



INTEL[®] OPTANE[™] SSD DC P4800X

WORLD'S MOST RESPONSIVE DATA CENTER SSD

April 2017

INTRODUCING INTEL[®] OPTANE[™] SSD DC P4800X

World's Most Responsive Data Center SSD¹

Delivering an **industry leading combination of low latency, high endurance, QoS and high throughput**, the Intel® Optane™ SSD is the first solution to **combine the attributes of memory and storage**. This innovative solution is optimized to **break through storage bottlenecks** by providing a new data tier. It accelerates applications for **fast caching and storage, increasing scale per server** and reducing transaction cost. Data centers based on the latest Intel® Xeon® processors can now also **deploy bigger and more affordable datasets** to gain new insights from larger memory pools.



1. Responsiveness defined as average read latency measured at queue depth 1 during 4k random write workload. Measured using FIO 2.15. Common configuration - Intel 2U PCSD Server ("Wildcat Pass"), OS CentOS 7.2, kernel 3.10.0-327.el7.x86_64, CPU 2 x Intel® Xeon® E5-2699 v4 @ 2.20GHz (22 cores), RAM 396GB DDR @ 2133MHz. Intel drives evaluated - Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P3700 1600GB. Samsung drives evaluated - Samsung® SSD PM1725a, Samsung® SSD PM1725, Samsung® PM963, Samsung® PM953. Micron drive evaluated - Micron® 9100 PCIe® NVMe® SSD. Toshiba drives evaluated - Toshiba® ZD6300. Test - QD1 Random Read 4K latency, QD1 Random RW 4K 70% Read latency, QD1 Random Write 4K latency using fio-2.15.

*Other names and brands may be claimed as the property of others.

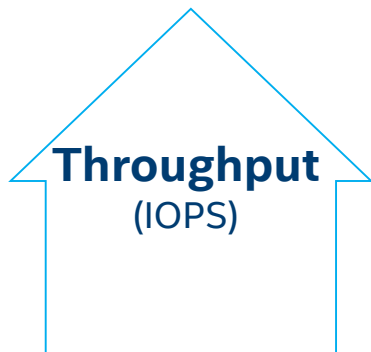
MOST RESPONSIVE DATA CENTER SSD IN THE WORLD

1. Responsiveness defined as average read latency measured at queue depth 1 during 4k random write workload. Measured using FIO 2.15. Common configuration - Intel 2U PCSD Server ("Wildcat Pass"), OS CentOS 7.2, kernel 3.10.0-327.el7.x86_64, CPU 2 x Intel® Xeon® E5-2699 v4 @ 2.20GHz (22 cores), RAM 396GB DDR @ 2133MHz. Intel drives evaluated - Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P3700 1600GB. Samsung drives evaluated - Samsung* SSD PM1725a, Samsung* SSD PM1725, Samsung* PM963, Samsung* PM953. Micron drive evaluated - Micron* 9100 PCIe* NVMe* SSD. Toshiba drives evaluated - Toshiba* ZD6300. Test - QD1 Random Read 4K latency, QD1 Random RW 4K 70% Read latency, QD1 Random Write 4K latency using fio-2.15.

*Other names and brands may be claimed as the property of others.

Intel[®] Optane[™] SSD DC P4800X

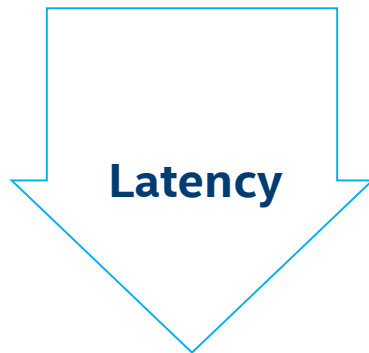
**Breakthrough
Performance**



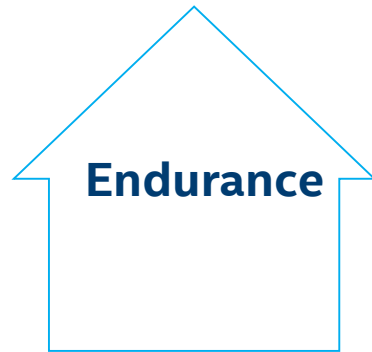
**Predictably
Fast Service**



**Responsive
Under Load**



**Ultra
Endurance**



STORAGE PERFORMANCE CHARACTERIZATION

Latency vs. Load: NAND SSD vs. Intel® Optane™ SSD (Intel® SSD DC P3700 vs. Intel® Optane™ SSD DC P4800X)



10x latency reduction

- < 10usec latency[†]

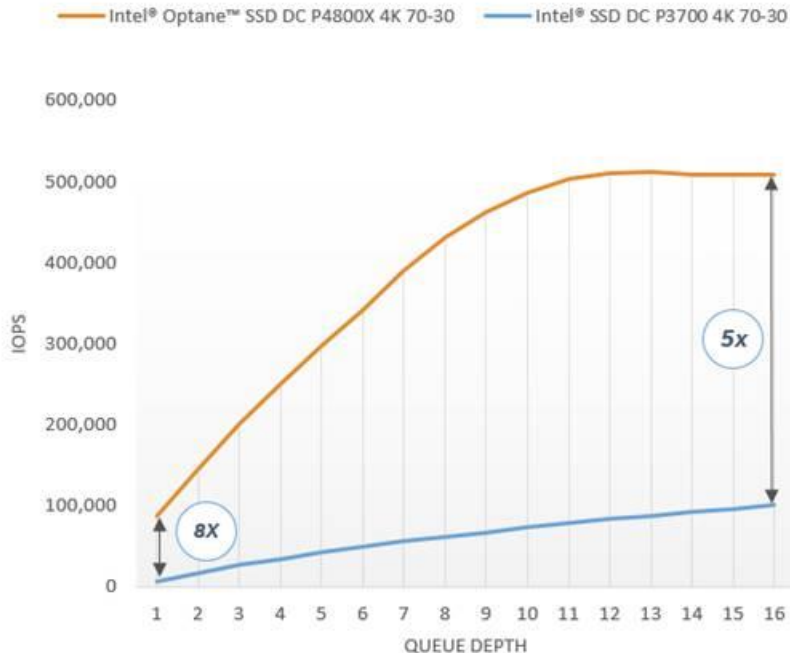
100x QoS improvement

- < 200usec 99.999th r/w[†]

