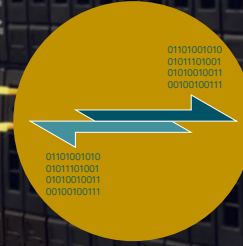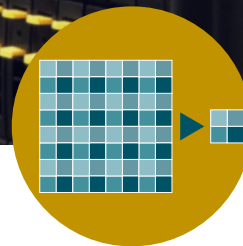**30 times more IOPS**
Serve more users

96% lower latency
Provide a better customer experience

Data deduplication ratio of 11 to 1
Make the most of storage capacity

compared to a legacy storage solution

Improve database performance and response time with the HPE 3PAR StoreServ 8440 all-flash array

and store more data in less space thanks to deduplication

The company where Arthur works has a fantastic cafeteria. Lately, though, he's been brown-bagging it and eating in his office to avoid running into database administrators. "You have to do something about the database servers!" they usually say, but he knows the problem is actually storage.

While hard drive-based arrays once met the company's needs, the data demands of employees and customers have exploded. Upgrading to speedier all-flash storage seems necessary, but Arthur is concerned about capacity. What his company needs is an SSD-based solution that can accommodate its current and future volumes of data. Could the HPE 3PAR StoreServ 8440 Storage array, which is powered by Intel® Xeon® processors, be what Arthur is looking for?

In the Principled Technologies datacenter, we tested this all-flash storage solution, along with the older, hard drive-based HPE 3PAR StoreServ 7400 Storage array. We found that upgrading to the 8440 could dramatically improve both performance and response time and boost storage efficiency with inline deduplication. With results like that, Arthur could start eating in the cafeteria again!

This report uses a fictional scenario in which a datacenter administrator considers upgrading to the all-flash HPE 3PAR StoreServ 8440 Storage array. While the story is hypothetical, it's based on PT facts. For more detailed testing information, see the appendices beginning on page 6.

When storage is the bottleneck

As Arthur knows, for IO-intensive database applications, your storage solution can be just as important as your other datacenter resources—if not more so. When the storage can't keep up, applications can't use server hardware efficiently. Response times increase and users become frustrated. And if your users are online customers, they probably look for other places to shop.

Arthur has gotten the most complaints from the department that runs the company's numerous websites and the data analysis team, who crunch numbers to get insights that drive the company's business decisions. Both groups need the speed that solid-state flash storage delivers.

Replacing the older hard drive-based storage arrays in their datacenter with the all-flash HPE 3PAR StoreServ 8440 Storage arrays would certainly improve performance. But by how much? And what about storage capacity? Higher-performance, Tier 1 storage can sometimes come at the expense of storage space. Would Arthur be trading one set of complaints for another with the 8440? Not necessarily. It has inline deduplication capabilities, which the older array lacks, so smaller capacity might actually be smarter capacity.

About HPE 3PAR StoreServ 8000 Storage, powered by Intel Xeon processors

The 3PAR StoreServ 8440 Storage array is part of a series of enterprise-class flash arrays from HPE. We tested some of the features of these arrays, such as Adaptive Data Reduction, an approach to deduplication, which we discuss on page 4. Other features of 3PAR StoreServ 8440 Storage that we didn't test include HPE InfoSight (see box below) and six nines of guaranteed data availability. Learn more about HPE 3PAR StoreServ 8000 Storage at https://www.hpe.com/us/en/product-catalog/storage/disk-storage/pip.hpe-3par-storeserv-8000-storage.8737813.html

About HPE InfoSight

Managing datacenter storage involves monitoring and reporting, maintenance and support, risk assessment and alerting, as well as forecasting and planning for all the organization's arrays. Often, these tasks are disconnected, manual, and cumbersome. HPE 3PAR StoreServ 8000 Storage includes a tool designed to redefine the storage management experience and predict and prevent problems before they impact business: HPE InfoSight.

According to HPE, InfoSight gives storage managers a cloud portal with dashboard views of the following information across all their 3PAR arrays:

- Performance trending and capacity predictions to optimize the current environment and plan for the future
- Health checks and best practice information to ensure the optimal health of every 3PAR system
- Recommendations based on historical usage data to continually improve performance and availability

For more information, visit the HPE InfoSight web page at https://www.hpe.com/us/en/storage/infosight.html#hf-header
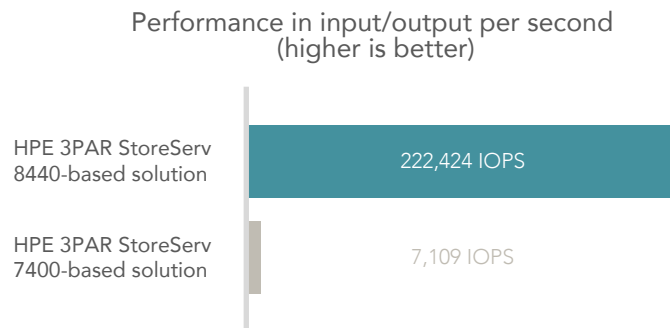
Note: We did not test HPE InfoSight.

