two 4Gb Fibre Channel ports per controller and one 100Mb Ethernet management port. We used two active 4Gb Fibre Channel loops to connect the shelves to the controller. We used two Fibre Channel ports per controller to connect the array to the Fibre Channel switch. We connected the Ethernet management port directly to the internal network card on the host. Figure 11 shows the wiring diagram for the HP StorageWorks SAN. This array has a separate controller; each disk shelf must connect both to that controller and to the other shelf.

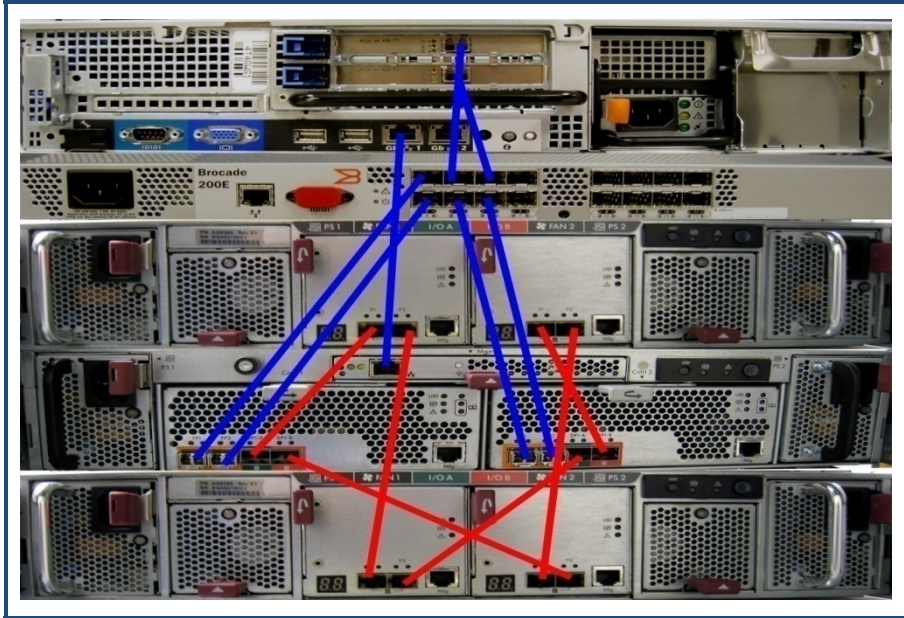**Figure 11: HP StorageWorks SAN wiring diagram. Blue lines represent iSCSI or Fibre Channel connections between the server and the switch and the switch and the array. Red lines represent connections to different parts of the array.**

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

10

Appendix C: Storage configuration and setup

The rest of this section includes the formulas we used for Simulated Exchange configuration calculations, the results of those calculations for the tested arrays, and the steps we took to configure the arrays.

Simulated Exchange configuration calculations

We defined the simulated Exchange configuration using the following guidelines:

- Initial database size, equal to 60 percent of the total formatted capacity.
- To allow for growth in the database files, we allocated 80 percent of useable disk capacity for the database LUNs and the rest to log LUNS.
- We created a new storage group for every 100 GB of the initial database size based on Microsoft Exchange recommendations.
- Average mailbox size of approximately 250 MB with mailbox count rounded down to the nearest 50 mailboxes.
- One mailbox per user.

We calculated the simulated exchange configuration using the formulas in Figure 12. Figure 13 shows the simulated exchange configuration, Figure 14 shows the primary storage hardware, Figure 15 shows the primary storage software, and Figure 16 shows the primary storage disk configuration.

Item	Value
IOPS per mailbox	0.5 (0.42 is typical of a very heavy user profile plus 20 percent headroom)
Database files capacity utilization percentage	60 percent
Database LUN capacity utilization percentage	80 percent
Mailbox size quota	250 MB
Mode	Cached
Number of hosts	1
Number of mailbox stores/storage group	1
Total useable space	The amount of space available for the use of files after formatting
Number of mailboxes	(Database files capacity utilization percentage) x (Total usable space) x (1,024 MB) / (250 MB Mailbox size) (round down to the nearest 50 MB)
Initial database size	Total useable space * database files capacity utilization percentage
Mailbox size	Initial database size / estimated number of mailboxes (round down to nearest 5 MB)
Database LUN size	Total useable space * database LUN capacity utilization percentage
Initial percentage storage capacity utilization	(Database LUN size) / (Initial database size)
Number of storage groups	(Initial database size / 1,024 MB) / 100 GB (round to the nearest integer)

Figure 12: Simulated exchange configurations calculations.

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

11

Simulated Exchange configuration

System	Dell EqualLogic SAN (iSCSI)	HP StorageWorks SAN (Fibre Channel)
Number of Exchange mailboxes simulated	5,100	4,000
Number of hosts	1	1
Mailbox size (MB)	250	250
Number of storage groups	13	10
Number of mailbox stores/storage group	1	1
Number of mailboxes/mailbox store	392	400
Total number of mailbox store LUNS/storage group	1	1
Simulated profile: I/Os per second per mailbox	0.5	0.5
Database LUN size (GB)	130	130
Log LUN size (GB)	30	30
Initial total database size for performance testing (GB)	1,245	977
Percentage formatted capacity used by Exchange database	60 percent	60 percent

Figure 13: Simulated Exchange configuration.

Primary storage hardware

System	Dell EqualLogic SAN (iSCSI)	HP StorageWorks SAN (Fibre Channel)
Storage connectivity (Fibre Channel, SAS, SATA, iSCSI)	iSCSI	Fibre Channel
Storage model and OS/firmware revision	Dell EqualLogic PS5000XV Firmware v3.3.3	HP StorageWorks 4400 Enterprise Virtual Array Firmware XCS v9.00.10
Storage cache	2 GB (1 GB per array)	4 GB (2 GB per controller)
Number of storage controllers	4 (2 per shelf)	2
Number of storage ports	6 (3 per controller)	4 (2 per controller)
Maximum bandwidth of storage connectivity to host	1 Gb x 4	4 Gb x 4
Switch type/model/firmware revision	Dell PowerConnect 5448 v1.0.0.31	Brocade 200E OS v6.0.0b
HBA/NIC model and firmware	Intel PRO/1000PT NIC with Jumbo Frames enabled	QLogic QLE2460
Number of HBAs/NICs per host	2	2
Total number of disks tested in solution	32	24

Figure 14: Primary storage hardware.