[†] vs. NAND based SSD

Breakthrough Performance

4K 70/30 RW Performance at Low Queue Depth



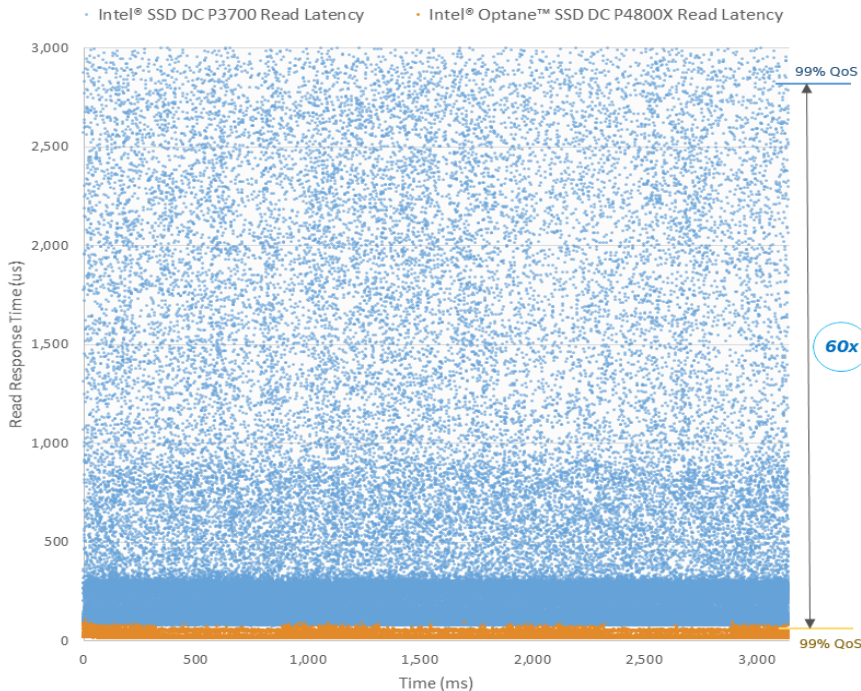
- ✓ **5-8x faster** at low Queue Depths¹
- ✓ Vast majority of **applications generate low QD** storage workloads

1. Common Configuration - Intel 2U PCSD Server ("Wildcat Pass"), OS CentOS 7.2, kernel 3.10.0-327.el7.x86_64, CPU 2 x Intel® Xeon® E5-2699 v4 @ 2.20GHz (22 cores), RAM 396GB DDR @ 2133MHz. Configuration - Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P3700 1600GB. Performance - measured under 4K 70-30 workload at QD1-16 using fio-2.15.

Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.

Predictably Fast Service

Read QoS in Mixed Workload



✓ up to **60X** better at 99% QoS¹

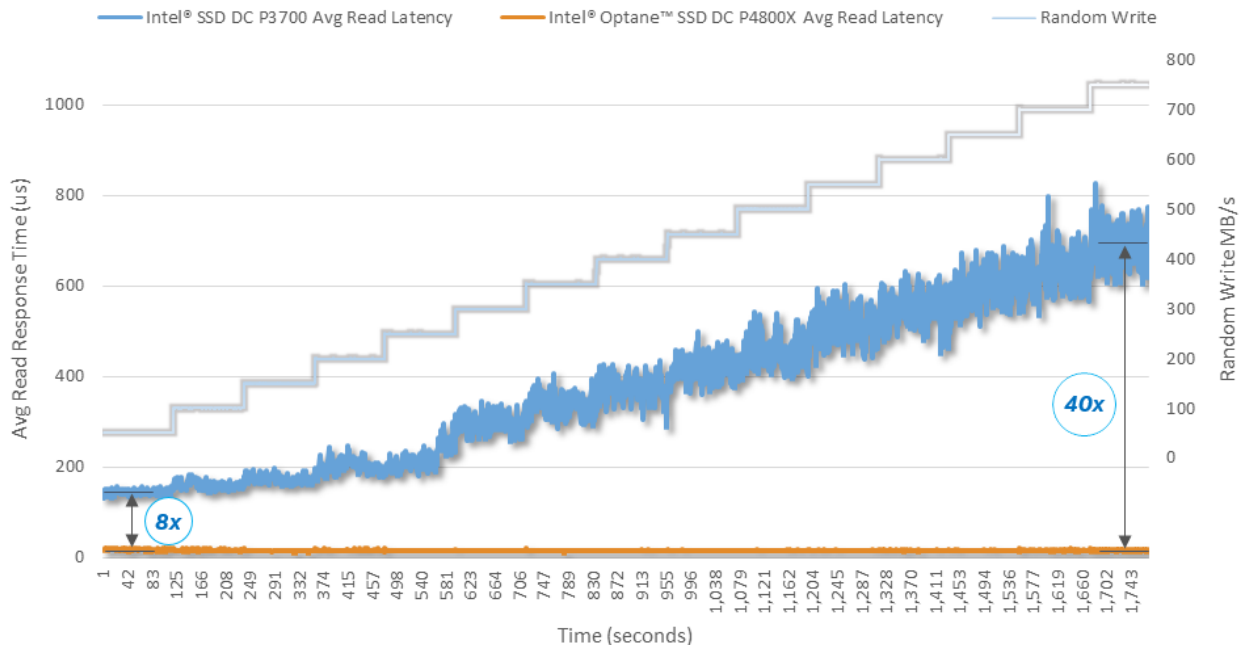
✓ Ideal for critical applications with aggressive latency requirements

