LATEST INTEL TECHNOLOGIES POWER NEW PERFORMANCE LEVELS ON VMWARE VSAN

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November 2017

Enabling you to make the best technology decisions

EXECUTIVE OVERVIEW*

The new Intel® Xeon® Scalable platform is designed to support today's enterprise application needs; specifically workloads requiring high I/O combined with intensive processor and memory access found in virtualized data centers. However, improving the processing performance without also improving the storage would lead to an unbalanced system, one unable to achieve optimal performance.

One trend that has been enabled by increasing processing capabilities is the emergence of Hyperconverged systems that utilize server platforms together with internal storage hardware and software defined storage to deliver an integrated platform for virtual applications. While many organizations have evaluated Hyperconverged appliances, some found that the performance of first generation systems was not suitable for their most demanding workloads.

Working with Intel and VMware, Evaluator Group tested several next generation Hyperconverged configurations based on VMware vSAN and Intel technologies, including a new class of storage media known as Optane™ for extreme performance levels. The systems used during testing utilized Vmware vSAN 6.6 along with Intel's new scalable system architecture including Intel Optane and 3D NAND NVMe storage.

In this paper we show both the performance and price / performance benefits achievable by using next generation Hyperconverged systems based on Intel Xeon Scalable processor systems with Intel Optane and 3D NAND Flash storage, running VMware ESXi and vSAN software to provide the Hyperconverged environment.

KEY INSIGHTS

Findings

Evaluator Group utilized the latest Intel Xeon Scalable processor systems and Intel storage, together with VMware ESXi and vSAN to construct a Hyperconverged cluster. Testing utilized multiple virtual server workloads, with results showing dramatic performance and price / performance increases compared to the previous generation of Hyperconverged systems.

Intel Xeon Scalable systems and storage provided the following benefits vs. the previous generation systems:

- Up to 2.3 X better performance and price / performance for virtual server workloads
- Up to 89% better performance for transactional database workloads
- Up to 3X more virtual desktops per cluster
- Record IOmark-VM-HC of $302 / VM

Take-away

Intel Xeon Scalable processors together with Optane and 3D NAND enable increased VM density, better performance and efficiency.

EVALUATION OVERVIEW

Evaluator Group analyzed Intel based Hyperconverged systems running three different workloads, including virtual server applications, virtual desktops (VDI) and transactional database workloads. The test scenarios were designed to recreate typical application workloads seen in enterprise environments.

Virtual Server Workload Results

The IOmark-VM benchmark was chosen to measure the storage performance of typical server virtual machine workloads. This benchmark has published results for earlier generations of Hyperconverged appliances, including previous results for Intel hardware based vSAN systems.

Note: ***Comparisons to previous Evaluator Group testing of Intel based Hyperconverged system performance in 2016 is available.[1] New benchmark results for Configuration "B" below are available at IOmark.org.[2]***

Test Configurations and Results

The metrics captured included performance and price / performance for each configuration. Performance was measured using the IOmark-VM benchmark, with validated performance results noted below. Each of the configurations was tested using VMware ESXi and vSAN in a 4-node cluster configuration running the IOmark-VM benchmark.

Additional configuration details along with pricing for each configuration is provided in Appendix A.

- Configuration "A" (P4600 + P4500 - no Deduplication)
  - IOmark-VM-HC validated configuration
  - Storage: Media: 1 x Intel DC P4600x + 3 x Intel DC P4500
  - Performance: 680 IOmark-VM-HC
  - Price / Performance: $361 / IOmark-VM-HC
- Configuration "B" (Optane + SATA S3520 - no Deduplication)
  - IOmark-VM-HC validated configuration
  - Storage: Media: 1 x Intel Optane DC P4800x + 8 x Intel DC S3520 SSD's
  - Performance: 800 IOmark-VM-HC
  - Price / Performance: $293 / IOmark-VM-HC
- Configuration "C" (Optane + P4500 - with Deduplication)
  - IOmark-VM-HC validated configuration
  - Storage: Media: 2 x Intel Optane DC P4800x + 4 x Intel DC P4500
  - Performance: 800 IOmark-VM-HC
  - Price / Performance: $302 / IOmark-VM-HC (***Note**: This configuration used for IOmark-VM-HC results)*
- Configuration "D" (Optane + P4500 - no Deduplication)
  - Not IOmark-VM-HC validated (Insufficient processing)
  - Storage: Media: 2 x Intel Optane DC P4800x + 4 x Intel DC P4500
  - Performance: 1,120 IOmark-VM's (***Note:** Measured as a storage system, not Hyperconverged*)
  - Price / Performance: $237 / IOmark-VM (***Note:** Measured as a storage system, not Hyperconverged*)

Evaluator Group comments: Performance improvements of 50% between generations is considered to be a significant performance achievement. The achieved 2X and greater improvements in both performance and price - performance represents significant enhancements.

