White Paper

Intel® Optane™ Solid State Drives Manufacturing Automation

Intel® Optane™ Solid State Drives Boost Virtual Server Performance for Intel® Memory Manufacturing Automation

Using Intel Optane SSDs in the VMware vSAN cache tier increased virtual server performance at Intel manufacturing fabs.

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Intel manufacturing facilities are complex environments, with each factory managed by hundreds of servers running 24/7 across two data centers for full redundancy. Reliability and efficient performance are key for automation management, process control, inventory, and analytics. Although the automation execution servers are stand-alone machines, most application, website, and database services run on VMware vSAN clusters for better operational efficiency (see Figure 1). Virtualization helps reduce costs and complexity, but performance can be constrained by storage performance.

To boost performance for virtualized workloads, Intel replaced NAND solid state drive (SSDs) in the VMware vSAN cache tier with Intel Optane SSDs, which are ideal for handling write-intensive cache operations. By replacing three 960 GB NAND SSDs with only two 375 GB Intel Optane SSDs in the cache tier, performance jumped for production applications, such as defect analysis, equipment-configurations-management web applications, and so on. Intel also saw advantages in routine operations, such as physical-to-virtual server conversions and SQL database restorations.

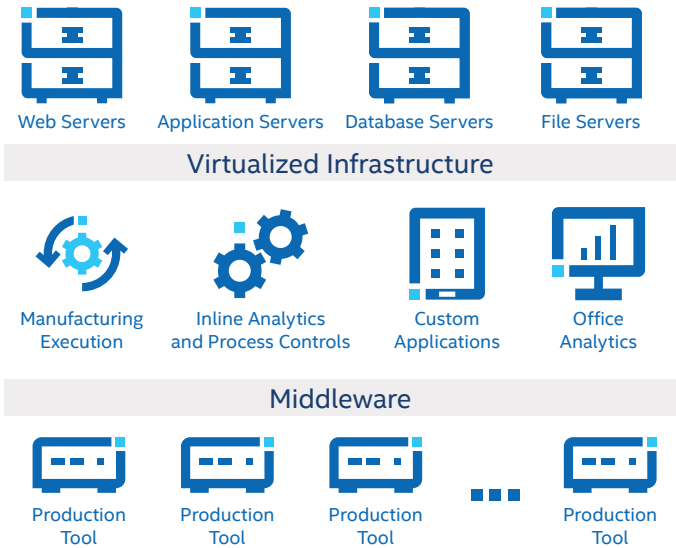


Figure 1. Intel fabs consolidate web, application, and database servers on VMware vSAN clusters for operational efficiency and reduced total cost of ownership (TCO)

In addition, by switching to more efficient Intel Optane SSDs for cache, Intel needed fewer physical drives in each server, which freed up space for future capacity growth.

Performance jumped for production applications after replacing three 960 GB NAND SSDs with only two 375 GB Intel Optane SSDs in the cache tier.

Intel manufacturing automation sets a high bar

Intel fabrication facilities are well known for their sophisticated manufacturing and processing systems. The memory factory in Dalian, China, is no exception. It is a complex environment of automation execution systems, web servers, application servers, and database servers. Together, they enable a carefully orchestrated symphony of automation and monitoring that initiates processing of thousands of silicon wafers per week.

In addition, that complex landscape undergoes frequent changes. Whenever Intel introduces new process technologies, its fabs need to quickly respond with customizations to the execution flows, shop-floor inline controls, and analytics capabilities. As a result, the production and support systems need to be both reliable and efficient in order to maintain high manufacturing levels without increasing costs or complexity.

One of the ways Intel maintains efficiency is through virtualization. Although mission-critical automation workloads are assigned to physical machines, other services, including databases and web apps, are virtualized on VMware vSAN clusters to provide consolidation that helps reduce costs and complexity. The vSAN clusters are hosted on physical servers powered by high-performance Intel® Xeon® Platinum processors.

