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Introduction

SanDisk Fusion ioMemory-based HP Workload Accelerators have long helped customers realize new levels of technical and financial efficiencies in virtualized environments, scaling up virtual machine (VM) performance densities and enabling higher productivity and service levels. When combined in a solution with VMware Virtual SAN and Horizon View software on HP ProLiant DL360 Gen9 Servers, customers have one of the most cost-effective, high-performing solutions for client virtualization/virtual desktop infrastructure (VDI) needs.

VMware Virtual SAN is software-defined storage for VMware vSphere. By clustering server-attached HP Workload Accelerators as a flash tier for caching, and standard hard disks for capacity, Virtual SAN creates a flash-optimized, highly resilient shared datastore designed for virtual environments.

VMware Horizon View virtual desktop infrastructure enables end users to access all of their virtual desktops, applications, and online services through a single workspace. Horizon View is the virtual desktop host infrastructure for VMware vSphere. This platform enables end-user desktops as virtual machines on top of ESXi hosts.

In this white paper, we discuss the benefits of a solution that combines VMware Horizon View with VMware Virtual SAN, using SanDisk flash-based HP PCIe Workload Accelerators in a cluster of HP ProLiant DL360 Gen9 Servers. A key solution benefit is the high level of responsiveness of the virtual desktops and applications as measured by response times.

Executive summary

Enterprise data centers are continually challenged to deliver more with fewer resources. One of the key benefits of virtualization is lower costs through shared resources. Be it compute or storage, virtual machines need to move seamlessly, using the shared resources provided by underlying infrastructure.

Traditionally, enterprise total cost of acquisition (TCA) has been very high when VDI deployment requires storage area networks (SANs) for shared storage to satisfy high availability for end-user desktops. Many VDI initiatives have actually been scrapped because of the high capital expenditure required.

VMware Virtual SAN (VSAN) bridges this gap. It not only provides shared storage with server-attached local disks, but also lowers TCA to a great extent. Leveraging enterprise flash-based HP Workload Accelerators from SanDisk lowers TCA, as well as overall total cost of ownership (TCO) for the entire solution. Flash increases the density of VM performance and enables more users and desktops to access the system. This reduces the server footprint and associated energy (power and cooling) consumption typically required.

This white paper demonstrates how enterprise data centers can build a cost-effective VDI infrastructure using VMware Virtual SAN combined with the very fast storage input/output (I/O) provided by SanDisk-based HP Workload Accelerators. The result is a highly available solution that delivers high performance with improved levels of responsiveness, scale, and flexibility.

SanDisk—an HP and VMware Virtual SAN partner—helped design and test solution application response times, which is a critical service-level requirement for VDI environments. Using VMware View Planner, application response times of this three-server solution were benchmarked across a broad set of CPU and disk-sensitive desktop applications and were well below targeted thresholds, and therefore extremely fast:

Remote access mode:
- CPU-sensitive applications: 95th percentile (0.92 seconds)
- CPU- and disk-sensitive applications: 95th percentile (4.33 seconds)

Local access mode:
- CPU-sensitive applications: 95th percentile (0.57 seconds)
- CPU- and disk-sensitive applications: 95th percentile (3.09 seconds)
HP Virtual SAN solution summary

This solution is based on best-of-breed compute, storage, and virtualization technologies. It uses the following elements:

- HP ProLiant DL360 Gen9 Servers
- SanDisk Fusion ioMemory-based HP PCIe Workload Accelerators
- vSphere 5.5
- Virtual SAN and Horizon View for virtual desktop workloads

The Virtual SAN storage platform allows the solution to easily scale the number of users by configuring larger or additional HP Workload Accelerators in each server, as well as additional servers in the cluster.

The following table shows the benchmark scores for two different run modes, which will be explained later. The scores are for Group A (CPU-sensitive application operations) and Group B (CPU- and disk-sensitive operations). VMware View Planner calculates these scores automatically and generates reporting at the end of the test run. This score highlights whether or not a system can accommodate a given VDI desktop density.

The scores for Group A and Group B indicate excellent results — in the 95th percentile and much less than the response threshold target of one second for Group A and six seconds for Group B. Note that this solution can accommodate more than the 100 VMs/virtual desktop/users per node used in the testing.

**Testing process**

For the validation testing in the Virtual SAN environment, we used the VMware View Planner standard benchmark workload, with the Group A (CPU-sensitive) and Group B (CPU- and I/O-sensitive) scores, to determine the Virtual SAN environment capability for hosting VDI.

The View desktop was created using Microsoft Windows 7, 32-bit operating system standard image. Necessary configuration changes are done according to the View Planner installation and configuration user guide. All the applications, which are part of the View Planner pre-selected workload requirements, are installed inside this image.