1 "Evaluating Server-Based Storage Performance", Evaluator Group 2016: www.evaluatorgroup.com/document/evaluating-server-based-storage-performance-enterprise-workloads/

2 IOmark.org: www.iomark.org/sites/default/files/IOmark-VM_report_Intel-vSAN_170711a.pdf

The results for configurations "A" and "B" are reported as IOmark-VM-HC, denoting the configuration supported all server and storage requirements necessary to run the reported workload. Configuration "D" above had storage performance that exceeded the server requirements for Hyperconverged and therefore the storage only results are reported as IOmark-VM for this configuration.

Performance Comparison

Shown below in Figure 1 are the performance results for three tests previously reported on the left, along with three new results to the right. See Appendix B for details on the previous and new configurations details.

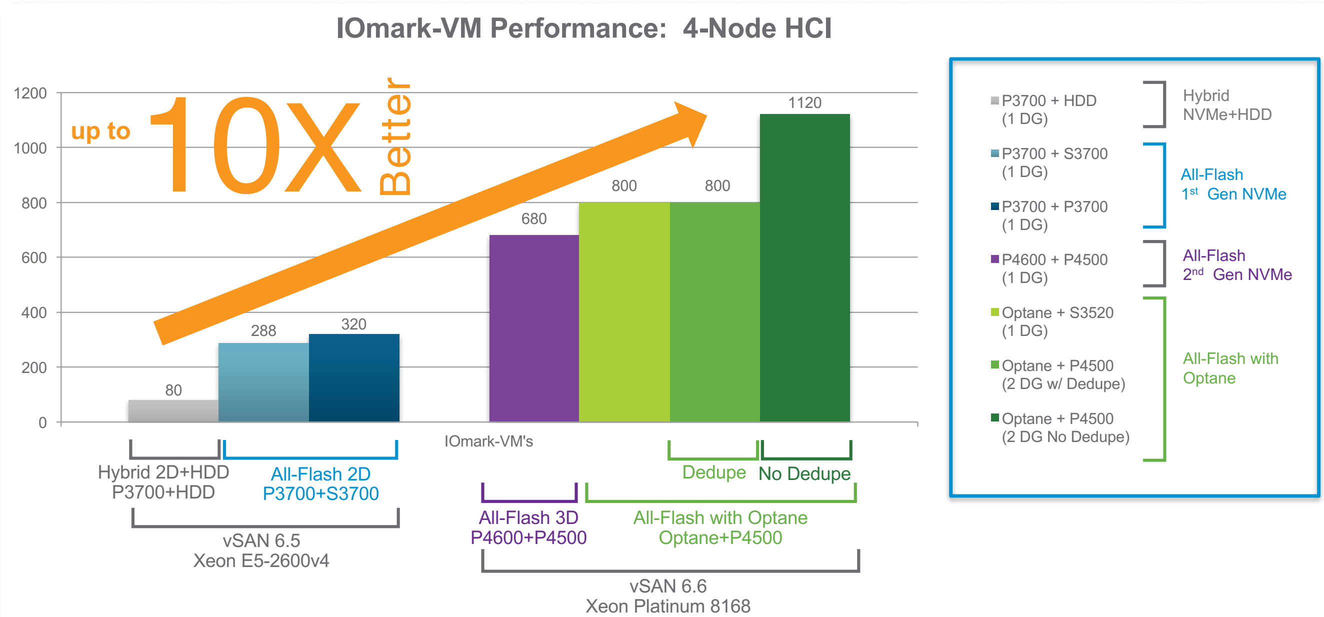


Figure 1: Performance Comparison of Intel Hyperconverged Systems

As shown above, the first three data points on the left (80, 288 and 320) are based on previous generation Intel servers, older NVMe devices and the previous version of vSAN. The four new data points on the right are based on current generation Intel Xeon processor systems, together with new Intel NVMe devices and the latest version of VMware vSAN 6.6. From these data points it is clear that the results obtained with the new Xeon Scalable processor systems together with Intel Optane and 3D NAND storage media and vSAN 6.6 provide significant performance improvements compared to the prior generation systems.