Intel Xeon Scalable processors offer high performance for physical servers and for VMware vSAN. Overall performance of virtualized applications, however, is highly influenced by storage-cache-tier performance. That's because in an all-flash VMware vSAN cluster, 100 percent of the cache device is dedicated to write-buffering (up to a maximum of 600 GB). Better latency, higher disk throughput, and increased input/output operations per second (IOPS) are all essential for high-performing solutions, which makes the role and design of the cache tier critical in high-volume, latency-sensitive application use cases like Intel's manufacturing lines. Therefore, any performance increases to the cache tiers would likely boost overall performance for the Intel manufacturing workloads running on the vSAN clusters.

The Intel Optane technology advantage for cache

Recently, Intel needed to upgrade the operating system on many of its manufacturing VMware vSAN servers. This upgrade process provided a unique opportunity to replace the existing NAND SSD cache drives with Intel Optane SSDs to boost the performance of the cache tier.

The Intel automation architects knew that the unique architecture of Intel Optane technology makes it optimal for high-performing storage and computing. For example, Intel Optane SSDs can maintain consistent low-latency performance with high endurance, even as workloads increase significantly. Intel Optane technology architecture and characteristics make these drives ideal for use in the write-intensive cache tier of a vSAN cluster.

In addition, Intel Optane media does not need to erase data in blocks, which often leads to inefficient use of pages that need to be periodically cleared through garbage collection. Intel Optane SSDs are byte-addressable, so there is no need for garbage collection. The result is a direct positive impact on both performance and endurance for Intel Optane SSDs, compared to NAND SSDs.

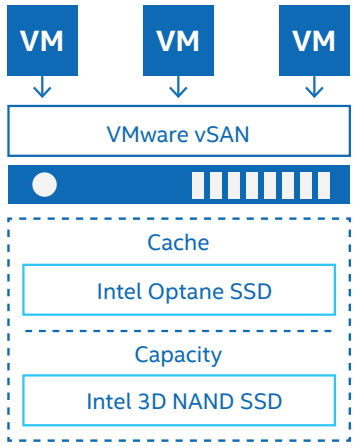


Figure 2. Intel Optane SSDs were used in the cache tier of the VMware vSAN cluster to increase the performance of write-intensive operations

Benchmark testing Intel Optane SSDs as cache

Before adopting the new design for the vSAN clusters, Intel validated the effectiveness of Intel Optane SSDs in the cache tier by capturing and comparing the performance data using HCIBench (a hyperconverged infrastructure [HCI] benchmark). The benchmarking tests were performed using two workload scenarios (70 percent read, 30 percent write random input/output [I/O], and 100 percent sequential write) that are relevant to Intel systems.

Despite the Intel Optane SSD configuration having a smaller cache size and fewer disk groups, HCIBench testing showed that the Intel Optane SSD configuration outperformed the existing configuration (see Table 1).

Table 1. Intel Optane SSDs exhibited greater throughput and lower latency than NAND SSDs for both 100 percent writes and a mixed read/write workload[1]

Intel Optane SSD Cache, Compared to NAND SSD Cache[1]	
70/30 Read/Write	**100 Percent Sequential Writes**
• 1.3x greater throughput • 1.98x lower read latency • 4.30x lower write latency	• 3.5x greater throughput • 7.63x lower write latency

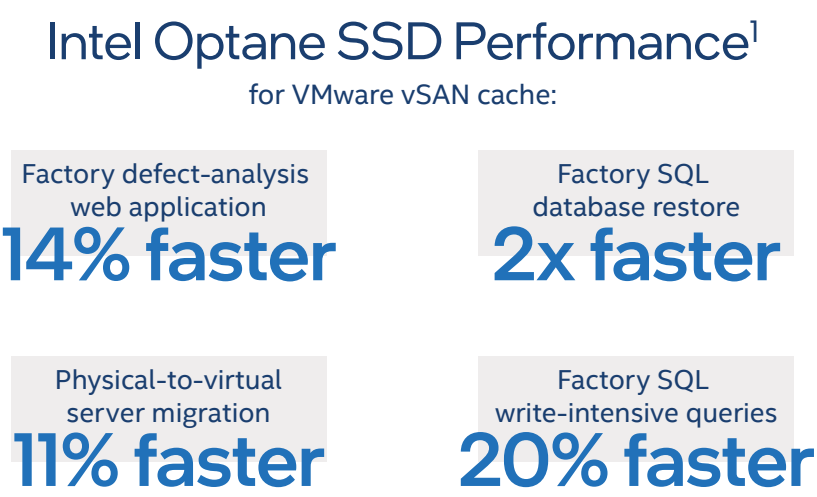


Figure 3. Data from the manufacturing production line showed that using fewer Intel Optane SSDs in cache improved performance compared to using a greater number of larger capacity NAND SSDs[1]