Putting the HPE 3PAR StoreServ 8440 to the test

To answer Arthur's questions, we set up two server configurations that were identical except for the storage arrays that each used:

- The older 8 Gbps HPE 3PAR StoreServ 7400 Storage array with hard drives

- The 16 Gbps all-flash HPE 3PAR StoreServ 8440 Storage array

On each configuration, we ran DiskSpd, a storage benchmarking tool. DiskSpd generates requests against storage devices in a way that simulates the IO patterns typical of SQL, offering insight into how the devices could handle online transaction processing (OLTP) workloads. The DiskSpd metric of input/output operations per second (IOPS) indicates a solution's potential to execute a number of OLTP transactions in a given amount of time.

As the chart below shows, the HPE 3PAR StoreServ 8440 array achieved 222,424 IOPS, outperforming the hard drive-based solution's 7,109 IOPS by a whopping factor of 31. Being able to process so many more transactions in a given amount of time with the same server has enormous potential value. For every active server, your company incurs costs: for admin time, software licensing, power and cooling, and precious datacenter space. If upgrading to the 8440 boosted the number of transactions a single server could perform by such a dramatic amount, Arthur's company could reduce its server count and save in all of these areas.

Performance in input/output per second
(higher is better)

|	
HPE 3PAR StoreServ 8440-based solution	222,424 IOPS
HPE 3PAR StoreServ 7400-based solution	7,109 IOPS

Performance results don't occur in a vacuum. When we view them along with latency results, we can assess their true impact. After all, no one wants a large increase in transactions at the expense of extremely high latency.

Let's look at the latency results we saw when we ran our test workload. As the chart below shows, the enormous performance win from the HPE 3PAR StoreServ 8440-based solution came with a dramatically lower latency of only 2.3 ms. Contrast that with the 70.9ms latency the older hard drive-based solution delivered. If Arthur upgraded, that difference would surely be noticeable to the database users who have been complaining.

Latency in milliseconds
(lower is better)

HPE 3PAR StoreServ 8440-based solution	2.3 ms
HPE 3PAR StoreServ 7400-based solution	70.9 ms
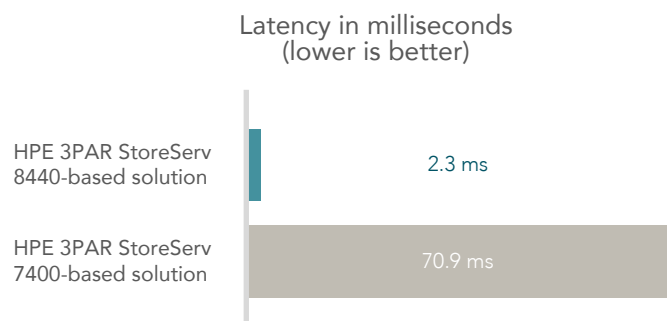
When less is more: The power of deduplication
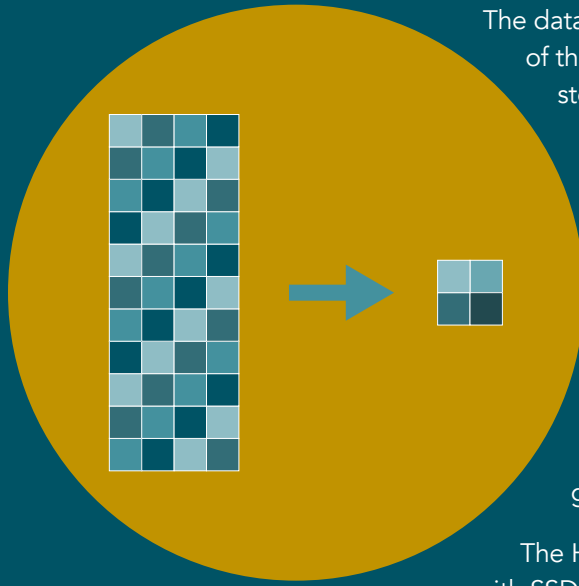
The data in any given storage repository typically contains multiple copies of the same chunks of information. To combat the inefficiency of storing every copy, strategies have evolved for deduplicating data. One approach is single-instance storage (SIS), where a system replaces duplicate chunks of data with references to a single, shared copy.