1. Common Configuration - Intel 2U PCSD Server ("Wildcat Pass"), OS CentOS 7.2, kernel 3.10.0-327.el7.x86_64, CPU 2 x Intel® Xeon® E5-2699 v4 @ 2.20GHz (22 cores), RAM 396GB DDR @ 2133MHz. Configuration - Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P3700 1600GB. QoS - measures 99% QoS under 4K 70-30 workload at QD1 using fio-2.15.

Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.

Responsive Under Load

Average Read Latency under Random Write Workload



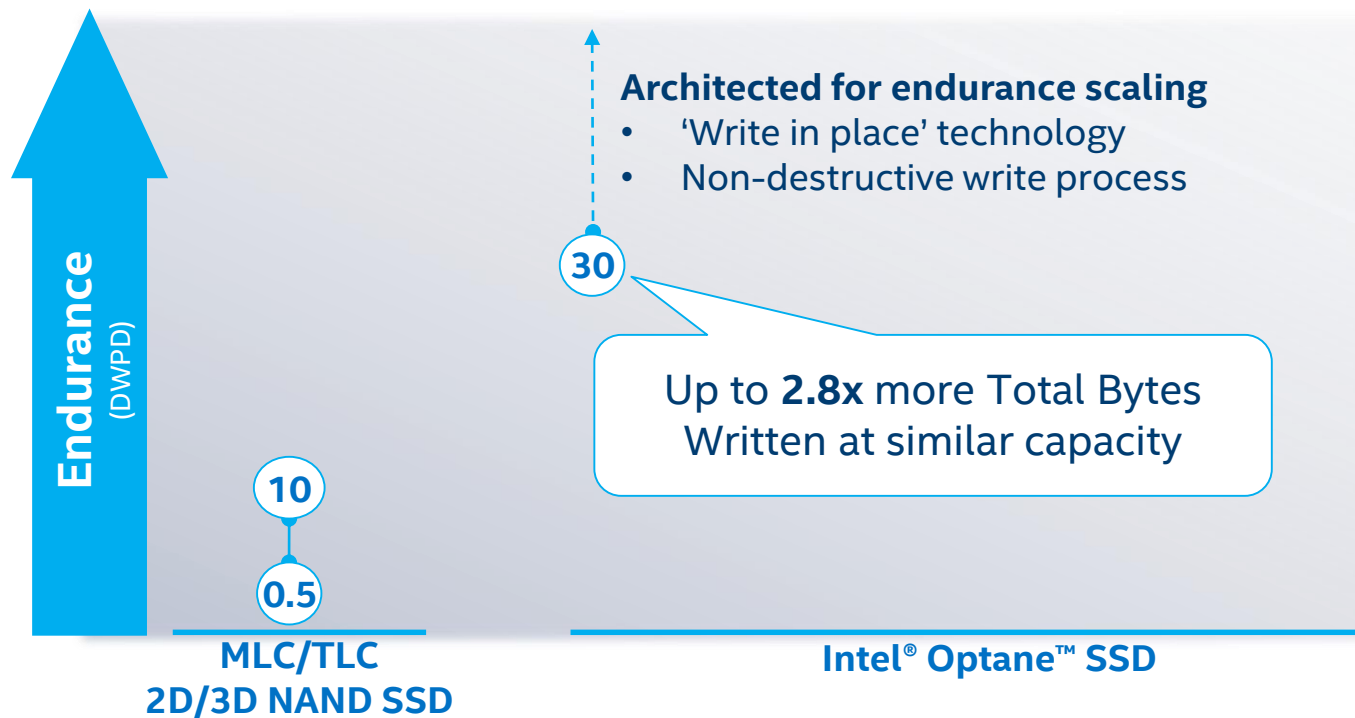
✓ up to **40X faster response time** under workload¹

✓ Consistently **amazing response time under load**

1. Responsiveness defined as average read latency measured at queue depth 1 during 4k random write workload. Measured using FIO 2.15. Common Configuration - Intel 2U PCSD Server ("Wildcat Pass"), OS CentOS 7.2, kernel 3.10.0-327.el7.x86_64, CPU 2 x Intel® Xeon® E5-2699 v4 @ 2.20GHz (22 cores), RAM 396GB DDR @ 2133MHz. Configuration - Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P3700 1600GB. Latency - Average read latency measured at QD1 during 4K Random Write operations using fio-2.15.

Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.