Intel Optane SSDs boost cache performance in production

Based on the success of the benchmark tests, Intel opportunistically incorporated the new design for vSAN clusters with Intel Optane SSDs into the new physical server configurations. All other hardware components, including the use of Intel Xeon Platinum 8168 processors, were identical both before and after the change. This consistency in hardware allowed Intel to capture performance data.

Figure 4 shows the original configuration, with all NAND SSDs for cache and capacity drives, and the new configuration, with Intel Optane SSDs for cache and NAND SSDs for capacity storage.[1] The configurations were used for machines hosting application, web, and database servers—all with redundancy for high availability.

Intel measured the performance of a Microsoft SQL Server database, web-based applications, and a manufacturing defect-detection application used in the manufacturing automation architecture. The results showed that the configuration (two disk groups of 375 GB Intel Optane SSDs in the cache tier) outperformed the original configuration (three disk groups of 960 GB NAND SSDs in the cache tier), especially in cases of write-intensive workloads. Detailed results are presented in the following sections.

Factory database server

Restoring a common factory SQL database was completed **2x faster** with Intel Optane SSDs in the cache tier.[1] Factory commands that included a mix of read and write queries performed similarly to the NAND SSD cache configuration, while write-intensive (INSERT, UPDATE, DELETE) queries performed up to 20 percent faster.

Defect-analysis application

A demanding defect-source-analysis application that is used to correlate defects to their sources ran **14 percent faster** on the two-disk-group configuration with Intel Optane SSDs as cache, compared to the three-disk-group configuration using NAND SSDs as cache.[1]

Factory web server

Intel compared production disk performance indicators for a web application on configurations with and without Intel Optane SSDs as cache. Virtual web servers in the new configuration performed with up to **10 times lower read latency and up to 40 times lower write latency**, compared to the original configuration.[1] Production-line workloads remained the same in both configurations.