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

12

Primary storage software

System	Dell EqualLogic SAN (iSCSI)	HP StorageWorks SAN (Fibre Channel)
HBA/NIC driver	9.7.34.0	9.1.3.18
HBA QueueTarget setting	N/A	Default
HBA QueueDepth setting	N/A	Default
Multi-pathing	EqualLogic HIT (Host Integration Toolkit) 3.1.2	MPIO (HP Multi-Path I/O Device Specific Module (DSM) for EVA 4x00/6x00/8x00 devices) v3.00.00 Configured Shortest Queue Service Time (SQST) with Auto-Load Balance (ALB) set
Host OS	Windows Server 2003 x64 R2 SP2	Windows Server 2003 x64 R2 SP2
ESE.dll file version	08.01.0240.005	08.01.0240.005

Figure 15: Primary storage software.

Primary storage disk configuration (Mailbox Store and transactional log disks)

System	Dell EqualLogic SAN (iSCSI)	HP StorageWorks SAN (Fibre Channel)
Disk type, speed, and firmware revision	32x Maxtor SAS 15k, 8K147S0088011, EQ02	12x HP FC 15k, BF146DA47C, HP04; 12x HP FC 15k, BF146DA47A, HP00
Raw capacity per disk (GB)	146	146
Number of physical disks in test	32	24
Total raw storage capacity (GB)	4,672	3,504
Raid level	RAID 10	RAID 10
Total formatted capacity (GB)	2,089	1,630
Storage capacity utilization	45 percent	39 percent
Database capacity utilization	60 percent	60 percent

Figure 16: Primary storage disk configuration (Mailbox Store and transactional log disks).

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

13

Storage disk configuration procedure

- We used all disks for database and log files except for disks vendors reserve for parity. We formatted each array as a RAID 10 array.
- If an array did not automatically balance the load between its RAID controllers, we created two or more aggregates to balance the load as evenly as possible. If possible, we used cross-referencing to maximize capacity and performance by placing each database volume and its corresponding log volume (e.g., log1 and db1) on separate aggregates.
- We used Diskpart to align all Exchange-related disks on a 64KB boundary.
- We tested each array after it completed background operations for the initial configuration, RAID expansion, RAID-level change, group expansion, and disk failure recovery.

Creating the volumes

Dell EqualLogic SAN

1. Log into the group manager using username "admin" and password "password".
2. Click Create volume.
3. Name the volume db# (# is the storage group number 1-13).
4. Click Next.
5. Enter 130 for the Volume size.
6. Click Next.
7. Check the Limit access to iSCSI initiator name checkbox.
8. Enter "iqn.1991-05.com.microsoft:eqlps5000xv" as the initiator name.
9. Click Next.
10. Click Finish.
11. Repeat steps 1-10 12 times, changing the volume name each time.
12. Click Create volume.
13. Name the volume log# (# is the storage group number 1-13).
14. Click Next.
15. Enter 30 for the Volume size.
16. Click Next.
17. Check the Limit access to iSCSI initiator name checkbox.
18. Enter "iqn.1991-05.com.microsoft:eqlps5000xv" as the initiator name.
19. Click Next.
20. Click Finish.
21. Repeat steps 12-20 12 times, changing the volume name each time.
22. Run Microsoft iSCSI Initiator:
    a. Select the Discovery Tab.
    b. Click Add.
    c. Enter the IP Address for the Group.
    d. Select the Targets tab.
    e. Click the Refresh button.
    f. Select the first Inactive Target listed.
    g. Click Log On.
    h. Check the Automatically restore this connection when the system boots checkbox.
    i. Check the Enable multi-path check box.
    j. Click OK.
    k. Repeat steps f through j 26 times.
23. Open a command prompt.
24. Type cd c:\windows\system32.
25. Type diskpart.exe.
26. Type List Disk to determine the name of the RAID array.
27. Type Select Disk # where Disk # is the name of the RAID array.
28. Type Create partition primary align=64.
29. Repeat steps 27 and 28 with every log and database volume.

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

14

30. Type `Exit`.
31. In Windows, click Start, right-click My Computer, and select Manage.
32. Click Disk Management.
33. Right-click each of the new partitions, and select Format.
34. Name each disk db# or log#, and format the disks as NTFS.
35. Mount the database volumes:
    a. Right-click on the first 130GB drive, and select Change Drive Letter and paths.
    b. Click Add.
    c. Select Mount in the following empty NTFS folder.
    d. Click Browse.
    e. Click on the C:\ drive.
    f. Click New Folder.
    g. Enter "db#" as the name.
    h. Click OK.
    i. Click OK.
    j. Click OK.
    k. Repeat steps a through j 12 times, changing the db# name each time.
36. Mount the log volumes:
    a. Right-click on the first 30GB drive, and select Change Drive Letter and paths.
    b. Click Add.
    c. Select Mount in the following empty NTFS folder.
    d. Click Browse.
    e. Click on the C:\ drive.
    f. Click New Folder.
    g. Enter "log#" as the name.
    h. Click OK.
    i. Click OK.
    j. Click OK.
    k. Repeat steps a through j 12 times, changing the log# name each time.

HP StorageWorks SAN
1. Log into the StorageWorks Command View EVA.
2. Enter the username "hpadmin" and password "password".
3. Expand the Menu next to the name of the array.
4. Click Hosts.
5. Click Add Host.
6. Enter "Server1" as the name.
7. Select Fibre Channel as the Type.
8. Enter the first Fibre Channel adapter's WWN from the server in the Port World Wide Name.
9. Click Add host.
10. Click OK.
11. Click Ports.
12. Click Add port.
13. Enter the second Fibre Channel adapter's WWN.
14. Click Add port.
15. Click OK.
16. Click on Disk Groups.
17. Click Create disk group.
18. Name the Disk Group "Disk Group1".
19. Enter "12" for the number of disks.
20. Set the Requested level of disk drive failure to "none".
21. Click Create disk group.
22. Click OK.
23. Repeat steps 16-22 once, changing the Disk Group to "Disk Group 2".
24. Click on Virtual Disks.

