Solution Brief

Intel® Optane™ SSDs
Manufacturing Automation

Boosting vSAN Performance for Increased Manufacturing Equipment Uptime

Intel Optane Solid State Drives (SSDs) meet low-latency requirements for increased workloads on virtualized industrial machines.

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Executive summary

Silicon manufacturing fabs use a complex combination of material, tools, and sophisticated processes to manufacture products. This paper provides insights into one of the infrastructure architecture improvements Intel memory factories chose to minimize cost, save clean room space, and ensure scalability when new process technologies or more tools need to be set up. The introduction of virtualization also made the platform easier to maintain as well. This paper also shows how one fab was able to introduce a new non-NAND-based storage technology, Intel Optane SSDs, without significant changes, in order to deliver the performance that manufacturing automation architecture needed.

Introduction

Intel's manufacturing is world famous for its automation and sophisticated processes. These processes produce intricate, multilayered compute and memory chips as the final product. Intel fabrication facilities ("fabs") run thousands of "tools" (production equipment) on the factory floor.

Each tool and its interfaces depend on a dedicated compute device—a virtualized industrial PC (IPC) client that is hosted in a data center server cluster—to communicate with the MES (manufacturing execution system). Tool interfaces communicate with virtualized IPCs, which then convey tool health and other information via a software controller to the MES, inline process controls, and health-check/fault-tolerance systems (see Figure 1).

In a typical non-virtualized manufacturing setting, IPCs physically sit either on the factory floor next to the tool or in a separate data center, and the tool and the client work together. Intel made the unique decision to virtualize its IPCs to save costly clean room space in one of its fabs. This change produced several benefits, including consolidation, lower total cost of ownership (TCO), and faster time to results. (Read "Optimizing Operations with Virtualized Industrial PCs" for a more complete discussion on this solution.)

Increased workloads demand high performance for virtualization

Computing workloads that are typical in silicon manufacturing are directly proportional to material start. One of Intel's high-volume memory fabs has thousands of sophisticated automated tools and virtualized IPCs that execute millions of calls each day with the MES. Tens of thousands of calls are made daily from just one IPC. Cycle time, work-in-progress (WIP) turn, throughput time, and line yield are all key indicators of performance.

As a result, fault tolerance plays a critical role in silicon manufacturing. The dedicated connection between each tool and IPC is critical because it allows the line of communication to stay active for an entire message exchange session.

Semiconductor manufacturing terms

Fab: A wafer-fabrication facility.

Wafer: Purified silicon that has been melted to form an ingot, which is then sliced into discs. Semiconductor designs are transferred to wafers via a step-by-step process.

Lot: A logical container of materials to process. In silicon wafer fabs, a lot contains 1–25 wafers.

Tool: Equipment that processes materials, transferring the product design onto wafers layer by layer. A tool performs numerous operations to build complex transistors on a thin sheet of silicon.

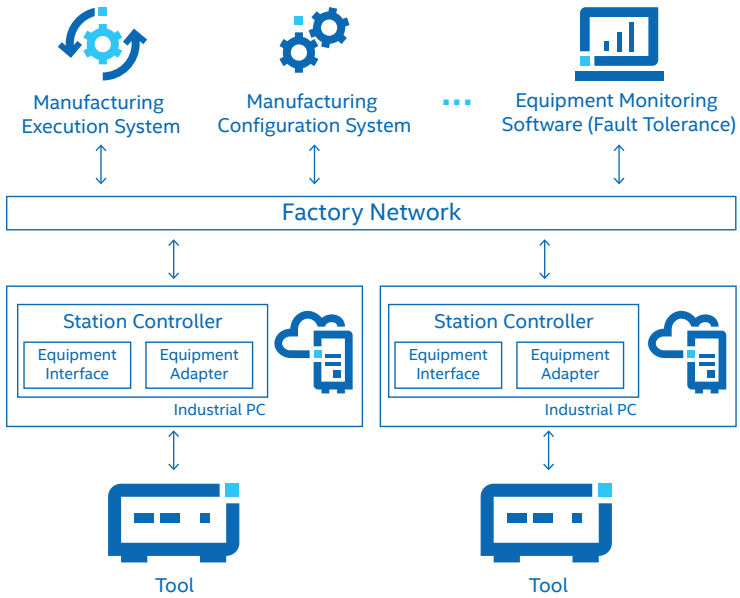

Figure 1. Each silicon manufacturing tool on the factory floor is individually paired with an IPC client that communicates with process controls thousands of times per day

Redundancy is not an option because the message exchange cannot be interrupted due to the 1-to-1 relationship between the tool and IPC. If data is not transmitted from the tool to the IPC, or from the IPC to inline process controls at the expected time (often a matter of seconds) and frequency, the fault-tolerance system triggers an alarm that shuts down material processing (also known as a lot abort). Although this type of shutdown is due to a false alarm, the effect is very real, causing expensive tool underutilization and/or material loss.