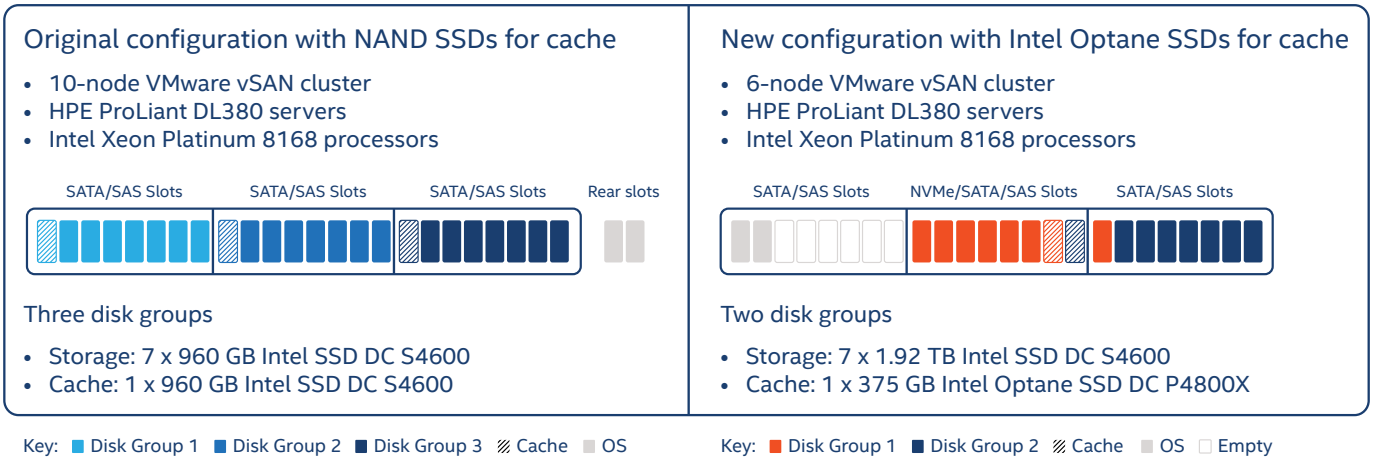
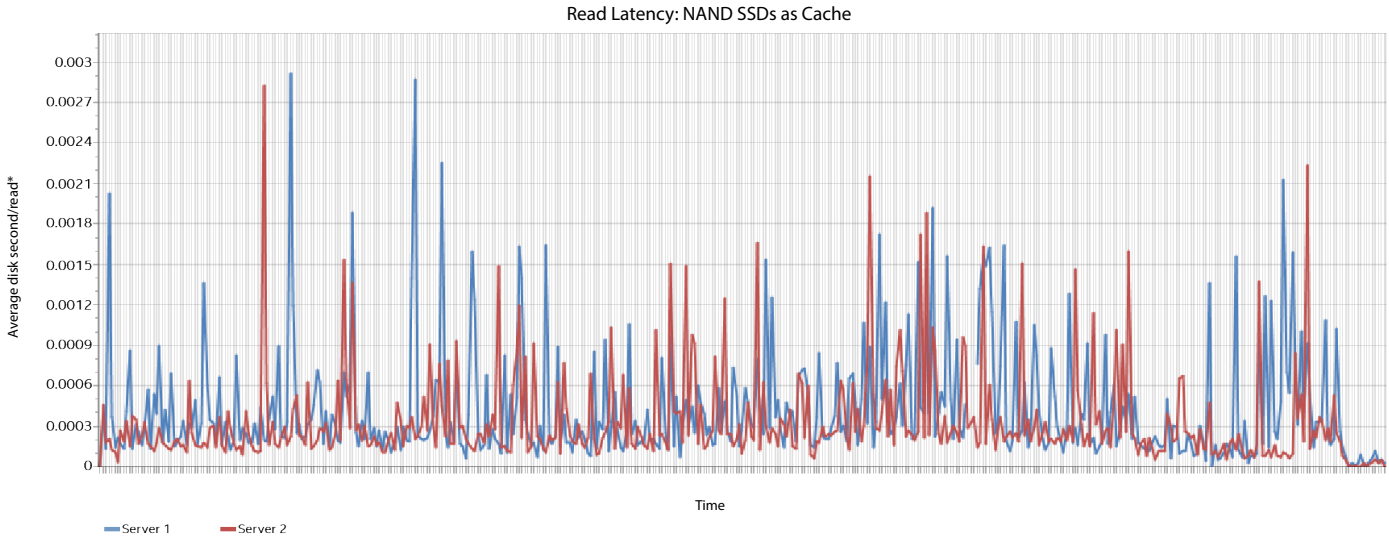


Figure 4. The original configuration was built with three disk groups (3 x 960 GB cache and 21 x 960 GB capacity); the updated configuration was built with two disk groups (2 x 375 GB cache and 14 x 1.92 TB capacity)