HPE 3PAR StoreServ arrays use the SIS inline deduplication for the solid-state tier of storage. This means an array scans each incoming block of information for familiar segments. When it identifies a block it has already saved, it creates a pointer to this block rather than saving the block again. The pointers use a small fraction of the space the blocks use, allowing a much greater amount of data to fit into a given amount of storage space.

The HPE 3PAR StoreServ 8440 we tested was outfitted exclusively with SSDs. When we ran our synthetic workload, we followed HPE best practices[1] and enabled deduplication only on the OS volume, not on the databases. (Note that because the older HPE 3PAR StoreServ 7400 Storage array we tested was outfitted exclusively with hard drives, we could not use deduplication.)

In our testing, the HPE 3PAR StoreServ 8440 achieved a deduplication ratio of 11 to 1. That means it could store a given amount of incoming raw data using only one-eleventh the amount of storage space an array without deduplication would need. Depending on the workload and software products you deploy, your deduplication ratios could vary (see sidebar).

What would this ratio mean for Arthur, who was concerned about his users having sufficient storage space with the 8440? Storage arrays are available with a range of different capacities. Because the cost of a given amount of space is higher for all-flash solutions than for those with spinning hard drives, customers typically choose smaller capacities. However, Arthur need not worry—given the deduplication efficiency of the HPE 3PAR StoreServ 8440 array, his company would likely experience a net gain in usable space.

Let's say the company configured its HPE 3PAR StoreServ 8440 arrays with half the storage capacity of the older hard-drive arrays it was replacing. Thanks to the 11 to 1 deduplication ratio of the 8440, the amount of usable storage capacity available to users would increase by a factor of five.

Savings through data reduction

HPE 3PAR StoreServ storage comes standard with HPE 3PAR Adaptive Data Reduction software, a collection of technologies including Zero Detect, deduplication, compression, and Data Packing. According to HPE, these technologies reduce a company's data footprint and make flash more affordable.

HPE analyzed publicly available data and determined that customers could expect to see savings along the following lines:

Application	Average savings
Virtual desktop infrastructure (VDI)	2.5–6.0X
Virtual server environments	1.5–2.5X
Databases	2.0–3.5X

The company even offers customers a Data Reduction Guarantee.

To learn more, see the HPE datasheet "Reduce your data footprint and storage costs" available at https://h20195.www2.hpe.com/V2/GetDocument.aspx?docname=a00020004enw

Conclusion

For any IO-intensive database solution, storage plays an essential role. An all-flash storage array can deliver far better performance and response time than one based on hard drives, but sometimes this advantage comes at the expense of usable storage capacity.

A company replacing older hard-drive storage with the HPE 3PAR StoreServ 8440 array, which is powered by Intel Xeon processors—would be very unlikely to face this tradeoff. In our testing, this solution's inline deduplication capabilities allowed it to store a given amount of raw data in less than one-tenth the storage space. Based on that ratio, an 8440 configured with half the raw storage capacity of an older hard drive-based array would still have more than five times the usable capacity. And of course, the 8440 boosted server performance in our testing by a factor of 30 while reducing latency to less than 4 percent of what it was with the older array.

It looks like Arthur's users can get the performance they demand—and plenty of storage space—with the HPE 3PAR StoreServ 8440. And Arthur can once again dine in the company cafeteria!

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1 "HPE 3PAR Storage—Adaptive Data Reduction Technologies," accessed March 8, 2018, https://h20195.www2.hpe.com/V2/GetDocument.aspx?docname=a00006358enw

On February 2, 2018, we finalized the hardware and software configurations we tested. Updates for current and recently released hardware and software appear often, so unavoidably these configurations may not represent the latest versions available when this report appears. For older systems, we chose configurations representative of typical purchases of those systems. We concluded hands-on testing on February 7, 2018.

Appendix A: System configuration information

Detailed configuration information for the server under test.