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

15

25. Click Create Vdisk.
    a. Enter "db#" (start at 1) for the name.
    b. Enter "130" for the size.
    c. Select Disk Group 1.
    d. Select Vraid 1 as the redundancy.
    e. Select Server1 as Present to host.
    f. Click Create Vdisk.
    g. Click OK.
    h. Click Create Vdisk.
    i. Enter "log#" (start at 6) for the name.
    j. Enter "30" for the size.
    k. Select Disk Group 1.
    l. Select Vraid 1 as the redundancy.
    m. Click Create Vdisk.
    n. Click OK.
    o. Repeat steps a through n 4 times, changing the log# and db# each time.
26. Click on Virtual Disks.
27. Click Create Vdisk.
    a. Enter "db#" (start at 6) for the name.
    b. Enter "130" for the size.
    c. Select Disk Group 2.
    d. Select Vraid 1 as the redundancy.
    e. Select Server1 as Present to host.
    f. Click Create Vdisk.
    g. Click OK.
    h. Click Create Vdisk.
    i. Enter "log#" (start at 1) for the name.
    j. Enter "30" for the size.
    k. Select Disk Group 2.
    l. Select Vraid 1 as the redundancy.
    m. Click Create Vdisk.
    n. Click OK.
    o. Repeat steps a through n 4 times, changing the log# and db# each time.
28. In Windows, right-click on My Computer, and select Manage.
29. Click Disk Management.
30. Initialize all the drives:
    a. Click Next.
    b. Click Next.
    c. Click Next.
    d. Click Finish.
31. Open a command prompt.
32. Type cd c:\windows\system32.
33. Type diskpart.exe.
34. Type List Disk to determine the name of the RAID array.
35. Type Select Disk # where Disk # is the name of the RAID array.
36. Type Create partition primary align=64.
37. Repeat steps 35 and 36 with every log and database volume.
38. Type Exit.
39. In Windows, click Start, right-click My Computer, and select Manage.
40. Click Disk Management.
41. Right-click each of the new partitions, and select Format.
42. Name each drive db# or log#, and format the drives as NTFS.
43. Mount the database volumes:
    a. Right-click on the first 135GB drive, and select Change Drive Letter and paths.
    b. Click Add.

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance
between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

16

     c.   Select Mount in the following empty NTFS folder.
     d.   Click Browse.
     e.   Click on the C:\ drive.
     f.   Click New Folder.
     g.   Enter "db#" as the name.
     h.   Click OK.
     i.   Click OK.
     j.   Click OK.
     k.   Repeat steps a through j 9 times, changing the db# name each time.

44. Mount the log volumes:
     a.   Right-click on the first 30GB drive, and select Change Drive Letter and paths.
     b.   Click Add.
     c.   Select Mount in the following empty NTFS folder.
     d.   Click Browse.
     e.   Click on the C:\ drive.
     f.   Click New Folder.
     g.   Enter "log#" as the name.
     h.   Click OK.
     i.   Click OK.
     j.   Click OK.
     k.   Repeat steps a through j 9 times, changing the log# name each time.

Appendix D: Storage layout

Each storage system had multiple databases, with the mailboxes evenly distributed among the databases. Each database had a corresponding log. We did not assign separate drives to databases and logs; instead, we split the databases into two to four sets and placed the logs for each set of databases on the drives with a different set of databases, keeping each database and its logs separate. This appendix shows the disk layout for each of the tested storage solutions.

Dell EqualLogic SAN

We configured the Dell EqualLogic SAN into one storage pool because it automatically distributes the load evenly across the drives and controllers. Figure 17 shows the storage array disk layout for the Dell EqualLogic SAN.

Dell EqualLogic SAN (iSCSI)			
Enclosure 1			
Drive 0	Drive 4	Drive 8	Drive 12
Drive 1	Drive 5	Drive 9	Drive 13
Drive 2	Drive 6	Drive 10	Drive 14
Drive 3	Drive 7	Drive 11	Drive 15
Enclosure 2			
Drive 0	Drive 4	Drive 8	Drive 12
Drive 1	Drive 5	Drive 9	Drive 13
Drive 2	Drive 6	Drive 10	Drive 14
Drive 3	Drive 7	Drive 11	Drive 15
Storage pool 1			
DB1		Log1	
DB2		Log2	
DB3		Log3	
DB4		Log4	
DB5		Log5	
DB6		Log6	
Log7		DB7	
Log8		DB8	
Log9		DB9	
Log10		DB10	
Log11		DB11	
Log12		DB12	
Log13		DB13	

Figure 17: Dell EqualLogic SAN disk layout.

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

18

HP StorageWorks SAN

Figure 18 shows the storage array disk layout for the HP StorageWorks SAN.

HP StorageWorks SAN (Fibre Channel)			
Enclosure 1			
Drive 0	Drive 3	Drive 6	Drive 9
Drive 1	Drive 4	Drive 7	Drive 10
Drive 2	Drive 5	Drive 8	Drive 11
Enclosure 2			
Drive 0	Drive 3	Drive 6	Drive 9
Drive 1	Drive 4	Drive 7	Drive 10
Drive 2	Drive 5	Drive 8	Drive 11
vDisk 1 (Controller A)		vDisk 2 (Controller B)	
DB1		Log1	
DB2		Log2	
DB3		Log3	
DB4		Log4	
DB5		Log5	
Log6		DB6	
Log7		DB7	
Log8		DB8	
Log9		DB9	
Log10		DB10	

Figure 18: HP StorageWorks SAN disk layout.