As material starts increased at the high-volume memory fab, the amount of data and transactions also increased. Enormous amounts of data had to be transferred with minimal delay among the tool, virtualized IPC, and MES. Intel Manufacturing Automation worked to design a more robust, efficient, and manageable solution using Intel Optane technology to optimize performance and avoid expensive production delays in the memory fab.

A solution that provides multiple benefits

Considering the 1-to-1 relationship between tools and IPCs, with no room for redundancy, traditional virtualization was not an option. Instead, Intel engineers implemented a "stretched cluster" design with thin provisioning across two data centers, which improves efficiency and reliability by providing a backup measure in case one data center goes down (see Figure 2). Unlike a standard cluster architecture, in a stretched cluster, servers are hosted in both data centers with witness servers watching over the vSAN.

For this architecture to work at its best, optimal network connectivity and cache tier performance are essential. Intel Optane SSDs were found to be better for the write-heavy disk operations in the cache tier than traditional NAND SSDs. Because of their predictable and consistent low latency, high endurance, and high read/write performance, Intel Optane Solid State Drives (SSDs) are ideal for the stretched cluster.

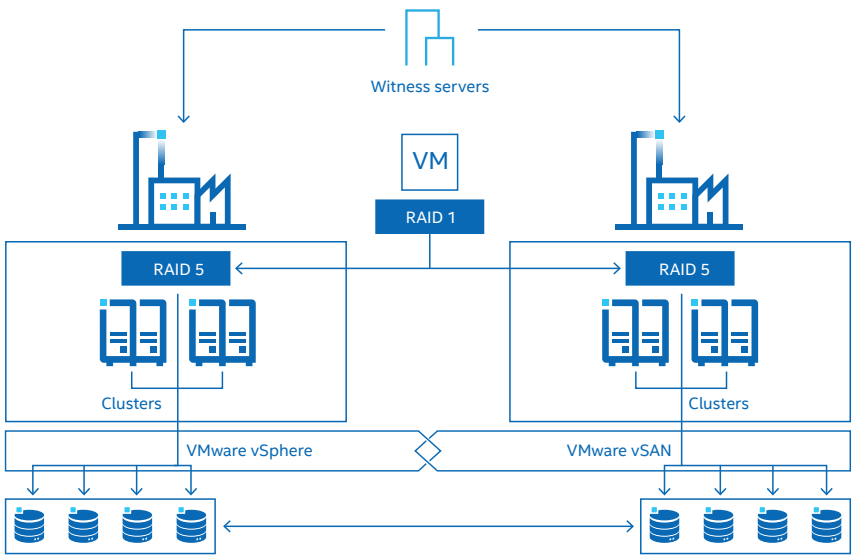

Figure 2. Reference design of the "stretched cluster" between two data centers—the cluster has several servers in each data center hosting many VMs

After running preliminary benchmark testing, Intel Manufacturing Automation engineers installed Intel Optane SSDs in one cluster to compare performance against an existing NAND SSD–based cluster. Table 1 shows the configuration details in the comparison.After running preliminary benchmark testing, Intel Manufacturing Automation engineers installed Intel Optane SSDs in one cluster to compare performance against an existing NAND SSD–based cluster. Table 1 shows the configuration details in the comparison.

Table 1. Configuration of memory fab facility data centers

Baseline cache tier (before implementing Intel Optane technology)	Improved cache tier (using Intel Optane technology for cache and SSDs for capacity)
18-node VMware vSAN cluster	8-node vSAN cluster
Per-node: 2 x Intel® Xeon® Platinum 8168 processor at 2.70 GHz, CPU sockets: 2	Per-node: 2 x Intel Xeon Platinum 8168 processor at 2.70 GHz, CPU sockets: 2
RAM capacity: 768 GB (24 x 32 GB DIMM); RAM model: HPE 32 GB 2Rx4 PC4-2666V-R Smart Kit	RAM capacity: 768 GB (24 x 32 GB DIMM); RAM model: HPE 32 GB 2Rx4 PC4-2666V-R Smart Kit
Storage: 3DG each with 7 x 960 GB Intel® SSD DC S4600 and cache 1 x 960 GB Intel SSD DC S4600	**Storage: 3DG each with 5 x 1.92 TB Intel SSD DC S4600 and cache 1 x 750 GB NVM Express (NVMe) Intel Optane SSD DC P4800X**
Network: vSAN redundant network over HPE Ethernet 10/25 Gb 2-port 640SFP28 adapter	Network: vSAN redundant network over HPE Ethernet 10/25 Gb 2-port 640SFP28 adapter
Operating system: VMware ESX 6.7U1	Operating system: VMware ESX 6.7U3