Server configuration information	HP ProLiant BL460c Gen8
BIOS name and version	I31 06/01/2015
Operating system name and version/build number	VMware ESXi 6.5.0 (build 7526125)
Date of last OS updates/patches applied	1/26/2018
Power management policy	High performance
Processor	
Number of processors	1
Vendor and model	Intel® Xeon® Processor E5-2640
Core count (per processor)	6
Core frequency (GHz)	2.5
Stepping	C2
Memory module(s)	
Total memory in system (GB)	32
Number of memory modules	4
Vendor and model	HPE SmartMemory 647651-081
Size (GB)	8
Type	RDIMM
Speed (MHz)	1600
Speed running in the server (MHz)	1600
Storage controller	
Vendor and model	Smart Array P220i Controller
Cache size (GB)	524288KB
Firmware version	8.00
Local storage	
Number of drives	1
Drive vendor and model	HP EH0300FBQDD
Drive size (GB)	300
Drive information (speed, interface, type)	15K, 6Gb SAS, HDD

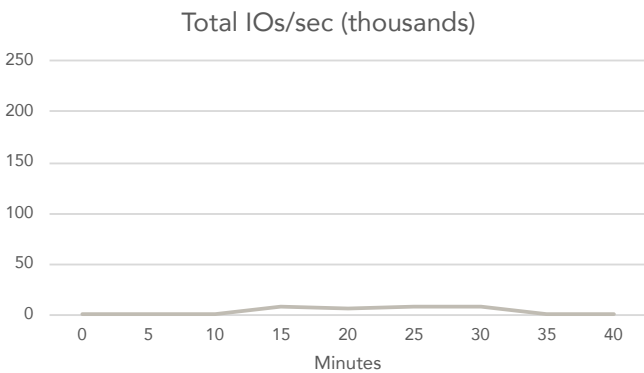| Server configuration information	HP ProLiant BL460c Gen8
Network adapter 1	
Vendor and model	HP FlexFabric 554FLB
Number and type of ports	2 x 10GbE
Driver version	11.1.183.23
Network adapter 2	
Vendor and model	HP QMH2572
Number and type of ports	2 x 8Gb FC
Driver version	v. 8.05.00

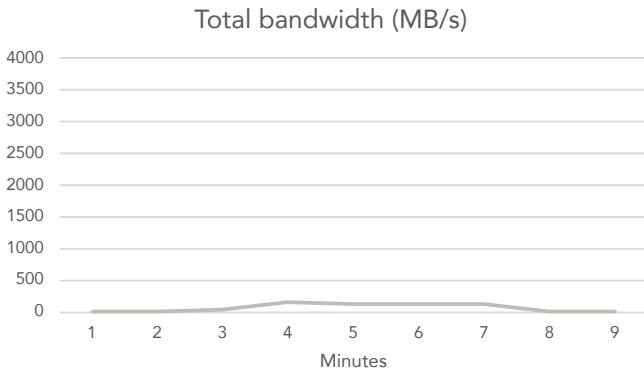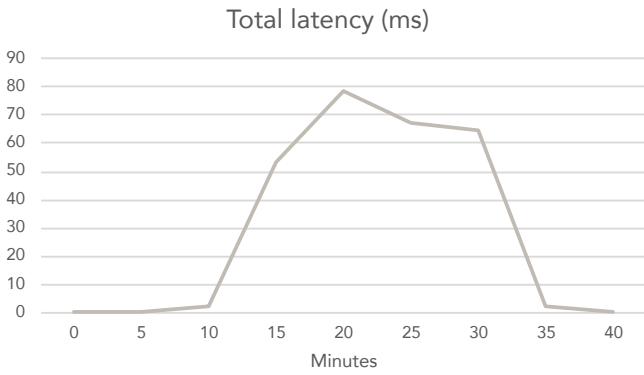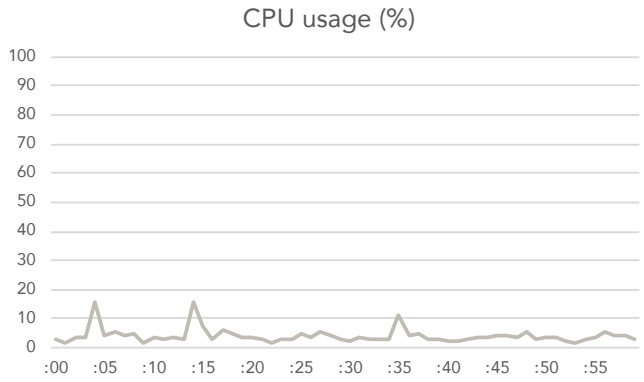Detailed configuration information for the storage solutions.