The VMware Virtual SAN default storage policy was applied to the desktop VM, which provides high availability in case one of the nodes goes down.

The View client desktop image was created with Windows 7, 32-bit operating system and configured according to the View Planner Installation and Configuration User Guide.

A three-node Virtual SAN cluster was created, and in the floating View composer, linked-clone pool desktops were provisioned on top of it. A floating pool desktop was created, keeping all the default settings except for choosing the Virtual SAN datastore to deploy the VM.
Figure 1: VMware Horizon view pool creation – datastore selection

View client desktops and other Horizon View infrastructure—such as View Planner Appliance, vCenter, AD-DNS, DHCP, and VMware Horizon View—are provisioned outside the Virtual SAN cluster.

Figure 2: Test bed architecture

The Virtual SAN datastore is configured using two disk groups in each node. Each disk group is configured with one caching tier, using one 2.6 TB HP Workload Accelerator and three capacity-tier hard disk drives (HDDs) per server.
**Three-node Virtual SAN architecture**

![Three-node Virtual SAN architecture](image)

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**Test results**

VMware View Planner allows executing the tests in different modes. We executed the tests in two modes: “local” and “remote.”

Local mode uses no client components – it is intended only for desktop performance in the system under test.

Remote mode uses one-to-one mapping between desktop and client. This is more representative where the client simulates user devices, such as thin client, mobile devices, etc., and users are connected to their respective desktops.

**View Planner Local Mode**

Figure 4 shows the application response time for Group A and Group B of View Planner workload.

![Group-A Application Response Time](image)

**Figure 4:** Response time – CPU-sensitive applications
As shown in figures 4 and 5, the response time for applications running in the desktops is well below the thresholds of one second (Group A) and six seconds (Group B).

**View Planner Remote Mode**

Figures 6 and 7 show the application response time for Group A and Group B of the View Planner workload.

**Figure 5:** Response time – disk- and CPU-sensitive applications

**Figure 6:** Response time – CPU-sensitive applications
Figure 7: Response time – disk- and CPU-sensitive applications

As shown in figures 6 and 7, the response time for the applications running in the desktops is well below the benchmark thresholds of one second (Group A) and six seconds (Group B).

Figure 8: CPU utilization (3-node Virtual SAN cluster)
Figure 9: Disk utilization (node 1)

Figure 10: Disk utilization (node 2)

Figure 11: Disk utilization (node 3)
The above input/output (I/O) charts are measured at the storage adapter level. Because each node in this Virtual SAN cluster is prepared using two disk groups, the input/output per second (IOPS) are aggregated for all the adapters and shown together. The test execution is a power-user profile; it generates the highest amount of IOPS in the system from the VDI user profile perspective.

Figure 12: Disk throughput (node 1)

Figure 13: Disk throughput (node 2)
The observed disk throughput is similar in behavior to the IOPS results as noted earlier.

**Disk latency**

View Planner measures latency in milliseconds (ms). During the steady-state portion of the run, the latency was below 1 ms and reported as zero; therefore, no latency graph was created.

**Test result observation**

From an application perspective, the quality of service (QoS) summary highlights results that are well below the benchmark limits. The results confirm extremely high application responsiveness with response times well below targeted threshold limits. These results also confirm the solution configuration can well accommodate many more desktops. As VMware Virtual SAN supports 100 VMs per node, we scaled to the supported limit and measured the QoS summary.

**QoS summary – Remote and Local test modes**

| Group A (CPU-sensitive applications) | 95th percentile 0.923584 seconds (threshold target of <= 1 second) |
| Group B (CPU- and disk-sensitive applications) | 95th percentile 4.32539 seconds (threshold target of <= 6 seconds) |

**Figure 15: QoS summary (Remote Mode)**

| Group A (CPU-sensitive applications) | 95th percentile 0.567323 seconds (threshold target of <= 1 second) |
| Group B (CPU- and disk-sensitive applications) | 95th percentile 3.089198 seconds (threshold target of <= 6 seconds) |

**Figure 16: QoS summary (Local Mode)**
# Virtual SAN solution test bed

The tables below describe the test bed.

