TECHNOLOGY BRIEF

Data Center Memory and Storage Hierarchy
Intel® Optane™ Technology

Intel® Optane™ Technology: Memory or Storage? Both.

Not NAND-based and not DRAM: this industry disrupting technology takes the best of both to establish new tiers in the memory/storage hierarchy.

The stakes are high in today's data centers. Organizations have access to massive quantities of data promising valuable insights and new opportunities for business. But data center architects need to rethink and redesign their system architectures to ingest, store, and process all that information. Similarly, application owners need to assess how they can process data more effectively. Those who don't re-architect might find themselves scrambling just to keep from being drowned in a data deluge.

The challenge for storage architects is that memory and storage solutions have historically been limited by capacity, performance, or cost. For example, traditional DRAM is great for in-memory processing of data at high speeds, but it's expensive and limited in capacity and scalability. NAND-based storage, such as traditional solid state drives (SSDs), offers greater capacity and a lower cost relative to DRAM, but it can't offer the same levels of performance. Hard-disk drives (HDDs) can provide massive storage at low prices, but spinning disks bring well-understood total-cost-of-ownership (TCO) issues around reliability, physical space requirements, cooling, and much more. These memory and storage limitations result in data center architecture gaps when trying to balance capacity, performance, and cost considerations.

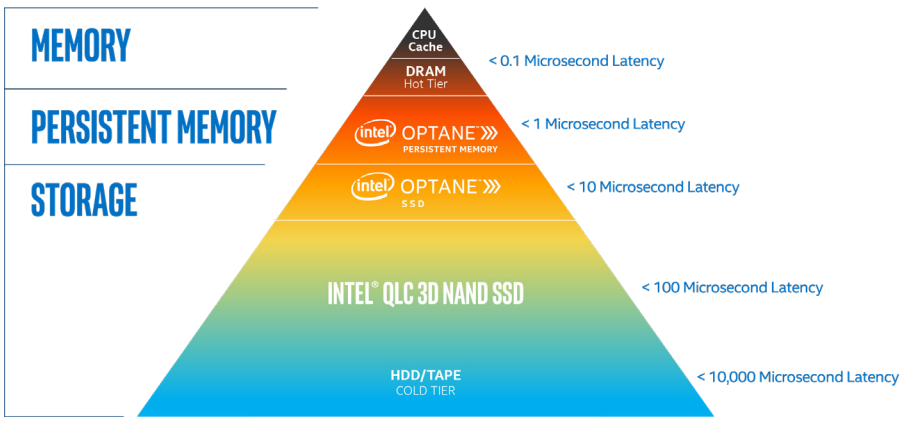

Figure 1. Intel® Optane™ technology fills memory and performance gaps in the data center