Storage configuration information	HPE 3PAR StoreServ 7400	HPE 3PAR StoreServ 8440
Controller firmware revision	3.3.1	3.3.1
Number of storage controllers	4	4
Number of storage shelves	4	4
Number of drives per shelf	24	24
Drive vendor and model number	HP HCBRE0450GBAS10K	HP HKCF0300S5xeN015
Drive size (GB)	450	300
Drive information (speed, interface, type)	10K, 6Gb SAS, HDD	15K, 6Gb SAS, SSD

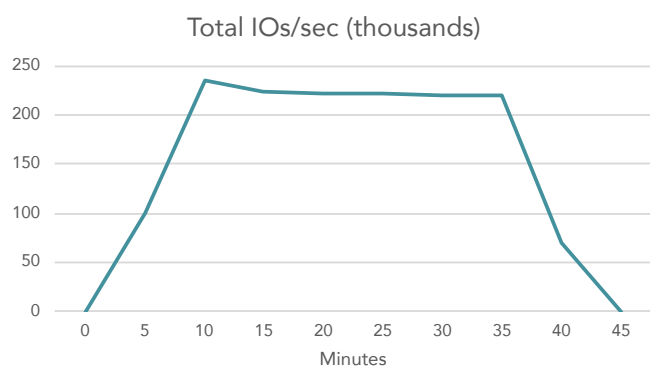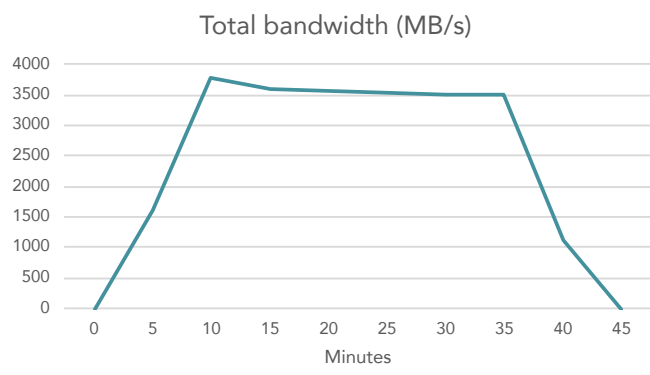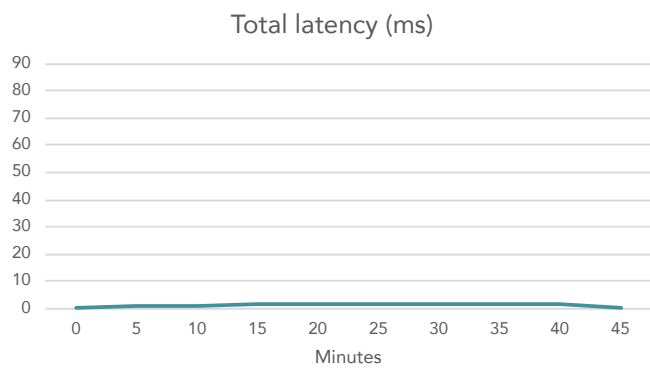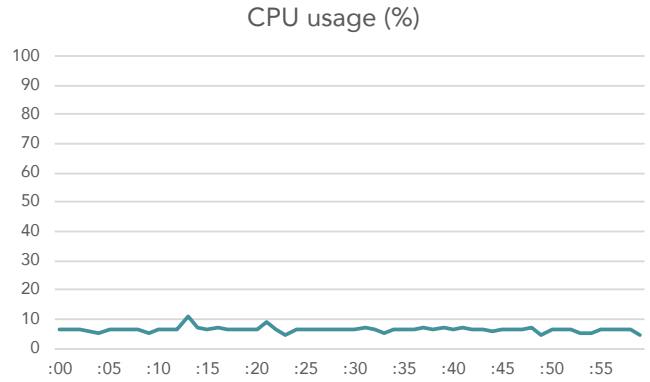Detailed configuration information for the server enclosure we used in our tests.

Server enclosure configuration information	HPE BladeSystem c7000 Enclosure G2
Number of management modules	1
Management module firmware revision	1.7
KVM module firmware	2.8.3
First type of I/O module	
Vendor and model number	HPE BladeSystem c7000 Onboard Administrator Tray
I/O module firmware revision	1.7
Number of modules	1
Occupied bay(s)	1-16
Power supplies	
Vendor and model number	HPE AC Module, Single Phase
Number of power supplies	6
Wattage of each (W)	2400
Cooling fans	
Vendor and model number	HPE Active Cool 200
Number of fans	10

Appendix B: Our results

HPE 3PAR StoreServ 7400 array

CPU usage (%)

Total latency (ms)

Minutes

Total bandwidth (MB/s)

Minutes

Total IOs/sec (thousands)

Minutes

HPE 3PAR StoreServ 8440 array

CPU usage (%)