Intel Optane technology delivers low latency and high performance

Switching from NAND to Intel Optane SSD–based clusters provided the high-volume memory fab with numerous performance benefits:

Improved vSAN performance: After Intel engineers installed Intel Optane SSDs in the cache tier, performance improved greatly. Although the workload remained the same for the IPC (see the top graph in Figure 3), latency dropped to near zero after the same IPC was migrated to the cluster with Intel Optane SSDs in the cache tier (see the bottom graph in Figure 3).

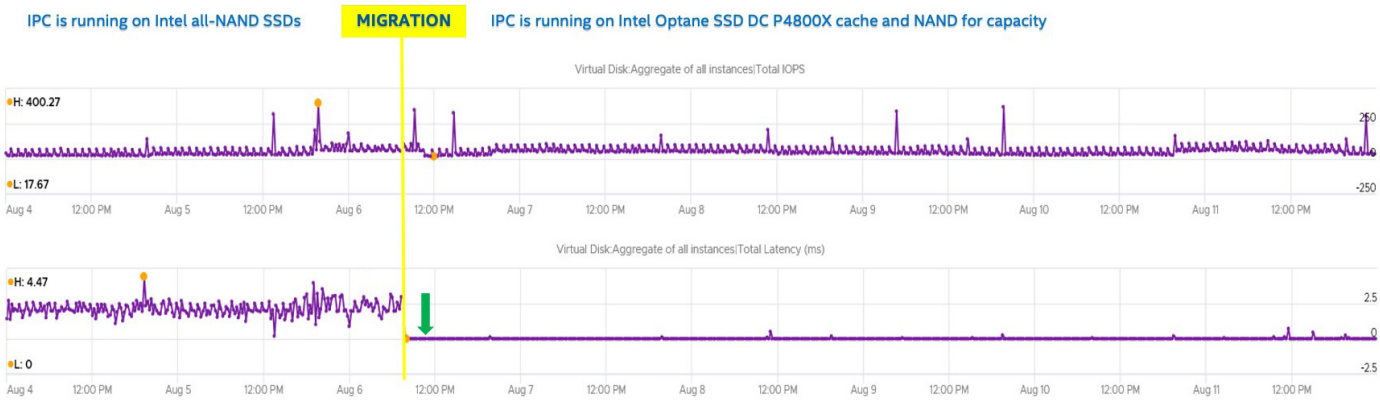

Figure 3. Comparison of IPC performance after switching from all NAND SSDs to a mix of NAND and Intel Optane SSDs (the yellow line marks the time the switch was made)

Improved shop floor application performance: Operations View is an application used in IPCs that allows users to remotely view and manage tools. When IPCs were migrated into the Intel Optane SSD cluster, the number of times that Operations View was unresponsive decreased by 79 percent, from 115 to 24 times per week. With less delay, the user interface (UI) displays application data quickly for precise remote management, as shown in Figure 5.