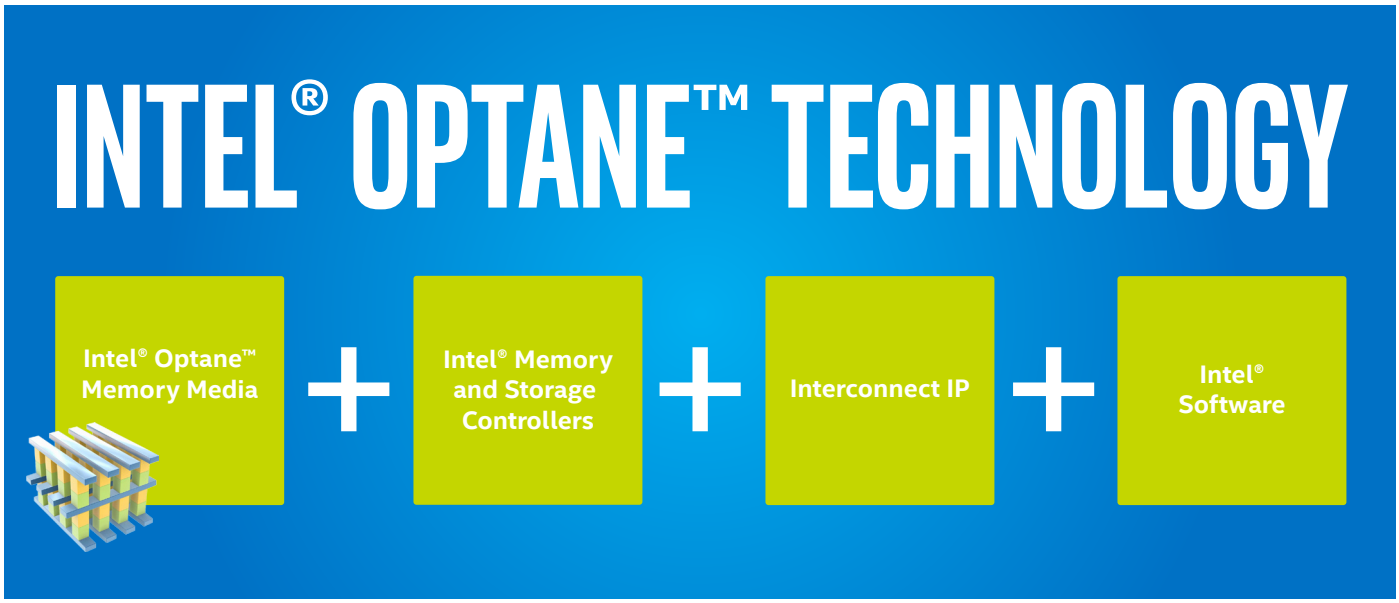

Figure 2. Intel® Optane™ technology combines Intel® Optane™ memory media with Intel® memory controllers and specialized hardware and software

A New Approach to Memory and Storage

Intel is pioneering a new approach for data center architectures that closes the gap between traditional memory and storage. The keystone to this approach is Intel® Optane™ technology. Intel Optane technology is not based on NAND; it's a whole new technology built on a unique architecture that allows memory cells to be individually addressed in a dense, transistor-less, stackable design. Intel Optane technology comprises Intel® Optane™ memory media combined with advanced system memory and storage controllers, along with interface hardware and software enhancements, as shown in Figure 2.

Memory and Storage Flexibility

Intel Optane technology is fundamentally different from both traditional DRAM and NAND-based drives, but it offers characteristics of both.

The key to Intel Optane technology is Intel Optane memory and storage media: a revolutionary new memory architecture that stacks memory grids in a three-dimensional matrix to improve density, increase performance, and provide persistence (Figure 3). This media architecture allows Intel Optane technology to act like DRAM (byte addressability, high endurance, write in place) or traditional storage (block addressability, persistence), depending on the use case or product configuration. That capability offers significant performance advantages compared to traditional NAND media-based drives. For example, because Intel Optane technology allows memory cells to be individually accessed and updated, there's no need for garbage collection. As a result, Intel Optane memory and storage media offers speeds close to DRAM, with the persistence of traditional SSDs.

One of the many benefits offered by the innovative architecture of Intel Optane memory and storage media is that it can be deployed in a variety of form factors that can connect to either the memory channel or the storage bus to provide a range of memory and storage solutions for storage designers.