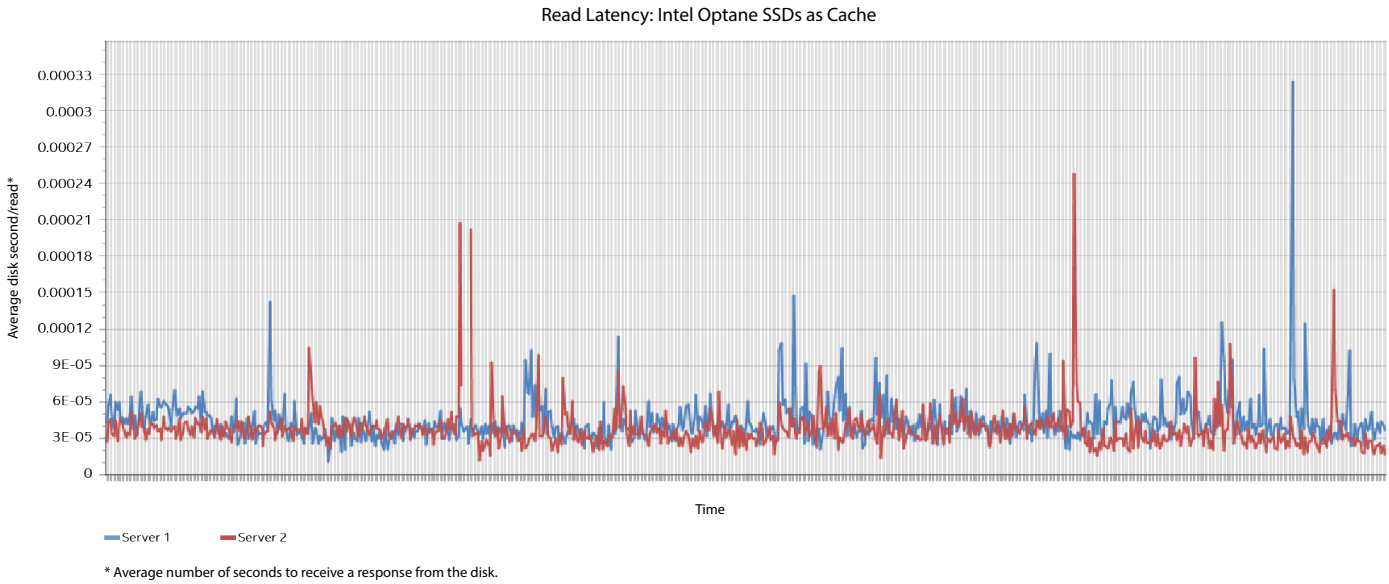


Figure 5. Comparison of read latency for two servers after switching from all NAND SSDs (top graph) to Intel Optane SSDs (bottom graph)[1]