Ultra Endurance



1. Comparing projected Intel® Optane™ SSD 750GB specifications to actual Intel® SSD DC P3700 800GB specifications.

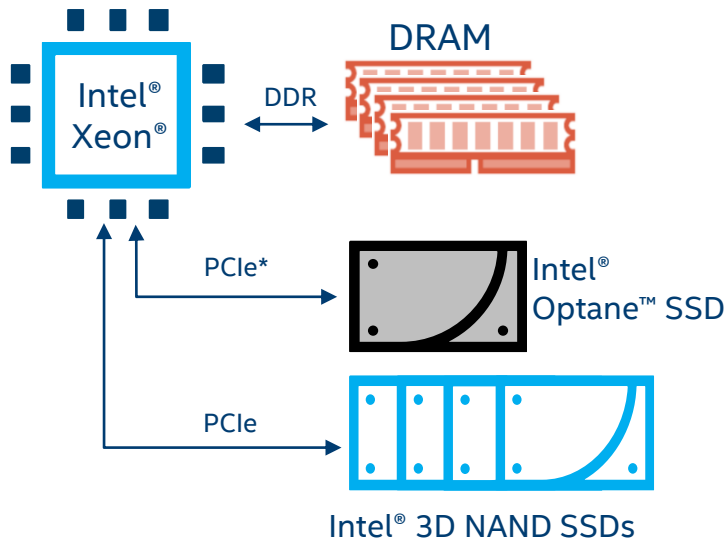
Total Bytes Written (TBW) calculated by multiplying specified or projected DWPD x specified or projected warranty duration x 365 days/year.

Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.

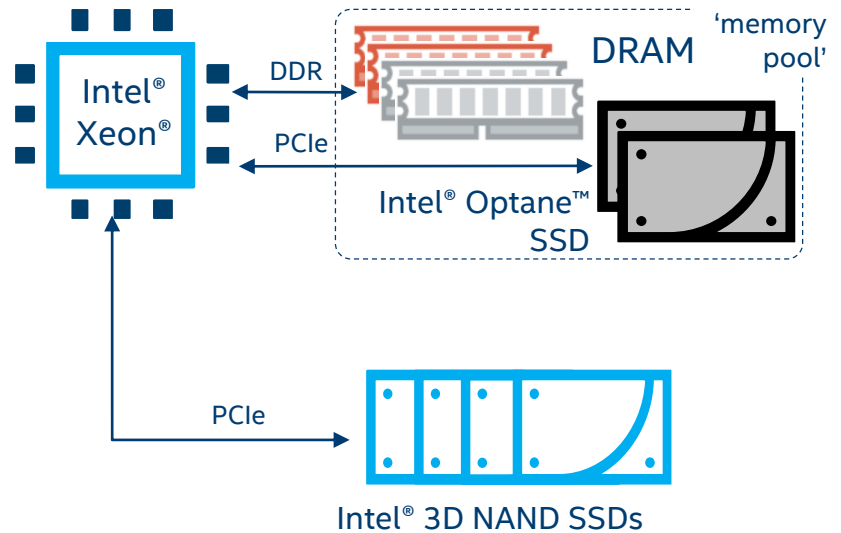
USAGE

Intel® Optane™ SSD Use Cases

Fast Storage and Cache



Extend Memory



*Other names and brands may be claimed as the property of others

FAST STORAGE AND CACHE



Intel® Optane™ SSD DC P4800X Series

Low Queue Depth Performance

vs. Intel® SSD DC P3700¹

70/30 Mixed	up to 8x faster
Random Read	up to 10x faster
Random Write	up to 3x faster

Quality of Service

vs. Intel® SSD DC P3700 @ 70/30¹

99% QoS	up to 60x better
99.99% QoS	up to 77x better



Responsiveness Under Load

vs. Intel® SSD DC P3700¹

200MB/s write pressure	up to 12.5x faster
400MB/s write pressure	up to 25x faster
600MB/s write pressure	up to 35x faster

Form Factors and Capacities

Form Factor	Capacity	Availability
AIC	375GB	Initial Mar 19, broad 2H
	750GB	Q2
	1.5TB	2H
U.2	375GB	Q2
	750GB	2H
	1.5TB	2H

1. Common Configuration - Intel 2U PCSD Server ("Wildcat Pass"), OS CentOS 7.2, kernel 3.10.0-327.el7.x86_64, CPU 2 x Intel® Xeon® E5-2699 v4 @ 2.20GHz (22 cores), RAM 396GB DDR @ 2133MHz. Configuration - Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P3700 1600GB. Performance - measured under 4K 70-30 workload at QD1-16 using fio-2.15. QoS - measures 99% QoS under 4K 70-30 workload at QD1 using fio-2.15. Latency - Average read latency measured at QD1 during 4K Random Write operations using fio-2.15. Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.



Break Bottlenecks to Increase Scale per Server

- Do more per server
- Reduce transaction cost of latency sensitive workloads
- Differentiate and monetize services with low, predictable latency



Intel® Optane™ SSD

Scale Cloud Storage Performance, Capacity and QoS in Ceph* AFA

Today

Slow writes to journal/metadata limits cluster capability

with Intel® Optane™ SSD

Write performance improves cluster scaling



Server Node

2 x Intel® Xeon® E5



Journal/Metadata

1 x NAND PCIe SSD



Object Storage

4 x 2TB Intel® SSD DC P3520



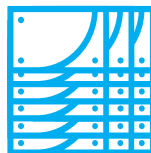
Server Node

2 x Intel® Xeon® E5



Journal/Metadata

1 x Intel® Optane™ SSD



Object Storage

18 x 2TB Intel® SSD DC P3520

up to

4.5x better storage efficiency¹

up to

4.5x more IOPS¹

up to

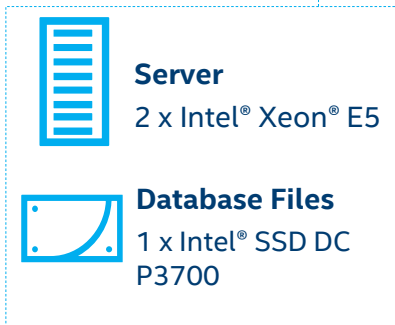
10x better responsiveness¹

1. System configuration: Common – 2 x 5-node Ceph clusters both on Ceph BlueStore Kraken release 11.0.2, each node with Ubuntu 16.04 updated to Linux kernel 4.6, each cluster using 4 x Intel® SSD DC P3520 2TB as OSD (object storage device). All NAND cluster with each node – Intel® SSD DC P3700 1.6TB for metadata (db + WAL), 2 x Intel® Xeon E5, NIC 4x10GbE. Cluster using Intel® Optane™ SSDs: each node – Intel® Optane™ SSD 187GB for metadata (db + WAL), 2 x Intel® Xeon® E5 Haswell, NIC 2x10GbE. Test – latency based on 16K RW from 100 clients with QD2 at >99.9% latency, performance based on 2 cluster RW (4K/8K/16K) results, NAND cluster limited by P3700, Optane scaling performance is estimation based on 4K RW data of Optane and P3520 SSD. *Other names and brands may be claimed as the property of others. Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.