## ESXi host configuration

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Specifications</th>
</tr>
</thead>
</table>
| Servers                   | • 3 x HP ProLiant DL360 Gen9 (Intel® Xeon® CPU E5-2690 v3 @ 2.60 GHz (24C) – Hyperthreading enabled)  
                             • 3 X 256 GB RAM                                             |
| Storage                   | • 2 x 2.6 TB HP PCIe LE Workload Accelerator in each server  
                             • 6 x 1 TB hard disk drives in each server                   
                             • 1 x HP Smart Array P440ar                                 |
| Network                   | • 2 x 10 Gb network interface card (NIC) in each server      
                             • 2 x 1 Gb NIC in each server                                |

## Virtual SAN configuration

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Specifications</th>
</tr>
</thead>
</table>
| Each disk group configuration | • 1 x 2.6 TB HP PCIe LE Workload Accelerator – Caching Tier  
                                • 3 x 1 TB hard disk drives – Capacity Tier                 |
| Disk group in each node   | • 2                                                           |
| Total Virtual SAN nodes   | • 3                                                           |

## Virtual machine configuration

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Specifications</th>
</tr>
</thead>
</table>
| Desktop                   | • Windows 7 Enterprise 32-bit Edition                        
                             • 1 vCPU, 2 GB RAM                                          
                             • VM Virtual SAN storage policy                            
                             – Failure to Tolerate = 1                                   
                             – Stripe Width = 1                                         |
| Client                    | • Windows 7 Enterprise 32-bit Edition                        
                             • 1 vCPU, 2 GB RAM                                          |
| VMware Horizon View Manager | • Windows 2012 R2 64-bit Edition                            
                                • 4 vCPU, 10 GB RAM                                         |
| VMware Horizon View Composer | • Windows 2012 R2 64-bit Edition                            
                                • 1 vCPU, 4 GB RAM                                          |
| VMware vCenter            | • Windows 2012 R2 64-bit Edition                            
                             • 4 vCPU, 16 GB RAM                                         |
Installed desktop application

<table>
<thead>
<tr>
<th>Master image</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golden Desktop</td>
<td>• Microsoft Office 2010 Professional 32 bit with no Service Pack</td>
</tr>
<tr>
<td></td>
<td>• Internet Explorer 8.0</td>
</tr>
<tr>
<td></td>
<td>• Mozilla Firefox 7.0</td>
</tr>
<tr>
<td></td>
<td>• Adobe® Reader 10.1.4</td>
</tr>
<tr>
<td></td>
<td>• Windows Media Player</td>
</tr>
<tr>
<td></td>
<td>• 7-zip</td>
</tr>
</tbody>
</table>

Infrastructure software configuration

Software installed

- VMware vSphere 5.5
- VMware Horizon View 6.1.1
- VMware View Planner 3.5
- Microsoft SQL Server (Embedded with vCenter)
- Fusion ioMemory Gen3 driver 4.2.0

HP Virtual SAN Ready Node configuration

The following table shows the Ready Node configuration.

<table>
<thead>
<tr>
<th>HP/SanDisk VDI Reference Architecture profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Components</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>System reference ID</td>
</tr>
<tr>
<td>CPU</td>
</tr>
<tr>
<td>Memory</td>
</tr>
<tr>
<td>SSD/flash</td>
</tr>
<tr>
<td>HDD</td>
</tr>
<tr>
<td>Controller</td>
</tr>
<tr>
<td>NIC</td>
</tr>
<tr>
<td>USB/SD</td>
</tr>
</tbody>
</table>

Ready Node configuration capacity and resiliency can be modified based on the environments’ size and uptime requirement.
Conclusion

This is the industry’s first Virtual SAN solution for VDI that takes advantage of PCIe flash, using SanDisk-based HP Workload Accelerators. It is a cost-effective, high-performance solution that can be easily deployed, managed, and scaled to meet new requirements, and it can be fully integrated into the industry-leading VMware infrastructure. The HP Workload Accelerators in the solution enable higher VM performance and density to increase service levels and enable extremely high application response times, while also reducing TCA and TCO costs.

The flexible and scale-out nature of the Virtual SAN architecture easily accommodates future VDI needs for additional virtual desktops. This is true whether the deployment is on-premises or as private or hybrid cloud infrastructure, such as with the Desktop-as-a-Service (DaaS) model, making the solution easy to adopt.

The solution test results described in this paper highlight the importance of having ultra-low latency, high-performance flash as a key enabler for the caching tier and its extremely fast application response times – a critical requirement for VDI.

Acknowledgements

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• Patric Chang, Sr. Director, SanDisk Inc.
• Adaora Onyia, Senior Manager, Hewlett-Packard Company
• Grant Jacobson, Director, SanDisk Inc.

Resources

Customers can find more information about SanDisk, VMware, and HP via the links listed below:

• SanDisk resources
  – SanDisk website
    sandisk.com
  – SanDisk ESS products
    sandisk.com-enterprise
  – HP Workload Accelerators
  – SanDisk/HP Web portal
    hp.sandisk.com

• VMware resources
  – VMware website
    vmware.com
  – VMware Horizon View
    vmware.com/products/horizon-view
  – VMware Virtual SAN
    vmware.com/products/virtual-san

• HP resources
  – HP website
    hp.com/country/us/en/uc/welcome.html
  – HP ProLiant DL360 Gen9 Server
  – HP Smart Array P440ar
  – HP Workload Accelerators
  – HP/SanDisk Web portal
    hp.sandisk.com
Appendix A – SanDisk Fusion ioMemory HP PCIe Workload Accelerators

Ultra-low latency and high performance for real-time data access
The SanDisk Fusion ioMemory-based HP PCIe Workload Accelerator is designed to deliver a powerful flash solution of pure performance with ultra-low latency combined with high enterprise-grade endurance. It is a cost-effective solution for mixed-use application workloads that include virtualization, databases, business intelligence, and real-time financial data processing.