Efficiency Comparison

While performance results are interesting, improving VM density and lowering the cost of infrastructure is often the most important considerations for IT environments. The price / performance results measured show compelling value obtained by moving to new Intel Xeon Scalable systems and VMware vSAN 6.6.

As shown below in Figure 2, the cost per VM is significantly lower by using higher performing systems and storage. These results clearly show that the lowest cost on a per VM basis is obtained by using new Intel Optane and 3D NAND storage together with VMware vSAN 6.6.

Older systems without sufficient storage performance leads to VMs that are starved for I/O throughput, wasting the precious processor and memory resources of these systems. As a result, it was common for IT administrators to over-provision storage capacity, in order to achieve the required performance.

With new Intel Optane and 3D NAND media, IT architects are able to choose storage media for performance and capacity independently, enabling systems that exactly meet both the capacity and performance requirements.

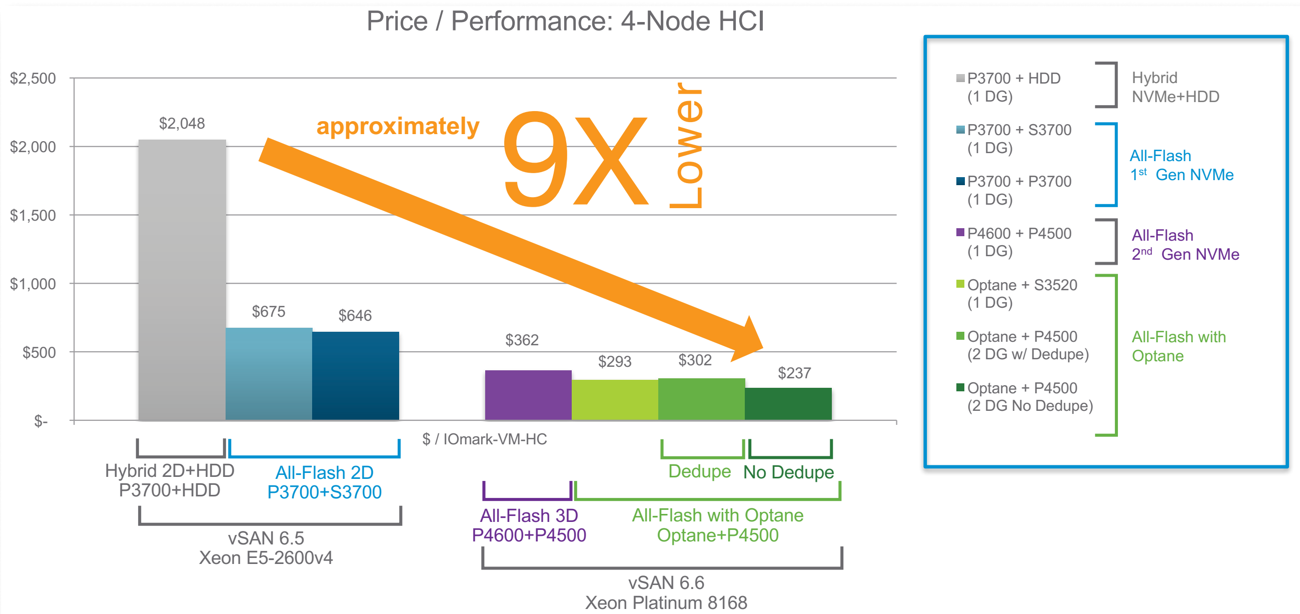


Figure 2: Price / Performance Comparison of Intel Hyperconverged Systems

Storage Capacity Comparison

Storage capacity requirements vary significantly between companies, workloads and for other reasons. In Hyperconverged environments excess storage capacity can be wasteful, since that capacity is not easily shared with other compute systems. Therefore, optimally configured Hyperconverged systems will have sufficient storage capacity for the workloads being run on them without excessive capacity.

The usable capacity includes RAID overhead reductions and capacity gains from deduplication and compression. For IOmark-VM, the data is approximately 2.5:1 reducible. The capacity factors used for each configuration are listed in the configuration details section of Appendix A.