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

19

Appendix E: Jetstress 2007 performance tests

Jetstress 2007 performance tests

Jetstress 2007 is a tool that Microsoft developed to help administrators verify the performance and stability of the disk subsystem, the subsystem Exchange stresses most, before putting their Exchange server into a production environment. Jetstress simulates the Exchange database and log file loads produced by a specific number of users, thus allowing administrators to verify the performance and stability of their disk subsystem before putting their server into a production environment. Jetstress tests both responsiveness and throughput, giving a pass/fail rating for responsiveness and reporting throughput in I/O operations per second. Jetstress uses read and write latency as its primary measure of responsiveness. Results also report these latency values.

The Jetstress reliability test measures the reliability of the storage array, primary storage performance, and streaming backup/recovery performance. We ran the primary storage performance tests only. The primary storage performance testing identifies the maximum sustainable Exchange I/O that the storage system can handle while providing acceptable responsiveness over a 2-hour period.

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

20

Appendix F: Test procedures

We set up our test environment and installed Microsoft Windows 2003 Server x64 Enterprise Edition Service Pack 2 on the test server. To get starting values for the first Jetstress performance test run, we ran the Jetstress disk subsystem throughput test and used its estimated thread count as the thread count for the first Jetstress performance test.

We ran the Jetstress performance test multiple times, and with different thread counts, on each storage solution. Our goal was to find the peak IOPS result for each solution. We define the peak result as the result of the run that had the highest IOPS but that also provided a passing Jetstress score for user experience.

We followed a different process based on whether the first run passed or failed. If the first run passed, we repeated the test with higher mailbox counts until the test failed because of unsatisfactory responsiveness. If the first run failed, we decreased the mailbox count and proportionately increased the average mailbox size. We did so to find the highest mailbox count and correspondingly the highest transactional I/O load that would get a passing Jetstress score.

Installing Microsoft Windows 2003 Server x64 Enterprise Edition Service Pack 2 on the server

We began our testing by installing a fresh copy of Microsoft Windows 2003 Server x64 Enterprise Edition Service Pack 2 on the server. We followed this process for each installation:

1. Assign a computer name of "Server".
2. For the licensing mode, use the default setting of five concurrent connections.
3. Enter a password for the administration logon.
4. Select Eastern Time Zone.
5. Use typical settings for the Network installation.
6. Use "Testbed" for the workgroup.

Note: We used default BIOS settings on the server.

Installing Jetstress

We followed this process to install Jetstress on the test server:

1. Download the Microsoft .Net Framework Version 2.0 Redistributable Package (x64) from http://www.microsoft.com/DOWNLOADS/details.aspx?familyid=B44A0000-ACF8-4FA1-AFFB-40E78D788B00&displaylang=en.
2. Run NetFx64.exe.
3. Click Next.
4. Accept the terms of the License Agreement, and click Next.
5. Click Finish.
6. Download the Microsoft Exchange Server Jetstress Tool (64-bit) v. 08.02.0060 from http://www.microsoft.com/downloads/details.aspx?FamilyID=73dfe056-0900-4dbb-b14a-0932338cecac&DisplayLang=en.
7. Run Jetstress.msi.
8. Click Next.
9. Accept the terms of the License Agreement, and click Next.
10. Click Next.
11. Click Next.
12. Click Close.
13. Copy the following files from an Exchange 2007 SP1 64-bit installation disk:
    - ese.dll
    - eseperf.dll
    - eseperf.hxx
    - eseperf.ini
14. Paste the files in C:\Program Files\Exchange Jetstress.
15. Run JetstressWin.exe.

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

21

16. Click Start new test.
17. Click Exit.

Preparing for the test

To prepare for the test, we first ran a Jetstress disk subsystem throughput test to find a starting point for tuning the mailbox profile.

1. Run JetstressWin.exe.
2. Click Start new Test.
3. Click Next.
4. Select Create a new test configuration file.
5. Name the file "ArrayName_Initial_Run.xml".
6. Click Next.
7. Select Test disk subsystem throughput.
8. Click Next.
9. Change the value to 60 in the Size the database storage capacity percentage box.
10. Leave the default value of 100 in the Target IOPS using throughput capacity percentage box.
11. Click Next.
12. Select Performance.
13. Click Next.
14. Set the test duration to 2 hours.
15. Click Next.
16. Set the number of storage groups using the following calculations:
    - **Database files capacity utilization percentage.** 60 percent. We allocated 60 percent of useable disk capacity for initial database files, or as close as we could get to 60 percent with increments of 50 mailboxes.
    - **Total useable space.** The amount of space available for the use of files, after accounting for parity drives and formatting.
    - **Initial database size.** Total useable space * Database files capacity utilization percentage.
    - **Number of storage groups:** (Initial database size / 1,024 MB) / 100 GB (round to the nearest integer).
17. Leave the number of databases set to 1.
18. Click Next.
19. Select Create new databases.
20. Click Execute Test.
21. Once the test has finished, record the thread count from the disk subsystem throughput. We use this value as the thread count for the first Jetstress test run in step 14 below.

Running the test

Before testing, we ensured that all Ethernet ports were active and connected at 1 Gb to the iSCSI switches and 4 Gb for the Fibre Channel switches for maximum performance and availability. We then followed this process for each test:

1. Run JetstressWin.exe.
2. Click Start new Test.
3. Click Next.
4. Select Create a new test configuration file.
5. Name the file "ArrayName_Run#.xml".
6. Click Next.
7. Select Test an Exchange mailbox profile.
8. Enter a description in the text box.
9. Click Next.
10. Set the number of mailboxes using the following formula (rounding the result down to the nearest 50):

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

22

60 percent database files capacity utilization x formatted capacity x 1,024 MB
250MB mailbox size