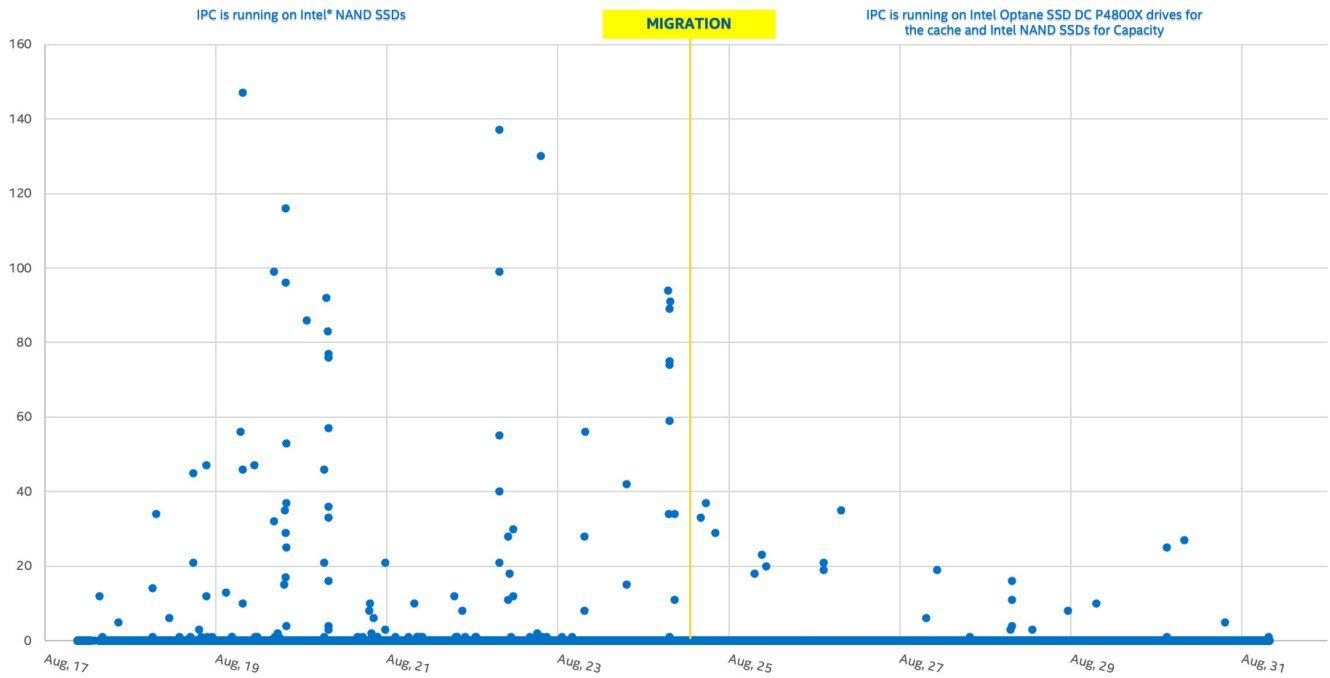

Figure 4. The improved performance of the Operations View application before and after Intel Optane SSDs were installed in the cache tier

Day Two operations benefits

- **Faster vMotions:** VMware vSphere vMotion ran 55 percent faster, performing a live migration in four minutes instead of nine (see Figure 5).
- **Reduced time for patching/updates:** Historically, IPC VM patching is demanding on both CPU and disk performance. In the cluster using Intel Optane SSDs in the cache, patching/update time was cut in half, with the time window for patching reduced from 1 hour to 30 minutes.

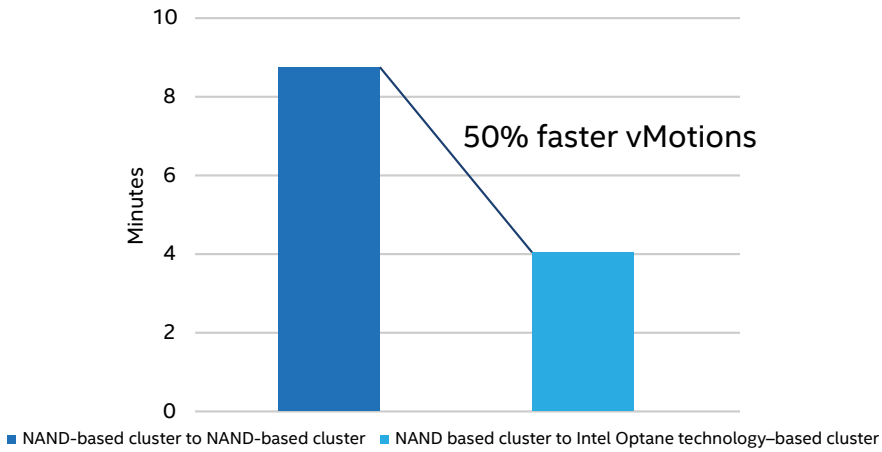

Figure 5. Improvement in VMware vSphere vMotion with Intel Optane SSDs in the cache tier

Conclusion

Intel Optane SSDs are shown to be well suited for write-intensive use cases like this virtualized IPC, including critical factory applications and databases. The combination of vSAN with Intel Optane technology delivers the high performance needed for data- and transaction-intensive workloads in manufacturing automation.

Learn more

Read more about the transition to virtualized IPCs in the white paper, "**Optimizing Operations with Virtualized Industrial PCs.**"

Visit the Intel Optane SSD website: **intel.com/optanedatacenter**

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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