Comparison to Previous Systems

Comparing the new Intel Xeon Scalable processor systems using Optane and 3D NAND flash storage to earlier test results, as referenced in the paper "Evaluating Server-Based Storage Performance" there are several important results.

Virtual Desktop Workload Results

A virtual desktop or VDI workload was created using the IOmark-VDI benchmark to measure storage performance. This benchmark has published results for earlier generations of Hyperconverged appliances, however no previous vSAN systems have reported their IOmark-VDI results. Therefore comparisons between the tested Intel Xeon Scalable processor systems with vSAN and previous IOmark-VDI results have several differences between their configurations.

Test Configurations and Results

The primary limitation of the tested system was determined to be the CPU and memory available. This was based upon recommendations from the two primary VDI brokers, VMware View and Citrix XenDesktop. Each VDI desktop was allocated the following resources:

- Current VDI configuration (P4600 + P4500 - no Deduplication)
  - 48 CPU cores, 1.5 TB DRAM and 3 TB of usable capacity per node
  - 2 vCPU's per VDI, 3 GB RAM and 5.6 TB storage per VDI instance
  - 10.5 : 1 CPU over-provisioning and no DRAM over-provisioning
  - Performance: 2,048 IOmark-VDI
  - Price / Performance: $132.44 / IOmark-VDI-HC

Comparison to Previous Results

Shown below in Figures 3 and 4 are the performance and price / performance results respectively for the latest Intel Xeon with vSAN results vs. the previous best VDI Hyperconverged results. See Appendix B for details on configurations tested.

Figures 3 and 4: VDI Performance and Price / Performance

From these results it is clear that the results obtained with the new Xeon Scalable processor systems together with Intel Optane and 3D NAND storage media and vSAN 6.6 provide significant performance and price / performance improvements compared to the prior generation systems. Key improvements include:

- Intel Xeon Scalable processor, enabling 512 VDI users per system with 2vCPU and 3 GB RAM per VDI
  - More cores, higher clock speed, 50% more DRAM and increased bandwidth vs. previous systems
- vSAN 6.6 enhancements, enabling 2X more performance using NVMe media vs. prior systems
  - 2X performance is based on Figure 1 results, showing 320 vs. 680 VM's for vSAN 6.2 vs. vSAN 6.6

Transaction Database Workload Results

The third workload tested was a transactional database, which utilized a workload similar to the well known TPC-C benchmark. Specifically the database workload tool HammerDB was used to run an un-audited TPC-C like workload on virtual Windows Server 2016 VMs with SQL Server 2016. It must be noted that these results cannot be compared to any other TPC workloads, although they do provide an accurate relative comparison between the two tested configurations. Each node was configured with two VM's for a total of eight VM's, each running the HammerDB workload. The results shown are the aggregate, or totals for all eight VM's.

Test Configurations and Results

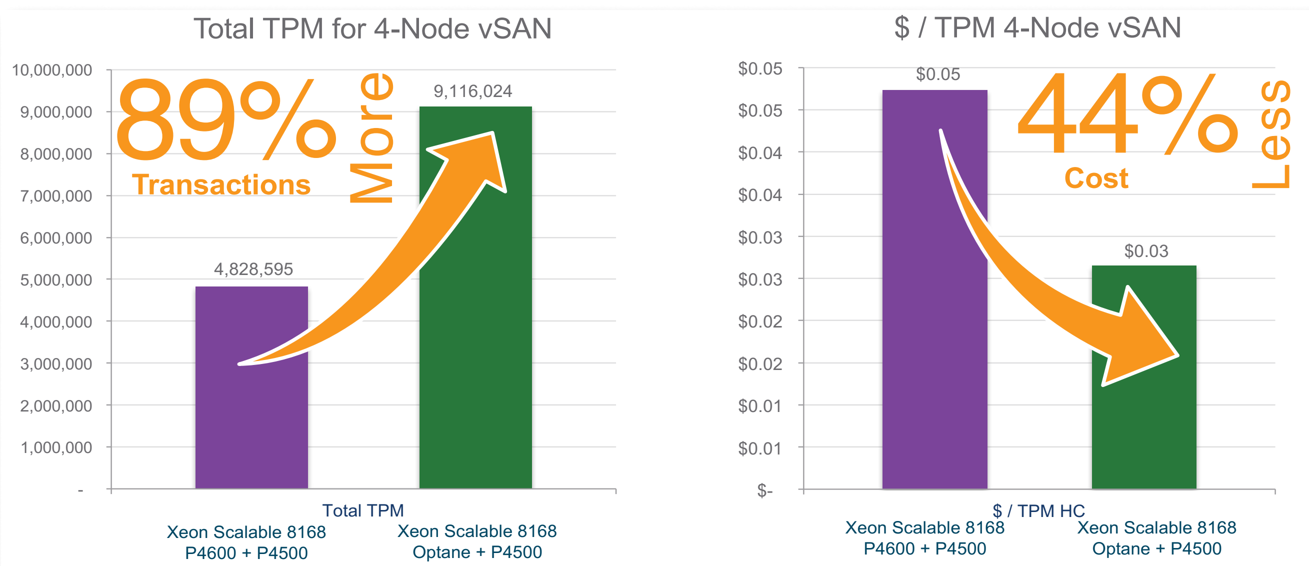
The primary limitation of the tested system was determined to be the storage performance for both configurations “A” and “B”. This indicates further gains may be possible using three vSAN disk groups and additional Optane media in configurations.