11. Enter .5 for IOPS/mailbox.
12. Set the Mailbox size to 250 MB.
13. Check the Suppress tuning checkbox.
14. For the first run, enter the number of threads that the automatic tuning from the Disk subsystem throughput test chose. For subsequent runs, use the thread count calculated in step 24.
15. Click Next.
16. Select the Performance test type.
17. Click Next.
18. Set the test duration to 2 hours.
19. Set the number of storage groups to the amount used in the preparatory Jetstress disk subsystem throughput test.
20. Click Next.
21. Select Create new databases.
22. Click Next.
23. Click Execute Test.
24. Wait for the test to finish; then check the output files to see if the run reported errors or failed by exceeding the Jetstress latency thresholds for the log or database files.
    a. If the run had errors or the latency exceeded the thresholds, proceed based on whether the run prior to this run passed or also failed:
        i. If the previous run was successful, its results show the maximum IOPS score. Save those results as Run 1 results.
        ii. If the previous run also had errors or exceeded the latency thresholds, decrease the number of threads by 1, and perform another run.
    b. If the run succeeds, perform the following steps:
        i. Save from the following files:
            * "Application" event log from each server as *servername_application.evt*, and include in result package
            * "System" event log from each server as *servername_system.evt*, and include in result package
            * The Jetstresswin configuration file used (e.g. ServerName_Run#.xml)
            * Performance_(TimeStamp).html
            * Performance_(TimeStamp).blg
            * DBChecksum_(TimeStamp).html
            * DBChecksum_(TimeStamp).blg
        ii. Record the items that we show in Appendix A, Figure 7: Results for the storage arrays.
        iii. Check the results for the run prior to this run, and proceed based on whether that run passed or failed.
            1. If the previous run was successful, increase the number of threads by 1, and perform another run.
            2. If the previous run had errors or exceeded the latency thresholds, the current runs results show the maximum IOPS score. Save those results as the Run 1 results.
25. Repeat the test two more times using the thread count used in the run that produced the results saved as Run 1 results in step 24.

Appendix G: Jetstress results files

Dell EqualLogic SAN (iSCSI)

Performance Test Result Report

Overall Test Result	**Pass**
Machine Name	SVCTAG-1F6HWG1
Test Description	5,100 Users 250MB Mailbox Size
Test Start Time	9/18/2008 10:13:13 AM
Test End Time	9/18/2008 2:54:59 PM
Jetstress Version	08.02.0060.000
Ese Version	08.01.0240.005
Operating System	Microsoft Windows Server 2003 R2 Service Pack 2 (5.2.3790.131072)
Performance Log	C:\Program Files\Exchange Jetstress\Performance_2008_9_18_12_48_31.blg C:\Program Files\Exchange Jetstress\DBChecksum_2008_9_18_14_55_0.blg

Database Sizing and Throughput

Achieved I/O per Second	6,667.51
Target I/O per Second	2,550
Initial database size	1,337,014,042,624
Final database size	1,358,151,237,632
Database files (count)	13

Jetstress System Parameters

Thread count	21 (per-storage group)
Log buffers	9,000
Minimum database cache	416.0 MB
Maximum database cache	3,328.0 MB
Insert operations	40 percent
Delete operations	30 percent
Replace operations	5 percent
Read operations	25 percent
Lazy commits	55 percent

Disk Subsystem Performance

LogicalDisk	Avg. Disk sec/Read	Avg. Disk sec/Write	Disk Reads/sec	Disk Writes/sec	Avg. Disk Bytes/Write
Database (c:\db1)	0.019	0.006	217.757	300.666	(n/a)

Database (c:\db2)	0.016	0.006	215.306	295.414	(n/a)
Database (c:\db3)	0.016	0.006	216.652	295.356	(n/a)
Database (c:\db4)	0.016	0.006	215.413	296.740	(n/a)
Database (c:\db5)	0.016	0.006	217.074	297.509	(n/a)
Database (c:\db6)	0.017	0.006	216.056	297.306	(n/a)
Database (c:\db7)	0.016	0.006	216.307	293.762	(n/a)
Database (c:\db8)	0.016	0.006	215.437	295.467	(n/a)
Database (c:\db9)	0.016	0.006	216.569	297.540	(n/a)
Database (c:\db10)	0.016	0.006	217.043	297.295	(n/a)
Database (c:\db11)	0.016	0.006	213.793	292.523	(n/a)
Database (c:\db12)	0.016	0.006	216.590	298.174	(n/a)
Database (c:\db13)	0.016	0.006	217.092	298.668	(n/a)
Log (c:\log1)	0.000	0.003	0.000	132.335	5,036.292
Log (c:\log2)	0.000	0.003	0.000	132.090	5,049.042
Log (c:\log3)	0.000	0.003	0.000	136.295	4,899.804
Log (c:\log4)	0.000	0.003	0.000	132.089	5,042.511
Log (c:\log5)	0.000	0.003	0.000	135.643	4,928.547
Log (c:\log6)	0.000	0.003	0.000	131.108	5,079.545
Log (c:\log7)	0.000	0.003	0.000	134.792	4,929.176
Log (c:\log8)	0.000	0.003	0.000	130.435	5,089.416
Log (c:\log9)	0.000	0.003	0.000	135.336	4,969.695
Log (c:\log10)	0.000	0.003	0.000	130.679	5,104.170
Log (c:\log11)	0.000	0.003	0.000	133.986	4,970.399
Log (c:\log12)	0.000	0.003	0.000	130.991	5,093.271
Log (c:\log13)	0.000	0.003	0.000	134.332	4,976.250

Host System Performance

Counter	Average	Minimum	Maximum
Percent Processor Time	13.229	7.583	20.065
Available Mbytes	11,721.519	11,218.000	11,749.000
Free System Page Table Entries	16,756,000.333	16,755,809.000	16,756,899.000
Transition Pages RePurposed/sec	0.000	0.000	0.000

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

25

Pool Nonpaged Bytes	107,804,407.467	105,295,872.000	108,523,520.000
Pool Paged Bytes	47,976,089.600	47,923,200.000	48,488,448.000
Database Page Fault Stalls/sec	0.000	0.000	0.000