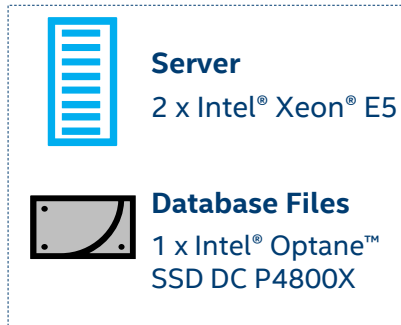
Intel® Optane™ SSD

Scale Workload and Reduce Cost on MySQL*

with all NAND SSD



with Intel® Optane™ SSD



up to **10x** more transactions per second @ same service¹

up to **91%** lower cost per transaction¹

TPS	1395
Latency	~11ms @ 2 9s
\$/transaction	~\$10.09

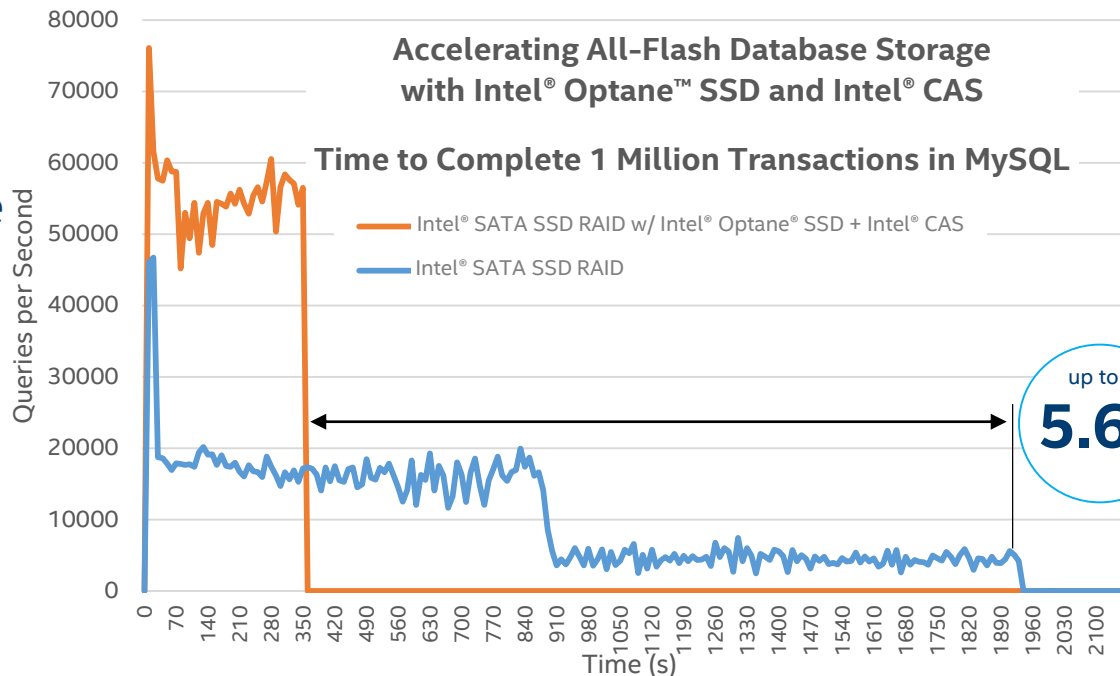
TPS	16480
Latency	~10ms @ 2 9s
\$/transaction	~\$0.90

1. System configuration: Server Intel® Server System R2208WT2YS, 2x Intel® Xeon® E5 2699v4, 384 GB DDR4 DRAM, boot drive- 1x Intel® SSD S3710 Series (400 GB), database drives- 1x Intel® SSD P3700 Series (400 GB) and 1x Intel® Optane™ SSD P4800X Series (140 GB prototype), CentOS 7.2, MySQL Server 5.7.14, Sysbench 0.5 configured for 70/30 Read/Write OLTP transaction split using a 100GB database. Cost per transaction determined by total MSRP for each configuration divided by the transactions per second. *Other names and brands may be claimed as the property of others. Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.

Intel® Optane™ SSD

Faster Transactions in MySQL*

Sustained performance under load accelerates large batch workloads



1. System configuration - Intel® Server System R2208WT2YS, 2x Intel® Xeon® E5 2699v4, 128 GB DDR4 DRAM, boot drive- 1x Intel® SSD S3500 Series (240GB), database drives- 3x RAID 5 Intel® SSD S3520 Series (1.6 TB) with 1x Intel® RAID Controller RS3DC080, cache drive- Intel® SSD P4800X Series (375 GB), CentOS 7.3, MySQL Server 5.7.17, Sysbench 0.5 configured for 70/30 R/W OLTP transaction split using a 1500GB database. Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance. *Other names and brands may be claimed as the property of others.