Total latency (ms)

Minutes

Total bandwidth (MB/s)

Minutes

Total IOs/sec (thousands)

Minutes

Appendix C: How we tested

Physical setup

We connected an HPE c7000 blade chassis to two SAN fabrics via four Fibre Channel (FC) cables per fabric. Likewise, we connected each 3PAR StoreServ array to both SAN fabrics, with four FC cables per fabric from the 3PAR 7400 array, and eight FC cables per fabric from the 3PAR 8440 array. The c7000 chassis and 3PAR 7400 array used 8Gb FC HBAs, while the 3PAR 8440 array used 16Gb FC HBAs.
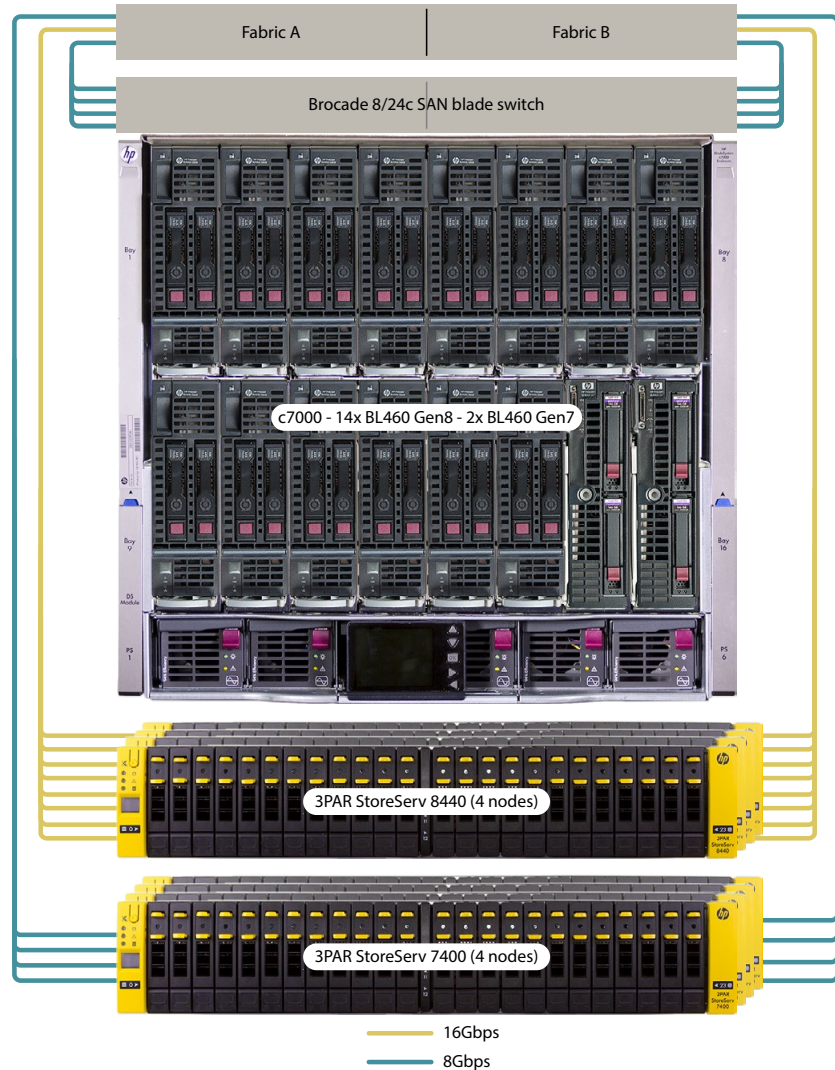
Configuring the HPE 3PAR 8440 and HPE 3PAR 7400 arrays

On each array, we created a RAID6 CPG with 48 drives (48 SSDs on the 8440 and 48 HDDs on the 7400) for our test LUNs and a RAID6 CPG with 48 drives for our OS LUNs. We created the LUNs necessary for the environment (see Table 1 for LUN sizing and layout).

LUN purpose	3PAR StoreServ 8440	3PAR StoreServ 7400
OS	1500GB x 1	1500GB x 1
Test	250GB x 14 (1 per host)	250GB x 14 (1 per host)

Table 1: LUN sizing and layout

Creating the storage pool

1. Log into the HPE 3PAR SSMC GUI.
2. At the top, click 3PAR StoreServ, and click Common Provisioning Groups under Block Persona.
3. In the left column, under Common Provisioning Groups, click Create CPG.
4. Under the General heading, enter a name, and verify the correct system is selected in the System drop-down menu.
5. Under the Allocation Settings heading, verify Device type is set to SSD 150K on the 8440, and FC 10K on the 7400.
6. Verify the RAID type is set to RAID6 for the test CPGs and the OS CPGs.
7. Change Availability to Magazine (Lower).
8. Click Create.
9. Repeat steps 1 through 8 for both storage arrays until you have a RAID6 OS CPG and a RAID6 test CPG on each array.