Test Log
9/18/2008 10:13:13 AM -- Jetstress testing begins.
9/18/2008 10:13:13 AM -- Prepare testing begins.
9/18/2008 10:13:13 AM -- Creating c:\db1\Jetstress1.edb.
9/18/2008 10:13:13 AM -- Database cache settings: (minimum: 32.0 MB, maximum: 256.0 MB).
9/18/2008 10:13:13 AM -- Database flush thresholds: (start: 2.6 MB, stop: 5.1 MB).
9/18/2008 10:28:15 AM -- 60.0 percent of 95.8 GB complete (11,693,271 records inserted).
9/18/2008 10:45:30 AM -- 100.0 percent of 95.8 GB complete (18,199,766 records inserted).
9/18/2008 10:45:33 AM -- Duplicating 12 databases:.
9/18/2008 12:48:04 PM -- 100.0 percent of 1.1 TB complete (1.1 TB duplicated).
9/18/2008 12:48:17 PM -- Attaching databases.
9/18/2008 12:48:17 PM -- Prepare testing ends.
9/18/2008 12:48:17 PM -- Dispatching transactions begins.
9/18/2008 12:48:17 PM -- Database cache settings: (minimum: 416.0 MB, maximum: 3.2 GB).
9/18/2008 12:48:17 PM -- Database flush thresholds: (start: 33.3 MB, stop: 66.6 MB).
9/18/2008 12:48:31 PM -- Database read latency thresholds: (average: 0.02 seconds/read, maximum: 0.05 seconds/read).
9/18/2008 12:48:31 PM -- Log write latency thresholds: (average: 0.01 seconds/write, maximum: 0.05 seconds/write).
9/18/2008 12:48:32 PM -- Operation mix: Sessions 21, Inserts 40 percent, Deletes 30 percent, Replaces 5 percent, Reads 25 percent, and Lazy Commits 55 percent.
9/18/2008 12:48:32 PM -- Performance logging begins (interval: 15,000 ms).
9/18/2008 12:48:32 PM -- Attaining prerequisites:.
9/18/2008 12:54:55 PM -- \MSExchange Database(JetstressWin)\Database Cache Size, Last: 3,150,914,000.0 (lower bound: 3,140,695,000.0, upper bound: none).
9/18/2008 2:54:57 PM -- Performance logging ends.
9/18/2008 2:54:57 PM -- JetInterop batch transaction stats: 61,104, 60,876, 61,111, 60,848, 60,934, 60,854, 60,715, 60,721, 60,980, 61,200, 60,447, 61,229, and 60,912.
9/18/2008 2:54:57 PM -- Dispatching transactions ends.
9/18/2008 2:54:57 PM -- Shutting down databases.
9/18/2008 2:54:59 PM -- Instance524.1 (complete), Instance524.2 (complete), Instance524.3 (complete), Instance524.4 (complete), Instance524.5 (complete), Instance524.6 (complete), Instance524.7 (complete), Instance524.8 (complete), Instance524.9 (complete), Instance524.10 (complete), Instance524.11 (complete), Instance524.12 (complete), and Instance524.13 (complete).
9/18/2008 2:55:00 PM -- Performance logging begins (interval: 30,000 ms).
9/18/2008 2:55:00 PM -- Verifying database checksums.
9/18/2008 4:35:19 PM -- c:\db1 (100 percent processed), c:\db2 (100 percent processed), c:\db3 (100 percent processed), c:\db4 (100 percent processed), c:\db5 (100 percent processed), c:\db6 (100 percent processed), c:\db7 (100 percent processed), c:\db8 (100 percent processed), c:\db9 (100 percent processed), c:\db10 (100 percent processed), c:\db11 (100 percent processed), c:\db12 (100 percent processed), and c:\db13 (100 percent processed).
9/18/2008 4:35:20 PM -- Performance logging ends.
9/18/2008 4:35:20 PM -- C:\Program Files\Exchange Jetstress\DBChecksum_2008_9_18_14_55_0.blg has 200 samples.
9/18/2008 4:35:35 PM -- C:\Program Files\Exchange Jetstress\DBChecksum_2008_9_18_14_55_0.html is saved.
9/18/2008 4:35:35 PM -- Verifying log checksums.
9/18/2008 4:35:40 PM -- c:\log1 (2 logs passed), c:\log2 (2 logs passed), c:\log3 (2 logs passed), c:\log4 (2 logs passed), c:\log5 (2 logs passed), c:\log6 (2 logs passed), c:\log7 (3 logs passed), c:\log8 (3 logs passed), c:\log9 (2 logs passed), c:\log10 (3 logs passed), c:\log11 (2 logs passed), c:\log12 (2 logs passed), and c:\log13 (3 logs passed).
9/18/2008 4:35:40 PM -- C:\Program Files\Exchange