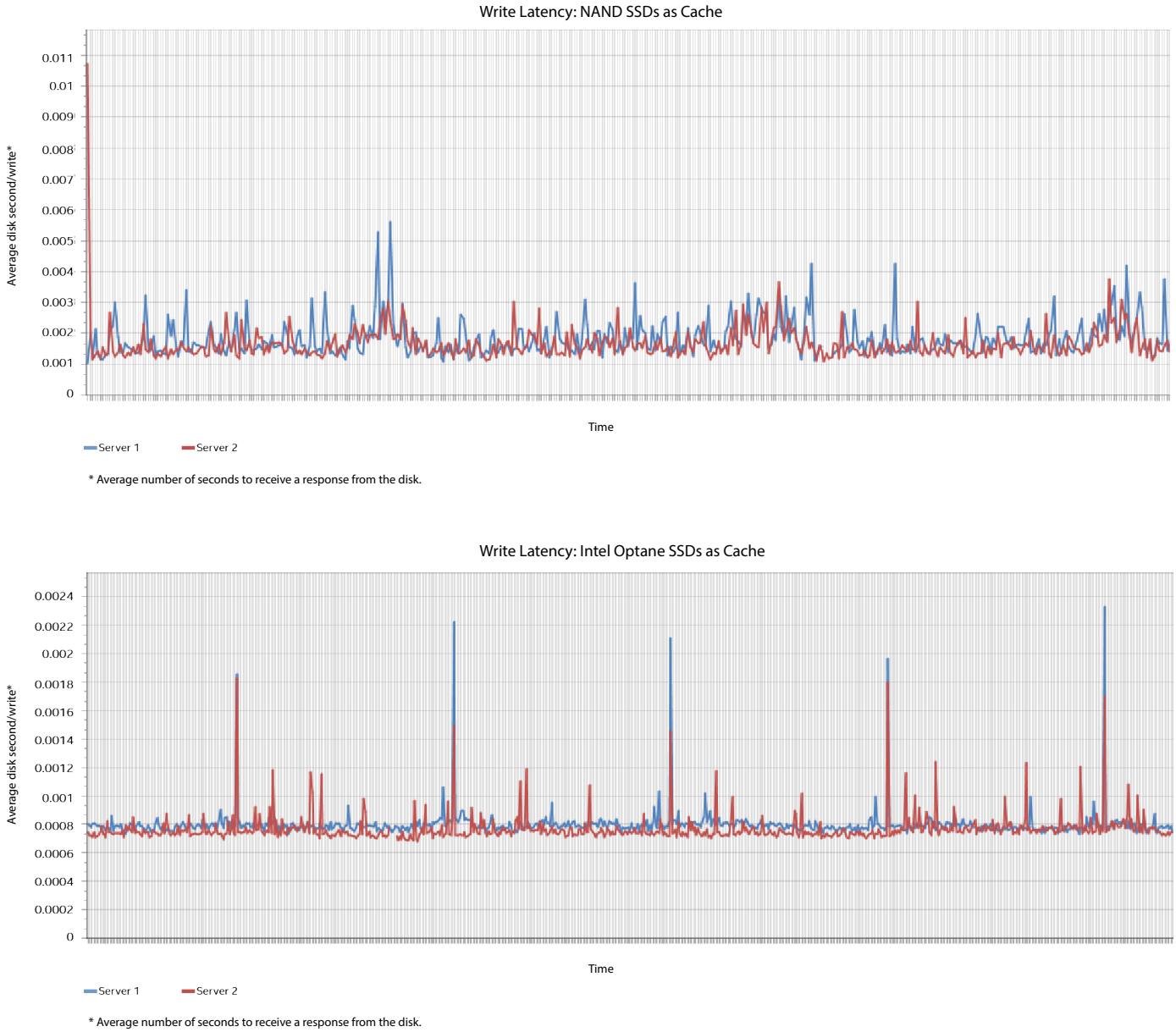


Figure 6. Comparison of write latency for two servers after switching from all NAND SSDs (top graph) to Intel Optane SSDs (bottom graph)[1]

Physical-to-virtual server migration

Using VMware vCenter Converter, the client/server migration of five physical servers (1 TB each) took only 4.5 hours on the configuration built with Intel Optane SSDs as cache, compared to 4 hours for the original configuration built with NAND SSDs as cache.

Better resource utilization

In addition to the performance improvements, Intel Optane SSDs demonstrated other gains for resource utilization and potential cost savings. For example, the NAND SSD cache drives took up more space in the server cages and required higher capacity drives. Switching from NAND SSDs to Intel Optane SSDs allowed the use of smaller capacity, highly efficient, and better performing cache, while also freeing up drive bays that could be used for expanding capacity storage as needed. By reducing the overall number of NAND SSDs, organizations can add capacity without increasing their data center footprints. Alternatively, businesses can maintain the same capacity while increasing performance and reducing power and cooling requirements in the data center.

Intel Optane SSDs: a perfect match for VMware vSAN clusters

Intel manufacturing automation was able to reduce the number of disk groups used by each server node in a VMware vSAN cluster from three to two, lowering the total cost of ownership (TCO). Additionally, Intel Optane SSD cache comprised 375 GB drives, compared to 960 GB drives, while maintaining the same or better performance. Based on these results, it's likely that using equal cache sizes would make the gains even more pronounced for the Intel Optane SSD cache–based vSAN configuration.

Deploy Intel Optane SSDs for your demanding workloads

Intel Optane SSDs allowed Intel manufacturing to improve performance for vSAN clusters, which in turn helped accelerate performance for critical production applications and routine operations. The exceptional combination of low latency, high endurance, and consistent responsiveness makes Intel Optane SSDs ideal for virtualized use cases in manufacturing automation or any demanding high-performance or hyperconverged architecture.