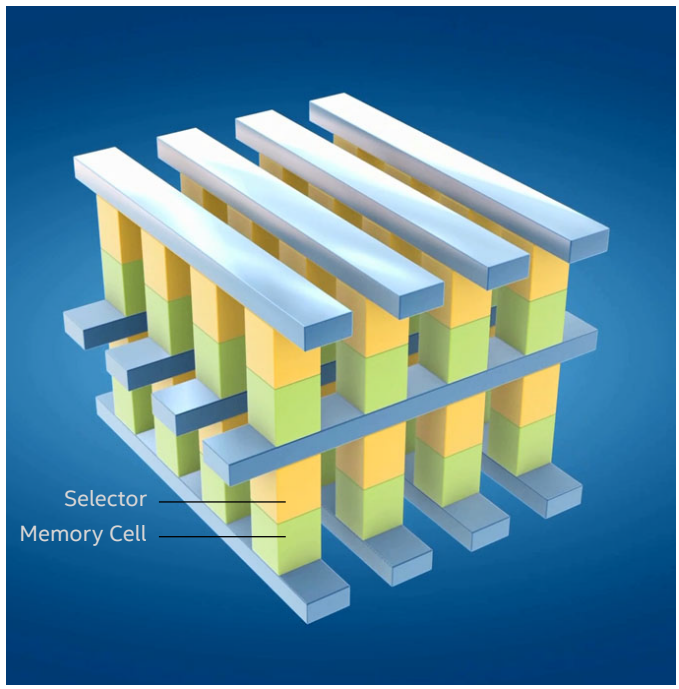

Figure 3. Intel® Optane™ memory and storage media offers properties of both memory and storage by using a revolutionary 3D structure that provides high density, low latency, and persistence

Intel Optane Technology as Persistent Memory

Intel® Optane™ persistent memory (PMem) in App Direct Mode delivers Intel Optane technology as persistent memory modules, which plug into standard DIMM slots on the memory channel. Unlike traditional DRAM, Intel® Optane™ PMem offers two important features to revolutionize memory and storage: persistence, which means data is retained even in the event of a power loss or restart, and high density—up to 512 GB per DIMM, which is double the maximum density of current DRAM DIMMs.

Applications that have been optimized for Intel Optane PMem avoid the significant software overhead of input/output (I/O) operations and instead benefit from much faster low-latency memory-access operations. This advantage enables organizations to transform their systems and services to deliver new advancements across a wide range of data center use cases, including improved analytics with in-memory databases, high-performance in-memory computing, artificial intelligence (AI), high-capacity virtual machines (VMs) and containers, and content delivery networks (CDNs).

Intel Optane PMem also significantly reduces in-memory database restart times because the database does not have to be reloaded into volatile memory after a shutdown. And with Intel Optane PMem, organizations can more affordably scale system memory capacity to unprecedented levels because the cost per gigabyte of memory is lower with Intel Optane PMem modules, compared to traditional DRAM DIMMs.

Intel Optane Technology as Volatile Memory

Intel Optane PMem in Memory Mode enables applications to make use of Intel Optane PMem as expanded volatile system memory. Memory Mode offers the advantage of additional system memory capacity (module sizes up to 512 GB), without needing to rewrite software.

Intel® Optane™ SSDs as memory-mapped I/O let businesses extend their DRAM for select Linux applications. One way to do this is to configure the Intel® Optane™ SSD DC P4800X to use Intel® Memory Drive Technology, which allows users to grow a server's volatile memory beyond DRAM capacity limits, or to replace high-capacity DIMMs with a higher-capacity, lower-cost/GB alternative that can provide similar performance to DRAM. In addition, Intel Memory Drive Technology requires no changes to application software. This capability is particularly beneficial to businesses and researchers in genomics, the pharmaceutical industry, radiology, and other fields that face a growing hunger for memory and storage, but that are constrained by the high cost and limited density of DRAM or the need for a large memory footprint.

Intel Optane Technology as Storage

Intel Optane PMem in Storage Over App Direct Mode makes PMem address space accessible through standard file APIs supported by current generation hypervisors and Windows and Linux operating systems. This allows existing storage-based applications to access the App Direct region of Intel Optane PMem modules without any modifications to the existing applications or the file systems that expect block storage devices. Storage over App Direct Mode provides high-performance block storage, without the latency of moving data to and from the I/O bus.

Intel Optane SSDs enable an entirely new storage tier between Intel Optane PMem and NAND SSDs that brings data closer to the processor for fast caching or fast storage of hot and warm data.

In contrast to traditional NAND-based SSDs, Intel Optane SSDs aren't limited to a "sweet spot" for peak performance. Intel Optane technology provides high random read/write performance, along with consistent, low latency that is ideal for demanding database applications that require frequent, high-speed caching, logging, or journaling. Businesses can

Table 1. Comparison of memory and storage: Intel® Optane™ PMem DIMMs and Intel® Optane™ SSDs