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

26

Jetstress\Performance_2008_9_18_12_48_31.blg has 505 samples.
9/18/2008 4:35:40 PM -- Creating test report.
9/18/2008 4:35:53 PM -- Volume c:\db1 has 0.0186 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\db2 has 0.0161 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\db3 has 0.0162 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\db4 has 0.0161 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\db5 has 0.0162 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\db6 has 0.0167 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\db7 has 0.0162 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\db8 has 0.0161 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\db9 has 0.0162 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\db10 has 0.0162 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\db11 has 0.0161 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\db12 has 0.0161 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\db13 has 0.0162 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\log1 has 0.0029 for Avg. Disk sec/Write.
9/18/2008 4:35:53 PM -- Volume c:\log1 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\log2 has 0.0029 for Avg. Disk sec/Write.
9/18/2008 4:35:53 PM -- Volume c:\log2 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\log3 has 0.0026 for Avg. Disk sec/Write.
9/18/2008 4:35:53 PM -- Volume c:\log3 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\log4 has 0.0029 for Avg. Disk sec/Write.
9/18/2008 4:35:53 PM -- Volume c:\log4 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\log5 has 0.0026 for Avg. Disk sec/Write.
9/18/2008 4:35:53 PM -- Volume c:\log5 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\log6 has 0.0029 for Avg. Disk sec/Write.
9/18/2008 4:35:53 PM -- Volume c:\log6 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\log7 has 0.0026 for Avg. Disk sec/Write.
9/18/2008 4:35:53 PM -- Volume c:\log7 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\log8 has 0.0029 for Avg. Disk sec/Write.
9/18/2008 4:35:53 PM -- Volume c:\log8 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\log9 has 0.0026 for Avg. Disk sec/Write.
9/18/2008 4:35:53 PM -- Volume c:\log9 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\log10 has 0.0029 for Avg. Disk sec/Write.
9/18/2008 4:35:53 PM -- Volume c:\log10 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\log11 has 0.0026 for Avg. Disk sec/Write.
9/18/2008 4:35:53 PM -- Volume c:\log11 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\log12 has 0.0029 for Avg. Disk sec/Write.
9/18/2008 4:35:53 PM -- Volume c:\log12 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Volume c:\log13 has 0.0026 for Avg. Disk sec/Write.
9/18/2008 4:35:53 PM -- Volume c:\log13 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 4:35:53 PM -- Test has 0 Maximum Database Page Fault Stalls/sec.
9/18/2008 4:35:53 PM -- Test has 0 Database Page Fault Stalls/sec samples higher than 0.
9/18/2008 4:35:53 PM -- C:\Program Files\Exchange
Jetstress\Performance_2008_9_18_12_48_31.xml has 479 samples queried.

HP StorageWorks SAN (Fibre Channel)

Performance Test Result Report

Overall Test Result	**Pass**
Machine Name	SVCTAG-1F6HWG2
Test Description	HP EVA 4400 4,000 Users 250 MB
Test Start Time	9/18/2008 10:14:55 AM
Test End Time	9/18/2008 1:37:52 PM
Jetstress Version	08.02.0060.000
Ese Version	08.01.0240.005
Operating System	Microsoft Windows Server 2003 R2 Service Pack 2 (5.2.3790.131072)
Performance Log	C:\Program Files\Exchange Jetstress\Performance_2008_9_18_11_31_40.blg C:\Program Files\Exchange Jetstress\DBChecksum_2008_9_18_13_37_52.blg

Database Sizing and Throughput

Achieved I/O per Second	2,684.535
Target I/O per Second	2,000
Initial database size	1,048,584,028,160
Final database size	1,058,123,972,608
Database files (count)	10

Jetstress System Parameters

Thread count	10 (per-storage group)
Log buffers	9,000
Minimum database cache	320.0 MB
Maximum database cache	2,560.0 MB
Insert operations	40 percent
Delete operations	30 percent
Replace operations	5 percent
Read operations	25 percent
Lazy commits	55 percent

Disk Subsystem Performance

LogicalDisk	Avg. Disk sec/Read	Avg. Disk sec/Write	Disk Reads/sec	Disk Writes/sec	Avg. Disk Bytes/Write
Database (C:\db1)	0.017	0.005	128.189	142.120	(n/a)

Database (c:\db2)	0.015	0.004	128.641	141.770	(n/a)
Database (c:\db3)	0.014	0.004	128.707	140.087	(n/a)
Database (c:\db4)	0.015	0.004	127.232	138.602	(n/a)
Database (c:\db5)	0.016	0.005	128.213	140.372	(n/a)
Database (c:\db6)	0.015	0.004	127.400	137.668	(n/a)
Database (c:\db7)	0.016	0.004	126.302	137.177	(n/a)
Database (c:\db8)	0.014	0.004	128.795	140.419	(n/a)
Database (c:\db9)	0.014	0.004	129.286	142.564	(n/a)
Database (c:\db10)	0.019	0.005	129.171	141.821	(n/a)
Log (c:\log1)	0.000	0.002	0.000	91.154	4,353.737
Log (c:\log2)	0.000	0.002	0.000	89.983	4,357.590
Log (c:\log3)	0.000	0.002	0.000	90.220	4,319.350
Log (c:\log4)	0.000	0.002	0.000	90.084	4,309.447
Log (c:\log5)	0.000	0.002	0.000	91.258	4,292.118
Log (c:\log6)	0.000	0.002	0.000	88.440	4,380.743
Log (c:\log7)	0.000	0.002	0.000	88.007	4,377.802
Log (c:\log8)	0.000	0.002	0.000	87.239	4,500.665
Log (c:\log9)	0.000	0.002	0.000	86.054	4,523.170
Log (c:\log10)	0.000	0.002	0.000	89.447	4,435.594

Host System Performance

Counter	Average	Minimum	Maximum
Percent Processor Time	2.490	1.589	3.945
Available Mbytes	12,385.646	12,208.000	12,427.000
Free System Page Table Entries	16,752,133.521	16,751,968.000	16,752,598.000
Transition Pages RePurposed/sec	0.000	0.000	0.000
Pool Nonpaged Bytes	62,717,098.667	61,509,632.000	63,057,920.000
Pool Paged Bytes	51,805,397.333	51,699,712.000	52,260,864.000
Database Page Fault Stalls/sec	0.000	0.000	0.000

Test Log

9/18/2008 10:14:55 AM -- Jetstress testing begins.
9/18/2008 10:14:55 AM -- Prepare testing begins.
9/18/2008 10:14:55 AM -- Creating C:\db1\Jetstress1.edb.
9/18/2008 10:14:55 AM -- Database cache settings: (minimum: 32.0 MB, maximum: 256.0 MB).
9/18/2008 10:14:55 AM -- Database flush thresholds: (start: 2.6 MB, stop: 5.1 MB).
9/18/2008 10:24:30 AM -- 60.0 percent of 97.7 GB complete (11,924,915 records inserted).