Learn more

Intel Optane SSDs: **intel.com/content/www/us/en/products/memory-storage/solid-state-drives/data-center-ssds/optane-dc-ssd-series.html**

How Intel optimized operations with virtualized industrial PCs: **intel.com/content/www/us/en/it-management/intel-it-best-practices/optimizing-operations-with-virtualized-industrial-pcs-brief.html**

How Intel Optane SSDs helped boost vSAN performance for increased manufacturing uptime: **intel.com/content/www/us/en/products/docs/storage/boosting-vsan-performance-manufacturing-brief.html**

[1] Performance results are based on testing by Intel IT from March to July, 2020. **Baseline:** 10-node VMware vSAN cluster. Per node: 2 x Intel Xeon Platinum 8168 processor (2.7 GHz/24 cores/205 W), CPU sockets: 2; RAM capacity: 768 GB—24 x 32 GB DIMM; RAM model: HPE 32 GB (1 x 32 GB) dual-rank x4 DDR4-2,666 CAS-19-19-19 registered; storage: 3 DG each with 7 x 960 GB Intel SSD DC S4600 and cache 1 x 960 GB Intel SSD DC S4600; network: vSAN redundant network over 10/25 Gb two-port HPE 640SFP28 Adapter; OS: VMware ESX 6.7. **New configuration:** Six-node VMware vSAN cluster. Per node: 2 x Intel Xeon Platinum 8168 processor (2.7 GHz/24 cores/205 W), CPU sockets: 2; RAM capacity: 768 GB—24 x 32 GB DIMM; RAM model: HPE 32 GB (1 x 32GB) dual-rank x4 DDR4-2,666 CAS-19-19-19 registered; storage: 2 DG each with 7 x 1.92 TB Intel SSD DC S4600 and cache 1 x 375 GB Intel Optane SSD P4800 NVMe; network: vSAN redundant network over 10/25 Gb two-port HPE 640SFP28 Adapter; OS: VMware ESX 6.7U3. 2–4x more write transactions with up to 7x improved latency: HCIBench run with VMware assistance on March 30, 2020: 70 read/30 write test: fio-8vmdk-100ws-4k-70rdpct-100randompct-4threads. 54 VM host on the baseline and 24 VM host on the new configuration. The results of the 70/30 were: Intel Optane SSD IOPS: 342,359 versus NAND SSD IOPS: 259,472; Intel Optane SSD write latency: 2.92 ms versus NAND SSD write latency: 12.57 ms; Intel Optane SSD throughput: 1,337 MB/s versus NAND SSD throughput: 1,013 MB/s, and also 100 percent write: fio-8vmdk-100ws-256k-0rdpct-0randompct-1threads. 54 VM host on the baseline and 24 VM host on the new configuration—for the large block/cluster size 100 percent sequential write test to get total throughput, Intel Optane SSD throughput 100% write: 5,338 MB/s versus NAND SSD throughput 100% write: 1,516 MB/s. SQL database restore 2x faster with Intel Optane SSDs: factory database restoration to both environments took 31 minutes on the new configuration versus 61 minutes on the baseline (2x faster). Write-intensive queries performed up 20 percent faster: factory database restoration to both environments, running two separate SQL session in loop, one doing read scan from all 555 database tables and a second session updating all database tables. The loop ran for 60 minutes on the baseline (all-flash) and 90 minutes on the new configuration (Intel Optane SSDs); update rate of 60,111 records/second on the baseline compared to 72,370 records/second on the new configuration; read 31.6M records/second on the baseline compared to 24.2M records/second on the new configuration. (Intel recommends using a different storage policy for large VMDK servers [>500 GB] to have a stripe with a four, as the new configuration includes double-sized disks (1.92 TB) compared to the baseline vSAN, so that object components would be less distributed.) Defect-source-analysis application ran 14 percent faster with Intel Optane SSDs: running the job against the same database, Intel repeated test four times and processed historical data; average run time in baseline was 2:04 minutes compared to 1:47 minutes on the new configuration. Document-management web page response: standard performance test in the factory production systems with the new configuration; application login, getting a document transaction, and filtering on the web user interface (UI) were all performed within defined limits or better. Physical to virtual (P2V) migration: P2V of five physical servers (1 TB) to the baseline system took 4.5 hours, compared to 4 hours on the new configuration.

Performance varies by use, configuration and other factors. Learn more at www.Intel.com/PerformanceIndex.

Performance results are based on testing as of dates shown in configurations and may not reflect all publicly available updates. See backup for configuration details. No product or component can be absolutely secure.

Your costs and results may vary.

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