Creating the virtual volumes

1. At the top, click 3PAR StoreServ, and click Virtual Volumes under Block Persona.
2. In the left column, under Virtual Volumes, click Create virtual volume.
3. Under the General heading, enter a name for the VVol.
4. Verify the correct system is selected in the System drop-down menu.
5. Set the Provisioning drop-down to Thin Provisioned.
6. For the OS volumes, set the Dedup option to Yes. For the test volumes, leave Dedup set to No.
7. Verify that the correct backing CPG is selected—the OS CPG for the OS volume and the test CPG for all test volumes.
8. Set the size of the VVol in the Size field to 250 GB for test volumes and 1500 GB for OS volumes, and click Create.
9. Repeat steps 1 through 8 as necessary to create all VVols for the environment..

Creating the virtual volume sets

1. At the top, click 3PAR StoreServ, and click Virtual Volume Sets under Block Persona.
2. In the left column, under Virtual Volume Sets, click Create virtual volume set.
3. Under the General heading, enter a name for the Virtual Volume Set.
4. Verify the correct system is selected in the System drop-down menu.
5. Click Add virtual volumes.
6. Select the OS volume and the test volume created for the first VM, and click Add.
7. Click Create.
8. Repeat steps 1 through 7 until you have a virtual volume set for all 14 VMs on the servers under test.

Adding the ESXi hosts

1. Complete setup for Installing VMware vCenter 6.5 before proceeding with the storage setup.
2. At the top, click 3PAR StoreServ, and click Hosts under Block Persona.
3. In the left column, under Hosts, click Create host.
4. Under the General heading, enter a name for the host in the Name field.
5. Verify the correct system is selected in the System drop-down menu.
6. Set the Host OS to VMware (ESXi).
7. Under the Paths heading, click Add FC.
8. In the Add FC window, select the WWNs associated with the first host, and click Add.
9. Click Create.
10. Repeat steps 1 through 9 to add the remaining hosts.

Creating the host sets

1. At the top, click 3PAR StoreServ, and click Host Sets under Block Persona.
2. In the left column, under Host Sets, click Create host set.
3. Under the General heading, enter a name for the host set in the Name field.
4. Under the Host Set Members heading, click on Add hosts.
5. Select all 14 hosts, and click Add.
6. Click Create.

Assigning virtual volume sets to host sets

1. At the top, click 3PAR StoreServ, and click Virtual Volume Sets under Block Persona.
2. In the left column, under Virtual Volume Sets, select the first VVol set.
3. On the right side, click Actions, and click Export.
4. Under the Export To heading, click Add.
5. At the top of the window, select the Host set option.
6. Select the Host set, and click Add.
7. Leave Export With section at default values, and click Export.

DiskSpd OLTP-like workload VMs	8440 VMs (14x)	7400 VMs (14x)
vCPUs	12	12
Memory	30 GB	30 GB
OS drive	1 x 55 GB (OS_SSD LUN)	1 x 55 GB (OS_HDD LUN)
Test drive	1 x 200 GB (TEST_SSD_HOSTX)	1 x 200 GB (TEST_HDD_HOSTX)

Table 2: VM and storage summary (X represents the number of the host of which the VM resides).

Installing VMware ESXi 6.5

1. Attach the installation media to the server.
2. Boot the server.
3. At the VMware Installer screen, press Enter.
4. At the EULA screen, to Accept and Continue, press F11.
5. Under Storage Devices, select the appropriate disk, and press Enter.
6. Select US as the keyboard layout, and press Enter.
7. Enter a root password twice, and press Enter.
8. To start the installation, press F11.
9. To reboot the server, remove the installation media, and press Enter.
10. After the server reboots, press F2, and enter root credentials.
11. Select Configure Management Network, and press Enter.
12. Select IPv4 Configuration, and enter the desired configuration details. Press Enter.
13. Select DNS Configuration, and enter the Primary DNS Server. Press Enter.
14. Press Esc, and type Y to accept changes.