Differentiate and Monetize Services

Responsiveness under load creates opportunities



**More IOPS
at low QD¹**



**Faster
Response
under load¹**

Existing models highlight opportunities

CSP	Service
Amazon* Web Services	25% premium for provisioned IOPS²
Microsoft* Azure	7x premium 1ms read SLA³
Google* Cloud	Per IOPS pricing⁴

1. Configuration: Intel 2U PCSD Server ("Wildcat Pass"), OS CentOS 7.2, kernel 3.10.0-327.el7.x86_64, CPU 2 x Intel® Xeon® E5-2699 v4 @ 2.20GHz (22 cores), RAM 384GB DDR @ 2133MHz. Application: fio-2.15. Workload 70/30 R/W.

2. Amazon* Web Services. <https://aws.amazon.com/ebs/pricing/>

3. Microsoft* Azure. <https://docs.microsoft.com/en-us/azure/storage/storage-premium-storage>

4. Google* Cloud. <https://cloud.google.com/compute/docs/disks/>

Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.

*Other names and brands may be claimed as the property of others

EXTEND MEMORY

Deploy Bigger, More Affordable Memory

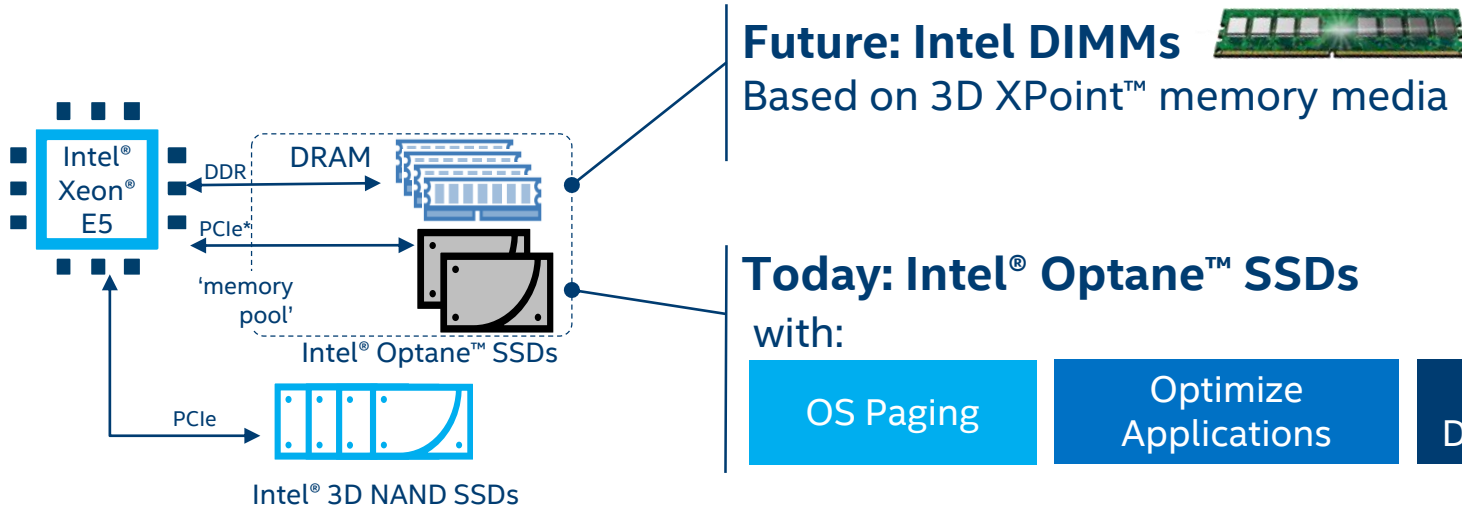
- Increase memory pool by up to **8x**¹
- Displace DRAM up to **10:1** in select workloads²
- Accelerate applications and gain new insights from **larger working sets**



1. 2-socket platform All-DRAM memory configuration hardware limited up to 1.5TB (assuming 24 DIMM sticks by 64GB). Intel® Memory Drive Technology software supports up to 12TB addressable space, while DRAM as a cache is only, resulting in up to 8X capacity increase.
2. Optane + IMDT configuration – 2 x Intel® Xeon® CPU E5-2699 v4 @ 2.20Ghz, Intel® Server Board S2600WT, 128GB DDR4 + 4* Intel® SSD Optane® (SSDPED1K375GA), CentOS 7.3.1611. All DRAM configuration – 2 x Intel® Xeon® CPU E5-2699 v4 @ 2.20Ghz, Intel® Server Board S2600WT, 768GB DDR4 CentOS 7.3.1611. Test - GEMM, segment size 18689, factor 22, threads 42.

Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.

Range of Options to Extend Memory



Today: Intel® Optane™ SSDs
with:

OS Paging

Optimize
Applications

Intel® Memory
Drive Technology

*Other names and brands may be claimed as the property of others.