The setup and configuration for the HammerDB workload for each storage configuration was as follows:

- Configuration “A” (2 @ Optane + 4 @ P4500 - no Deduplication)
  - HammerDB (TPC-C) workload with 800 warehouses, 56 workers
  - HammerDB run for 30 minutes with 1,000 virtual users, 1 ms user delay and repeat
  - SQL Server with 1 TB database on two striped devices, 65 GB log and 100 GB temp DB on 1 device ea.
  - vSAN with 2 disk groups per node, each with Optane cache + 2 @ P4500 capacity devices per node
- Performance: 9,116,024 HammerDB TPM
- Price / Performance: $0.027 / TPM (2.7 cents per TPC-C transactions per minute)

- Configuration “B” (1 @ P4600 + 3 @ P4500 - no Deduplication)
  - Identical HammerDB and SQL Server setup to Configuration “A”
  - SQL Server with 1 TB database on two striped devices, 65 GB log and 100 GB temp DB on 1 device ea.
  - vSAN with 1 disk group per node, each with P4600 cache + 3 P4500 capacity devices per node
- Performance: 4,828,595 HammerDB TPM
- Price / Performance: $0.027 / TPM (4.7 cents per TPC-C transactions per minute)

Shown below in Figures 5 and 6 are the performance and price / performance results respectively comparing configurations “A” and “B” identified above. See Appendix B for details on the configurations details.



Figures 5 and 6: Database Performance and Price / Performance

From these tests it is clear that the results obtained with the new Xeon Scalable processor systems, with Intel Optane as a cache together with Intel 3D NAND storage media and vSAN 6.6 provide significant performance improvements compared to the configuration using only 3D NAND media with vSAN. This was due to the fact that the configuration tested had its performance bounded by storage, meaning that storage performance was the primary bottleneck. It is likely further performance gains could be accomplished by using additional Optane devices in the vSAN storage configuration.

SUMMARY

Evaluator Group analysis found that the new Intel Xeon Scalable system architecture, combined with next generation solid-state storage technologies are able to deliver better performance and more importantly price / performance for a variety of common workloads running on Hyperconverged systems using vSAN.

Virtual server workloads are the most common applications run as on-premise private and hybrid cloud, as well as by cloud service providers. These demanding workloads require balanced system performance in order to achieve high system utilization while still meeting application performance requirements. These workloads were found to have up to 2.3 X better price / performance levels than previous generation systems and storage media as measured by IOmark-VM benchmark.

Virtual desktop or VDI workloads were also found to benefit, primarily from the increased processor and memory capabilities, but also from the improvements of vSAN 6.6 which enabled the use of new Intel high capacity NVMe devices while delivering 2X more performance versus prior generation NVMe devices with vSAN 6.2.

For transaction database applications, represented by multiple TPC-C like workloads running on SQL Server VM's, Intel's next generation Optane technology was found to provide significant performance and price / performance benefits. In order to maximize the transaction rate, each aspect of the system is important, requiring a greater number of CPU cores, increased memory capacity and bandwidth and in particular the storage enhancements in vSAN 6.6 which in turn enabled these configurations to utilize Intel's Optane storage media for the most demanding application workloads.

Taken together, each technology enhancement adds to the overall system capabilities, making Hyperconverged systems based upon Intel server and storage hardware combined with Hyperconverged infrastructure using VMware ESXi and vSAN able to deliver significantly better performance, but more importantly lower total cost when measured by the application results.