The HP PCIe Workload Accelerator is available in capacities from 1 TB to 6.4 TB, with ultra-low 92 μs/15 μs read/write data access latency, superior reliability with an uncorrectable bit error rate (UBER) of $10^{-20}$ (1 uncorrectable bit error in 800 years), and outstanding random read/write performance of up to 350 K/385 K IOPS. The HP Workload Accelerator is designed with Virtual Storage Layer software that delivers direct memory access, minimizes latency, and maximizes application throughput.

Figure 17: SanDisk Fusion ioMemory HP PCIe Workload Accelerators

Appendix B – Overview of VMware View Planner

VMware View Planner is a VDI workload generator that automates and measures a typical user’s desktop activity. The automated applications are Microsoft Office, PDF browse, watching a video, etc., and the operations on these applications are opening a file, browsing the Web, modifying, saving, and closing files, etc.

The central piece in the View Planner architecture is the Harness, the automated controller. It controls everything, from managing the participating desktop and client virtual machines, to starting the workload and collecting results, to providing a monitoring interface through a Web user interface.

The harness is a CentOS Linux-based appliance VM that interacts with Horizon View Manager components. It also runs a Web server to present a user-friendly interface.

As shown in figure 18, the appliance interacts with a VMware vCenter and Horizon View Manager, and with Active Directory/DNS to control desktop virtual machines and clients/users. It also communicates with client virtual machines to initiate remote protocol connections such as PCoIP, RDP, etc.

The appliance is responsible for starting the workload simulation in desktop virtual machines.

Upon simulation completion, results are uploaded and stored in a database on the appliance. Results can be viewed using the Web interface or extracted from the database at any time.
Appendix C – Overview of HP ProLiant DL360 Gen9 Server

HP ProLiant DL360 Gen9 Servers are uniquely optimized in system design and architecture.

Purpose-built for dense performance
World-renowned for supporting dense general-purpose computing needs, the HP ProLiant DL360 Server is an industry-leading server platform that delivers increased performance with the best memory and I/O expandability – packed in a dense 1U/2-socket rack design.

Continuing its legacy of reliability, serviceability, and continuously availability, the HP ProLiant DL360 Gen9 Server is the ideal choice for:

- **Space-constrained server environments** – For small- to medium-sized businesses and service providers
- **Dynamic workloads** – High-performance computing, databases, and virtualized private and public cloud. All these workloads require a top-rate balance of performance, energy efficiency, and density.
- **Compute-intensive applications** – Big Data, analytics, seismic discovery, and more
- **Low-latency and transactional applications** – Financial Services Industry

![Figure 19: HP ProLiant DL360 Gen9 Server](image)

Higher performance, extended support
Designed with performance in mind, the HP ProLiant DL360 Gen9 Server leverages the latest Intel Xeon E5-2600 v3 processors to offer up to 70 percent performance gains. You can manage your HP ProLiant DL360 Gen9 Server in any IT environment by automating the most essential server lifecycle management tasks – deploy, update, monitor, and maintain. And to support your heterogeneous IT environment, the DL360 Gen9 supports Microsoft Windows and Linux operating systems, as well as VMware and Citrix® virtualization environments.
Appendix D – Overview of VMware Virtual SAN

VSAN is a new storage solution from VMware that is fully integrated with vSphere. It automatically aggregates server disks in a cluster to create shared storage that can be rapidly provisioned from VMware vCenter during VM creation. It is a platform for VM Storage Policies designed to simplify virtual machine storage placement decisions for vSphere administrators. It is integrated with core vSphere features such as vSphere High Availability, vSphere DRS, and vMotion. It can also be used to address QoS requirements by creating VM Storage Policies that define the level of performance and availability required on a per-virtual machine basis.

SanDisk-based HP PCIe Workload Accelerators are a valuable enhancement to VSAN environments. They allow for the acceleration of I/O among the ESX servers, using enterprise-reliable PCIe flash for high-performance read/write caching and HDDs for cost-effective data persistence. Each vSphere host must have at least one Workload Accelerator when participating in the VSAN cluster. The more flash capacity the host has, the greater the number of users and performance boost, as more I/O can be cached.

Figure 20: VMware Virtual SAN high-level architecture