Intel® Optane™ SSD DC P4800X with Intel® Memory Drive Technology

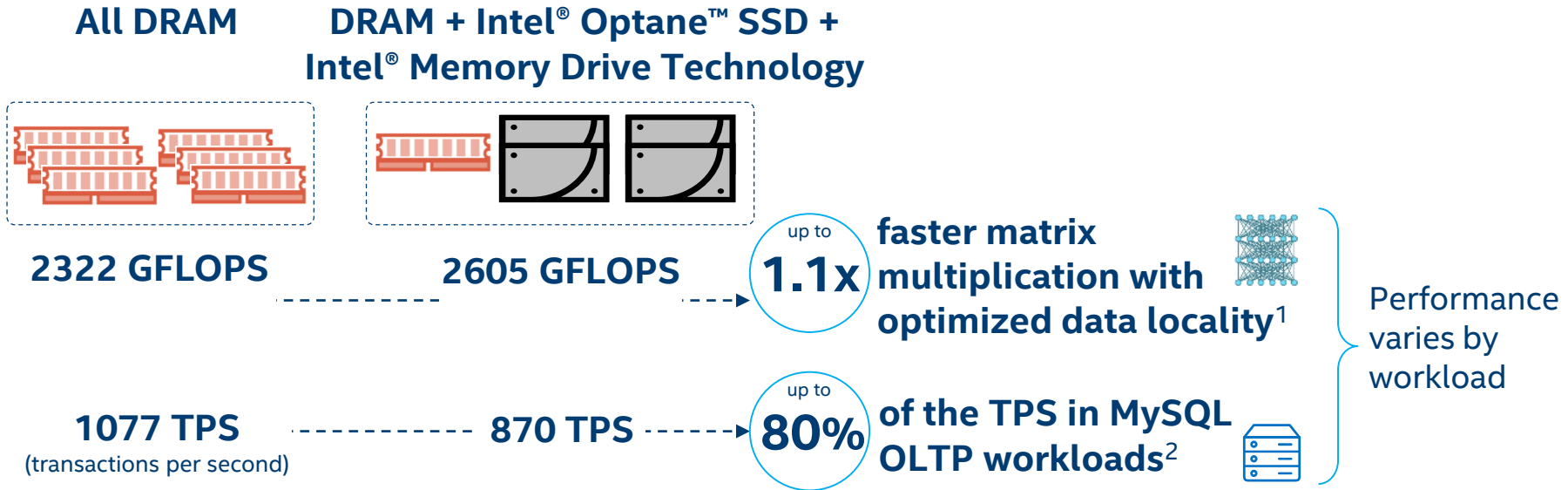
Intel® Memory Drive Technology



- Intel® Optane™ SSD DC P4800X integrates **transparently into memory** subsystem¹
- Middle layer SW boots prior to OS
- DRAM + Intel® Optane™ SSD + Intel® Memory Drive Technology emulate a **single volatile memory pool**
- **No changes** to OS and application required
- Supported on **Intel® Xeon® processors**

1. Maximum memory capacity varies by configuration. Maximum capacities measured binary are 320GiB for the 375GB drive, 640GiB for the 750GB drive and 1280GiB for the 1.5TB drive.

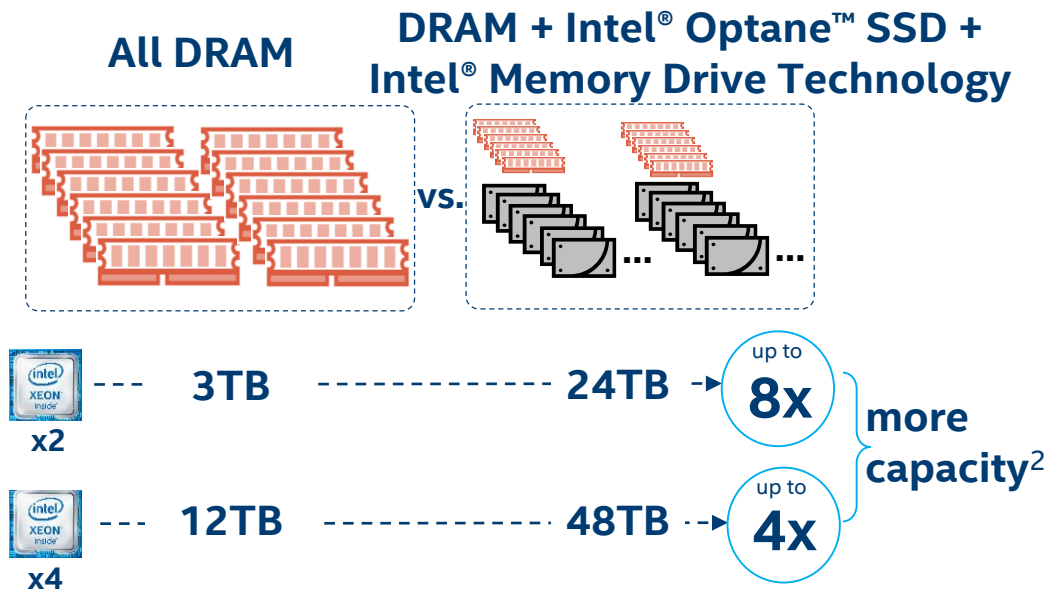
Intel® Optane™ SSD + Intel® Memory Drive Technology DRAM-like Performance in Select Applications



1. Optane + IMDT configuration – 2 x Intel® Xeon® CPU E5-2699 v4 @ 2.20Ghz, Intel® Server Board S2600WT, 128GB DDR4 + 4* Intel® SSD Optane® (SSDPED1K375GA), CentOS 7.3.1611. All DRAM configuration – 2 x Intel® Xeon® CPU E5-2699 v4 @ 2.20Ghz, Intel® Server Board S2600WT, 768GB DDR4 CentOS 7.3.1611. Test - GEMM, segment size 18689, factor 22, threads 42.
2. Optane + IMDT configuration – 2 x Intel® Xeon® CPU E5-2699 v4 @ 2.20Ghz, Intel® Server Board S2600WT, 128GB DDR4 + 4* Intel® SSD Optane® (SSDPED1K375GA), CentOS 7.3.1611. All DRAM configuration – 2 x Intel® Xeon® CPU E5-2699 v4 @ 2.20Ghz, Intel® Server Board S2600WT, 768GB DDR4 CentOS 7.3.1611. Test - Sysbench 0.5 configured for 70/30 Read/Write OLTP transaction split using a 675GB database.
Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.