	Intel® Optane™ Persistent Memory 	Intel® Optane™ SSD with Intel® Memory Drive Technology 	Intel® Optane™ SSD 
Interface	Memory Channel	PCIe Bus	PCIe Bus
Capacity	Up to 512 GB per DIMM	Up to 1.5 TB per SSD	Up to 1.5 TB per SSD,
Intel Platform	2nd Generation Intel® Xeon® Scalable	Any	Any
Function	App Direct Mode: Persistent Memory Memory Mode: Volatile Memory Storage Over App Direct Mode: Persistent Storage	Volatile Memory	Persistent Storage
Form Factor	DIMM	U.2, M.2, AIC	U.2, M.2, AIC
Operating System	Windows, Linux, VMware ESXi	Linux	Any

take advantage of this benefit by deploying Intel Optane SSDs to accelerate caching, as an alternative to using large quantities of costly, limited-capacity DRAM. With this strategy, organizations can deploy Intel Optane SSDs for caching, and high-capacity Intel® QLC NAND-based SSDs as affordable capacity storage.

Intel Optane SSDs also offer high endurance and quality of service, which makes them a good fit for write-intensive uses, such as online transaction processing (OLTP), high performance computing (HPC), and data caching and logging.

In particular, Intel Optane SSDs provide consistent, high performance under load, reaching peak performance at lower queue depths, where nearly all real-world applications operate. In comparison, traditional NAND storage drives often reach optimum performance levels only at higher queue depths—beyond the usable range of most applications. Peak performance at higher queue depths does not accurately reflect real-world drive performance. As a result, Intel Optane SSDs offer enhanced performance for applications, compared to NAND-based SSDs.

Quickly Access More Data with Intel Optane Technology

The versatility of Intel Optane technology allows organizations to deploy a solution that best meets their specific business needs and workloads. For example, when performance and persistence are key, Intel Optane PMem offers an outstanding option, while still supporting capacities much greater than standard DRAM. For organizations that need even greater memory capacities, Intel Optane SSDs with Intel Memory Drive Technology offer high capacities and flexibility to be used as memory or storage as needs change over time.

Many businesses can achieve significant gains in performance, capacity, and overall cost savings by simply deploying Intel Optane PMem and Intel Optane SSDs in their data centers. For example, most organizations run transactional databases as part of their operations. These businesses can create cost-effective solutions for transactional workloads by using low-latency SSD DC P4800X drives in the cache tier instead of standard NAND SSDs to handle write operations, while using Intel QLC 3D NAND SSDs in the capacity tier to handle read operations. This combination can lower operating costs while providing exceptional performance.

As another example, businesses can use Intel Optane PMem to extend or displace DRAM and move more data into memory for in-memory database platforms, like the SAP HANA platform. Higher memory densities mean that enterprises can consolidate larger transactional and analytics systems into the same physical space, which can help reduce costs in the data center.

Quickly Access More Data with Intel Optane Technology

These are just a few of the many ways Intel Optane technology can transform modern data centers. Intel Optane technology is ideal for all types of devices, applications, and services requiring fast access to large sets of data. The innovative architecture removes performance bottlenecks to optimize CPU utilization for platforms powered by Intel® Xeon® Scalable processors. That optimization can allow businesses to achieve:

- More transactions for sales
- Faster insights from larger datasets for analytics
- Greater productivity for creative work
- Deeper understanding of data for scientific research

Get started by deploying the SSD DC P4800X in the data center today, and Intel Optane PMem in early 2019, alongside general availability of 2nd generation Intel Xeon Scalable processors.

Learn More

- "Reimagining Memory and Storage in the Data Center:" **intel.com/content/www/us/en/products/docs/memory-storage/solid-state-drives/data-center-ssds/optane-ssds-transform-memory-storage-hierarchy-brief.html**
- Intel® Optane™ technology: **intel.com/optane**
- Intel® Optane™ SSD DC P4800X: **intel.com/content/www/us/en/products/memory-storage/solid-state-drives/data-center-ssds/optane-dc-p4800x-series.html**
- Intel® Optane™ persistent memory: **https://newsroom.intel.com/editorials/re-architecting-data-center-memory-storage-hierarchy/**

© Intel Corporation Printed in USA 0220/JW/PRW/NSG Please Recycle 338458-005US