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

29

9/18/2008 10:39:52 AM -- 100.0 percent of 97.7 GB complete (18,557,677 records inserted).
9/18/2008 10:39:54 AM -- Duplicating 9 databases:.
9/18/2008 11:31:18 AM -- 100.0 percent of 878.9 GB complete (878.9 GB duplicated).
9/18/2008 11:31:29 AM -- Attaching databases.
9/18/2008 11:31:29 AM -- Prepare testing ends.
9/18/2008 11:31:29 AM -- Dispatching transactions begins.
9/18/2008 11:31:29 AM -- Database cache settings: (minimum: 320.0 MB, maximum: 2.5 GB).
9/18/2008 11:31:29 AM -- Database flush thresholds: (start: 25.6 MB, stop: 51.2 MB).
9/18/2008 11:31:40 AM -- Database read latency thresholds: (average: 0.02 seconds/read,
maximum: 0.05 seconds/read).
9/18/2008 11:31:40 AM -- Log write latency thresholds: (average: 0.01 seconds/write, maximum:
0.05 seconds/write).
9/18/2008 11:31:41 AM -- Operation mix: Sessions 10, Inserts 40 percent, Deletes 30 percent,
Replaces 5 percent, Reads 25 percent, and Lazy Commits 55 percent.
9/18/2008 11:31:41 AM -- Performance logging begins (interval: 15,000 ms).
9/18/2008 11:31:41 AM -- Attaining prerequisites:.
9/18/2008 11:37:49 AM -- \MSExchange Database(JetstressWin)\Database Cache Size, Last:
2,421,907,000.0 (lower bound: 2,415,919,000.0, upper bound: none).
9/18/2008 1:37:51 PM -- Performance logging ends.
9/18/2008 1:37:51 PM -- JetInterop batch transaction stats: 36,451, 36,585, 36,352, 36,073, 36,278,
36,096, 35,966, 36,507, 36,470, and 36,565.
9/18/2008 1:37:51 PM -- Dispatching transactions ends.
9/18/2008 1:37:51 PM -- Shutting down databases.
9/18/2008 1:37:52 PM -- Instance1488.1 (complete), Instance1488.2 (complete), Instance1488.3
(complete), Instance1488.4 (complete), Instance1488.5 (complete), Instance1488.6 (complete),
Instance1488.7 (complete), Instance1488.8 (complete), Instance1488.9 (complete), and
Instance1488.10 (complete).
9/18/2008 1:37:53 PM -- Performance logging begins (interval: 30,000 ms).
9/18/2008 1:37:53 PM -- Verifying database checksums.
9/18/2008 2:04:22 PM -- C:\db1 (100 percent processed), c:\db2 (100 percent processed), c:\db3
(100 percent processed), c:\db4 (100 percent processed), c:\db5 (100 percent processed), c:\db6
(100 percent processed), c:\db7 (100 percent processed), c:\db8 (100 percent processed), c:\db9
(100 percent processed), and c:\db10 (100 percent processed).
9/18/2008 2:04:23 PM -- Performance logging ends.
9/18/2008 2:04:23 PM -- C:\Program Files\Exchange
Jetstress\DBChecksum_2008_9_18_13_37_52.blg has 52 samples.
9/18/2008 2:04:28 PM -- C:\Program Files\Exchange
Jetstress\DBChecksum_2008_9_18_13_37_52.html is saved.
9/18/2008 2:04:28 PM -- Verifying log checksums.
9/18/2008 2:04:36 PM -- c:\log1 (3 logs passed), c:\log2 (2 logs passed), c:\log3 (2 logs passed),
c:\log4 (3 logs passed), c:\log5 (2 logs passed), c:\log6 (3 logs passed), c:\log7 (2 logs passed),
c:\log8 (2 logs passed), c:\log9 (2 logs passed), and c:\log10 (2 logs passed).
9/18/2008 2:04:36 PM -- C:\Program Files\Exchange
Jetstress\Performance_2008_9_18_11_31_40.blg has 504 samples.
9/18/2008 2:04:36 PM -- Creating test report.
9/18/2008 2:04:47 PM -- Volume c:\db1 has 0.0167 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\db2 has 0.0147 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\db3 has 0.0142 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\db4 has 0.0145 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\db5 has 0.0164 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\db6 has 0.0154 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\db7 has 0.0159 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\db8 has 0.0141 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\db9 has 0.0140 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\db10 has 0.0194 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\log1 has 0.0018 for Avg. Disk sec/Write.
9/18/2008 2:04:47 PM -- Volume c:\log1 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\log2 has 0.0018 for Avg. Disk sec/Write.

9/18/2008 2:04:47 PM -- Volume c:\log2 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\log3 has 0.0017 for Avg. Disk sec/Write.
9/18/2008 2:04:47 PM -- Volume c:\log3 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\log4 has 0.0017 for Avg. Disk sec/Write.
9/18/2008 2:04:47 PM -- Volume c:\log4 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\log5 has 0.0016 for Avg. Disk sec/Write.
9/18/2008 2:04:47 PM -- Volume c:\log5 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\log6 has 0.0018 for Avg. Disk sec/Write.
9/18/2008 2:04:47 PM -- Volume c:\log6 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\log7 has 0.0019 for Avg. Disk sec/Write.
9/18/2008 2:04:47 PM -- Volume c:\log7 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\log8 has 0.0023 for Avg. Disk sec/Write.
9/18/2008 2:04:47 PM -- Volume c:\log8 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\log9 has 0.0025 for Avg. Disk sec/Write.
9/18/2008 2:04:47 PM -- Volume c:\log9 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Volume c:\log10 has 0.0020 for Avg. Disk sec/Write.
9/18/2008 2:04:47 PM -- Volume c:\log10 has 0.0000 for Avg. Disk sec/Read.
9/18/2008 2:04:47 PM -- Test has 0 Maximum Database Page Fault Stalls/sec.
9/18/2008 2:04:47 PM -- Test has 0 Database Page Fault Stalls/sec samples higher than 0.
9/18/2008 2:04:47 PM -- C:\Program Files\Exchange Jetstress\Performance_2008_9_18_11_31_40.xml has 479 samples queried.

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

31

About Principled Technologies

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

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

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

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

Principled Technologies, Inc.: Exchange 2007 SAN performance test: Comparing performance between Dell EqualLogic PS Series and HP StorageWorks 4400 Enterprise Virtual Array

32