A common perception is that new technologies are expensive; however, the reality is that using these technologies can provide significant price / performance advantages due to the high performance relative to their price. Testing using IOmark-VM, IOmark-VDI and HammerDB clearly show that the highest performing configurations also provide the greatest efficiency, delivering the lowest cost per virtual server, virtual desktop and database transaction.

When compared to first generation Hyperconverged systems using hybrid storage, the price / performance benefits of the Intel Xeon Scalable processor systems together with Intel Optane and 3D NAND NVMe storage are nearly an order of magnitude better. Even compared to most all-flash Hyperconverged systems, the new Intel based systems with vSAN deliver approximately 2X better performance and price / performance levels compared to recent all-flash Hyperconverged.

The IOmark-VM performance for the four-node cluster surpasses most all-flash storage systems tested to date, making it possible to run even the most I/O intensive applications using the latest Intel processors and server-based storage technology.

Final Observations

Storage performance has traditionally been a significant limitation for Hyperconverged system performance, leading applications to waste system resources while simultaneously being starved for I/O. Intel's new system and storage technologies, combined with VMware vSAN's enhancements enable enterprises to meet their application I/O needs, resulting in better performance while lowering IT costs.

IT organizations looking to improve their VM density, improve performance or lower the cost of running virtual workloads should utilize Intel's next generation Optane and 3D NAND media in order to leverage the full benefits of new Intel processors and HCI software such as VMware vSAN.

Appendix A – IOmark-VM Pricing

Provided in Table 1 is a summary of the three configurations tested, along with their respective costs, performance and the price / performance results. Data from this table is used in Figures previously listed.

Intel Storage / Node	Config "A"	Config "B"	Config "C"	Config "D"
	P4600 + P4500	Optane + S3520	Optane + P4500	Optane + P4500
Intel DC S3520-1200		8		
Intel DC P4500-2000			4	
Intel DC P4500-4000	3			4
Intel DC P4600-1600	1			
Intel DC P4800x-400		1	2	2
Raw Capacity / Node	12,000	9,600	8,000	16,000
IOmark-VM-HC Required Raw / Node	7,969	9,375	5,188	N/A
RAID Level Used	R-5 + R-10	R-5 + R-10	R-5 + R-10	R-5 + R-10
Dedup - Compression	No	No	Yes	No
Storage Overhead Factor	1.5	1.5	0.8	1.5
Usable Capacity / Node (GB)	8,000	6,400	10,667	10,667
VMmark Tiles / Node	21	25	25	35
IOmark-VM's / Node	170	200	200	280

Intel Test Configuration Pricing	P4600 + P4500	Optane + S3520	Optane + P4500	Optane + P4500
Intel DC S3520-1200	$ -	$ 5,239.92	$ -	$ -
Intel DC P4500-2000	$ -	$ -	$ 5,432.00	$ -
Intel DC P4500-4000	$ 7,914.00			$ 10,552.00
Intel DC P4600-1600	$ 1,499.00			
Intel DC P4800x-400	$ -	$ 1,520.00	$ 3,040.00	$ 3,040.00
1 Node Storage Media Total	$ 9,413.00	$ 6,759.92	$ 8,472.00	$ 13,592.00
4 Node Storage Media Total	$ 37,652.00	$ 27,039.68	$ 33,888.00	$ 54,368.00
4 Node System (Server Only)	$ 76,615.36	$ 77,431.36	$ 76,615.36	$ 76,615.36
4 Node VMware (ESXi)	$ 27,960.00	$ 27,960.00	$ 27,960.00	$ 27,960.00
4 Node VMware (vSAN)	$ 31,960.00	$ 31,960.00	$ 31,960.00	$ 31,960.00
3 Year Ent Support (HW + SW)	$ 66,127.01	$ 66,127.01	$ 66,127.01	$ 66,127.01
3 Year Media Maint. (5%)	$ 5,647.80	$ 4,055.95	$ 5,083.20	$ 8,155.20
Total 4 Nodes (HW, SW, Media, Mnt.)	$ 245,962.17	$ 234,574.00	$ 241,633.57	$ 265,185.57

Intel Price / Performance - Price / Cap.	P4600 + P4500	Optane + S3520	Optane + P4500	Optane + P4500
$ / VM (All + Maintenance)	$ 361.71	$ 293.22	$ 302.04	$ 236.77

Table 1 : Test Configuration and Pricing Details

Appendix B - IOmark-VM Details

For the server virtualization or VM workloads, the IOmark-VM application workload was utilized. By following guidelines and submitting results for audit and certification for Hyperconverged systems, Configuration "C" constitutes as a certified IOmark-VM-HC benchmark result. The remainder of configurations followed recommendations and review but were not published as certified results. However, the comparisons are valid as all testing was performed to the same standards, using the same test infrastructure and methods.