Deploying the VMware vCenter Server 6.5 Appliance

1. Open the installation media folder.
2. Select, vcsa-ui-installer, and right-click the installer application.
3. Click Run as Administrator.
4. Click Yes.
5. In the Appliance 6.5 Installer window, click Install.
6. At the Introduction, click Next.
7. Accept the terms of the license agreement, and click Next.
8. Select vCenter Server with an Embedded Platform Services Controller, and click Next.
9. Enter the IP address for the ESXi target server, the username, and the password. Click Next.
10. Click Yes to accept the certificate.
11. Enter and confirm a root password for the appliance, and click Next.
12. Select the deployment size (we selected Tiny and the default storage size), and click Next.
13. Check the box to enable thin disk mode, and click Next.
14. Enter the desired network information (IP address of the application, subnet, gateway, and DNS), and click Next.
15. Review the stage 1 information, and click Finish.
16. Click Continue to move to stage 2 of deployment.
17. At the introduction, click Next.

18. Enter the NTP servers for synchronization, enable SSH, and click Next.
19. Enter a domain name, password, and site name. Click Next.
20. For CEIP, click Next.
21. Review the stage 2 settings, and click Finish.
22. After setup completes, click Close.

Installing the VMware Enhanced Authentication Plugin

1. Open a web browser, and enter the IP address of the vCenter Server Appliance.
2. Click to open the vSphere Web Client (Flash).
3. Click Download Enhanced Authentication Plugin.
4. Click Save File.
5. Navigate to Downloads, and double-click to launch the installer application.
6. Click OK.
7. Click OK.
8. In the Installation welcome window, click Next.
9. Accept the terms in the License Agreement, and click Next.
10. Click Next.
11. Click Install.
12. Click Finish.
13. In the Plug in Service Installation window, click Next.
14. Accept the terms in the License Agreement, and click Next.
15. Click Next.
16. Click Install.
17. Click Finish.

Creating and configuring a Windows Server 2016 VM

1. From the vCenter web console, right-click the cluster or server, select New Virtual Machine, and click New Virtual Machine.
2. Select Create a new virtual machine, and click Next.
3. Enter a name for the virtual machine, select a datacenter, and click Next.
4. Select a compute resource, and click Next.
5. Select a datastore, and click Next.
6. Select desired compatibility/version, and click Next.
7. Select the Guest OS family (Windows), and the Guest OS version (Windows Server 2016), and click Next.
8. Customize the hardware as needed (we chose 12 vCPU and 30 GB Memory, a 50GB OS VMDK backed by the OS LUN, and added a second 200GB test VMDK backed by the host's test LUN), and click Next.
9. Review the configuration, and click Finish.
10. Connect to the virtual console by using either the web console or VRMC.
11. Attach the Windows Server 2016 installation media.
12. Power on the VM.
13. At the language selection screen, click Next.
14. Click Install Now.
15. Enter the product key, and click Next.
16. Select the Desktop Experience, and click Next.
17. Accept the license terms, and click Next.
18. Select Custom install.
19. Click Next.
20. Enter the desired password for the administrator, and click Finish.
21. Return to the vCenter web console.
22. Right-click the VM, select Guest OS, and select Install VMware Tools…
23. Return to the VM, double-click the VMware tools setup executable, and follow the instructions to install VMware tools.
24. Run Windows Update, and restart the VM as necessary.
25. Create a volume on the test hard disk, and assign it drive letter F.
26. Repeat steps 1 through 25 or repeatedly clone this new VM until you have 14 VMs residing on the 3PAR 8440 LUNs and 14 VMs residing on the 3PAR 7400 LUNs.

Running the DiskSpd benchmark

We tested each 3PAR array one at a time, removing connections from the array not in use and rebooting ESXi hosts between test runs. We ran the DiskSpd benchmark against all 14 VMs associated with a particular array at once.

1. Download DiskSpd from https://gallery.technet.microsoft.com/DiskSpd-a-robust-storage-6cd2f223/file/152702/1/Diskspd-v2.0.17.zip and extract the contents of the archive.

2. Before running any tests, on each VM we ran the following commands to generate a test file for DiskSpd to target:

```
fsutil file createnew F:\testfile.dat 199GB
fsutil file setvaliddata F:\testfile.dat 199GB
```

3. Open an elevated command prompt on each VM, and simultaneously run the following command:

```
C:\Users\Administrator\diskspd.exe -b16K -t12 -o3 -d1800 -w30 -W600 -r -h -L -Z1M F:\testfile.dat
```

4. Total the IOPS results across all 14 VMs, and report that as the IOPS score for the given run.

This project was commissioned by HPE.

Principled Technologies

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