Intel® Optane™ SSD + Intel® Memory Drive Technology

Larger Datasets Usher in a World of Possibilities¹



Accelerate
Cure Diseases
Eliminate Fraud

Unleash
Explore deep Sea/Space
Decode the Brain

Augment
Personalize Guidance
Enhance Decisions

Automate
Automate Driving
Search and Rescue

1. Source – Intel.
 2. **Two-socket DRAM only** - Intel® Xeon® Processor E5v4 supports up to 3TB DRAM (2 CPU x 12 DIMMs x 128GB). **Two-socket DRAM + Intel® Optane™ SSD** - Intel® Memory Drive Technology software supports up to 24TB addressable space per 2 sockets (3TB DRAM + 21TB Intel® Optane™ SSD (320GB x 66 U.2 slots)). **Four-socket DRAM only** - Intel® Xeon® Processor E7v4 supports up to 12TB DRAM (4 CPU x 24 DIMMs x 128GB). **Four-socket DRAM + Intel® Optane™ SSD** - Intel® Memory Drive Technology software supports up to 48TB addressable space per 4 sockets (12TB DRAM + 36TB Intel® Optane™ SSD (320GB x 112 U.2 slots)). Attainable capacity depends on server configuration. Please consult your server manufacturer. Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance.

ECOSYSTEM

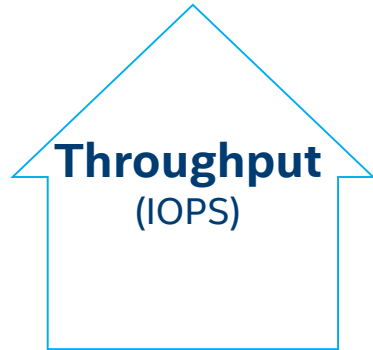
Broad and Growing Ecosystem



Other names and brands may be claimed as the property of others

Intel® Optane™ SSD DC P4800X Series

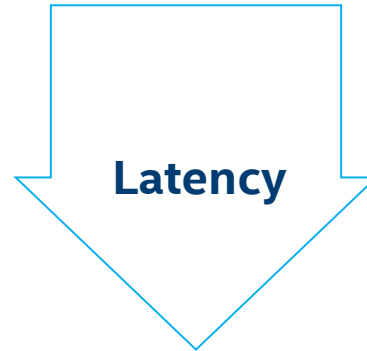
**Breakthrough
Performance**



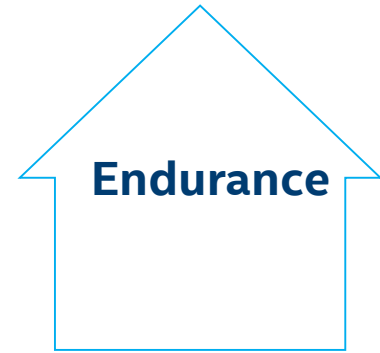
**Predictably
Fast Service**



**Responsive
Under Load**

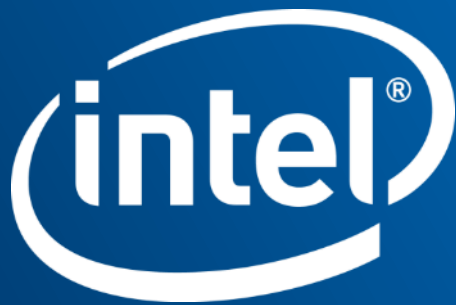


**Ultra
Endurance**



World's Most Responsive Data Center SSD¹

1. Responsiveness defined as average read latency measured at queue depth 1 during 4k random write workload. Measured using FIO 2.15. Common configuration - Intel 2U PCSD Server ("Wildcat Pass"), OS CentOS 7.2, kernel 3.10.0-327.el7.x86_64, CPU 2 x Intel® Xeon® E5-2699 v4 @ 2.20GHz (22 cores), RAM 396GB DDR @ 2133MHz. Intel drives evaluated - Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P3700 1600GB. Samsung drives evaluated - Samsung® SSD PM1725a, Samsung® SSD PM1725, Samsung® PM963, Samsung® PM953. Micron drive evaluated - Micron® 9100 PCIe® NVMe® SSD. Toshiba drives evaluated - Toshiba® ZD6300. Test - QD1 Random Read 4K latency, QD1 Random RW 4K 70% Read latency, QD1 Random Write 4K latency using fio-2.15. *Other names and brands may be claimed as the property of others.



Legal Notices and Disclaimers

Intel technologies' features and benefits depend on system configuration and may require enabled hardware, software or service activation. Learn more at intel.com, or from the OEM or retailer.

No computer system can be absolutely secure.

Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance. Consult other sources of information to evaluate performance as you consider your purchase. For more complete information about performance and benchmark results, visit <http://www.intel.com/performance>.

Cost reduction scenarios described are intended as examples of how a given Intel-based product, in the specified circumstances and configurations, may affect future costs and provide cost savings. Circumstances will vary. Intel does not guarantee any costs or cost reduction.

This document contains information on products, services and/or processes in development. All information provided here is subject to change without notice. Contact your Intel representative to obtain the latest forecast, schedule, specifications and roadmaps.

No license (express or implied, by estoppel or otherwise) to any intellectual property rights is granted by this document.

Intel does not control or audit third-party benchmark data or the web sites referenced in this document. You should visit the referenced web site and confirm whether referenced data are accurate.

Intel, the Intel logo, Xeon, Optane and 3D XPoint are trademarks of Intel Corporation in the U.S. and/or other countries.

*Other names and brands may be claimed as the property of others.

© 2017 Intel Corporation.