Server Configuration for Current Tests

As shown on page #2, and in Appendix A, there were four configurations tested, noted as "A", "B", "C" and "D". These configurations constitute the new tests shown in Figures 1 and 2.

The test configurations consisted of a cluster of 4 physical server nodes running VMware ESXi 6.5.0d with vSAN 6.6. The Hyperconverged systems used for testing included the following CPU, memory and network configuration. The storage media utilized changed for each configuration as noted.

- Each Node in the 4 node cluster consisted of an Intel Xeon Scalable system platform
  - Intel Server System R2208WF, with 4 U.2 NVMe accessible slots
  - CPU: 2 x Intel Xeon 8168 CPU (24 cores @ 2.7 Ghz w/ hyper threading)
  - Memory: Tested with 256 GB DRAM, priced for comparison at 768 GB DRAM
  - NIC : Tested with onboard 10 GbE X-540 AT2
  - Storage Media: Varied for each configuration, refer to Appendix A for details on media

Previously Reported Results

In Figures 1 and 2, previous results are shown for comparison. The previous results are those performed on behalf of Intel in 2016 and were reported in the document referenced in Footnote 1 on page #2. An overview of those configurations reported is noted below. The configuration details, along with the pricing information were taken from that paper and represent accurate prices at the time of original publication.

These tests consisted of a cluster of four physical server nodes running VMware ESXi 6.0 with vSAN 6.2.

- Configuration #1 (1 SSD + 4 HDD)
  - IOmark-VM-HC validated configuration
  - Storage: Media: 1 x DC S3700 + 4 x Seagate 1 TB 10K HDD
  - Performance: 80 IOmark-VM-HC ; Price / Performance: $2,048 / IOmark-VM-HC
- Configuration #5 (1 NVMe + 2 NVMe)
  - IOmark-VM-HC validated configuration
  - Storage: Media: 1 x DC P3700 + 2 DC P3700
  - Performance: 288 IOmark-VM-HC ; Price / Performance: $752 / IOmark-VM-HC
- Configuration #7 (2 NVMe+ 6 SSD + 1 NVMe)
  - IOmark-VM-HC validated configuration
  - Storage: Media: 3 Intel DC P3700 + 6 Intel DC S3700
  - Performance: 480 IOmark-VM-HC ; Price / Performance: $545 / IOmark-VM-HC

Pricing Data

Prices can change and although they were accurate at the time of publication, the prices may not be accurate currently. Pricing was gathered for individual components and then combined in order to provide prices for each configuration as detailed in Appendix A of this report. Price data gathered included list prices for all Intel components including systems, CPU's and storage media as well as for VMware ESXi and vSAN. DRAM prices used were for Crucial 32 GB DDR4-2400 memory. All pricing data was verified as accurate on the date of publication. Additional details available upon request.

Appendix C - IOmark-VDI Details

For the virtual deskop or VDI workloads, the IOmark-VDI application workload was utilized. None of the tested configurations were submitted for audit and certification, thus none of the results were published as certified IOmark-VDI or IOmark-VDI-HC results. However, all testing was performed to the same standards, using the same test infrastructure and methods by Evaluator Group, thereby enabling comparisons to other Evaluator Group reported IOmark-VDI results.

Server Configuration

The configuration consisted of a cluster of 4 physical server nodes running VMware ESXi 6.5.0d with vSAN 6.6. The Hyperconverged systems used for testing included the following CPU, memory and network configuration. The storage media utilized changed for each configuration as noted.

- Memory: 1.5 TB of memory was used for pricing purposes
- Storage Media: 1@ Intel P4600 cache and 3 @ Intel P4500 capacity devices per node
- Total cost for 4 server nodes with HW, SW, Media and maintenance was $271,235.61
- Total number of VDI instances supported on 4 node cluster was 2,048 “Standard” VDI users
- Cost per IOmark-VDI-HC is ($271,235.61 / 2,048) = $132.44 for a “Standard” VDI instance

Comparison to Previously Reported Results

As with IOmark-VM results, the IOmark-VDI results obtained were compared to previously reported IOmark-VDI results available on iomark.org website. The previous best reported results for IOmark-VDI-HC Hyperconverged instances running the “Standard” workload is as follows:

- Total cost for 4 server nodes with HW, SW, Media and maintenance was $140,700.00
- Total number of VDI instances supported on 4 node cluster was 640
- Cost per IOmark-VDI-HC instance is ($140,700.00 / 640) = $219.84

Note: Published results are available on iomark.org for a Hyperconverged system showing 1,020 IOmark-VDI-HC users running an “Office” workload. However, “Standard” and “Office” workloads are not directly comparable, hence the comparison to the 640 “Standard” VDI users was used.

Appendix D - Database Workload Details

For the database workload, the HammerDB workload generation tool was utilized. As previously shown on page 6, a TPC-C like workload was configured with 800 warehouses and 56 workers. There was a 30 minute ramp up time followed by a 30 minute measurement interval. Both configurations were tested in the same manner with the same hardware and vSAN configurations. The only variable between configurations "A" and "B" was the number and type of storage media utilized as noted below.

Server Configuration

The configuration consisted of the same cluster of 4 physical nodes as detailed in other tests and Appendix E.

Intel Storage / Node		
	TPC Config "A"	TPC Config "B"
	Optane + NVMe	NVMe
Intel DC P4600-1600		1
Intel DC P4500-2000	4	3
Intel DC P4500-4000		
Intel DC P4800x-400	2	
Raw Capacity / Node	8,000	6,000
TPC-C Required Usable / Node	3,000	3,000
RAID Level Used	R-10	R-10
Dedup - Compression	No	Yes
Storage Overhead Factor	2.0	2.0
Usable Capacity / Node (GB)	4,000	3,000
TPC-C VM's / Node	2	2
Total TPC-C / Node	2,279,006	1,207,149

Intel Test Configuration Pricing		
	Optane + NVMe	NVMe
Intel DC P4600-1600	$ -	$ 1,567.00
Intel DC P4500-2000	$ 5,432.00	$ 4,074.00
Intel DC P4500-4000		
Intel DC P4800x-400	$ 3,040.00	$ -
1 Node Storage Media Total	$ 8,472.00	$ 5,641.00
4 Node Storage Media Total	$ 33,888.00	$ 22,564.00
4 Node System (Server Only)	$ 76,615.36	$ 76,615.36
4 Node VMware (ESXi)	$ 27,960.00	$ 27,960.00
4 Node VMware (vSAN)	$ 31,960.00	$ 31,960.00
3 Year Ent Support (HW + SW)	$ 66,127.01	$ 66,127.01
3 Year Media Maint. (5%)	$ 5,083.20	$ 3,384.60
Total 4 Nodes (HW, SW, Media, Mnt.)	$ 241,633.57	$ 228,610.97

Intel Price / Performance - Price / Cap.		
	Optane + NVMe	NVMe
$ / TPC-C (All + Maintenance)	$ 0.03	$ 0.05

Table 3 : Configuration and Pricing Details for TPC-C like database workload

Appendix E - Hardware Details

Server Configuration

The configuration consisted of a cluster of 4 physical server nodes running VMware ESXi 6.5.0d with vSAN 6.6. The Hyperconverged systems used for testing included the following CPU, memory and network configuration. The storage media utilized changed for each configuration as noted.

- Each Node in the 4 node cluster consisted of an Intel Xeon Scalable system platform
  - Intel Server System R2208WF, with 4 U.2 NVMe accessible slots
  - CPU: 2 x Intel Xeon 8168 CPU (24 cores @ 2.7 Ghz w/ hyper threading)
  - Memory: Tested with 256 GB DRAM, priced for comparison at 768 GB DRAM
  - NIC : Tested with 40 GbE XL710, price configured with onboard 10 GbE X-540 AT2

Hyperconverged Software

- VMware ESXi 6.5.0d
- VMware vSAN 6.6
- VMware vCenter 6.5.0d

* This document was developed with Intel and VMware funding. Although the document may utilize publicly available material from various vendors, it does not necessarily reflect the positions of such vendors on the issues addressed in this document.

Note: Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as “Spectre” and “Meltdown”. Implementation of these updates may make these results inapplicable to your device or system.