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, Intel 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.
Exciting moment in time

Analyst and Press Briefing
March 15, 2017
THE MEMORY TECHNOLOGY EVOLUTION
...Is Not Enough
3D XPOINT™ MEMORY MEDIA
Breaks the memory/storage barrier

**MEMORY**

- **SRAM**
  - Latency: 1X
  - Size of Data: 1X

- **DRAM**
  - Latency: ~10X
  - Size of Data: ~100X

**3D XPoint™**
- Latency: ~100X
- Size of Data: ~1,000X

**STORAGE**

- **NAND SSD**
  - Latency: ~100,000X
  - Size of Data: ~1,000X

- **HDD**
  - Latency: ~10 Million X
  - Size of Data: ~10,000X

Technology claims are based on comparisons of latency, density and write cycling metrics amongst memory technologies recorded on published specifications of in-market memory products against internal Intel specifications.
INTEL® OPTANE™ TECHNOLOGY: BUILDING BLOCKS
Unleashing Breakthrough Performance for a New Generation of Computing

3D XPoint™ Memory Media + Intel Memory and Storage Controllers + Intel Interconnect IP + Intel Software

Optimized at every level to deliver 3D XPoint™ Memory Media advantages to the platform
INTEL® OPTANE™ SSD DC P4800X
World’s Most Responsive Data Center SSD

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.
**Intel® Optane™ SSD DC P4800X**

**Quality of Service**

**Low Queue Depth Performance**

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

**Form Factors and Capacities**

<table>
<thead>
<tr>
<th>Form Factor</th>
<th>Capacity</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIC</td>
<td>375GB</td>
<td>Initial Mar 19, broad 2H</td>
</tr>
<tr>
<td></td>
<td>750GB</td>
<td>Q2</td>
</tr>
<tr>
<td></td>
<td>1.5TB</td>
<td>2H</td>
</tr>
<tr>
<td>U.2</td>
<td>375GB</td>
<td>Q2</td>
</tr>
<tr>
<td></td>
<td>750GB</td>
<td>2H</td>
</tr>
<tr>
<td></td>
<td>1.5TB</td>
<td>2H</td>
</tr>
</tbody>
</table>

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.
Intel® Optane™ SSD DC P4800X

Breakthrough Performance

Predictably Fast Service

Responsive Under Load

Ultra Endurance

Throughput (IOPS)

Quality of Service

Latency

Endurance
STORAGE PERFORMANCE CHARACTERIZATION

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

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

- **10x latency reduction**
  - < 10usec latency †
- **100x QoS improvement**
  - < 200usec 99.999th r/w †

† vs. NAND based SSD
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 †
Breakthrough Performance

4K 70/30 RW Performance at Low Queue Depth

- Intel® Optane™ SSD DC P4800X 4K 70-30
- Intel® SSD DC P3700 4K 70-30

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.

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

¹ Vast majority of applications generate low QD storage workloads
Predictably Fast Service

- Ideal for critical applications with aggressive latency requirements
- up to 60X better at 99% QoS

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

- Intel® SSD DC P3700 Avg Read Latency
- Intel® Optane™ SSD DC P4800X Avg Read Latency
- Random Write

- up to 40X faster response time under workload
- Consistently amazing response time under load

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

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.
Ultra Endurance

Architected for endurance scaling

• ‘Write in place' technology
• Non-destructive write process

Up to 2.8x more Total Bytes Written at similar capacity

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.
Intel® Optane™ SSD Use Cases

**Fast Storage and Cache**

- **Intel® Xeon®**
  - DDR
  - PCIe
- **Intel® Optane™ SSD**
  - Intel® 3D NAND SSDs

**Extend Memory**

- **Intel® Xeon®**
  - DDR
  - PCIe
  - Intel® Optane™ SSD
- **Intel® 3D NAND SSDs**

*Other names and brands names may be claimed as the property of others*
Intel® Optane™ SSD
Scale Workload and Reduce Cost on MySQL*

Today

QoS limits work per service level

Server
2 x Intel® Xeon® E5

Database Files
1 x Intel® SSD DC P3700

with Intel® Optane™ SSD

Server
2 x Intel® Xeon® E5

Database Files
1 x Intel® Optane™ SSD DC P4800X

Improved QoS scales transactions

up to 10x more transactions per second @ same service

up to 91% lower cost per transaction

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 names 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.
Range of Extend Memory Options

**Future: Intel DIMMs**
Based on 3D XPoint™ memory media

**Today: Intel® Optane™ SSDs**
with:
- OS Paging
- Optimize Applications
- Intel® Memory Drive Technology

*Other names and brands names may be claimed as the property of others*
Intel® Optane™ SSD DC P4800X integrates transparently into memory subsystem\(^1\)

- 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

All DRAM

2322 GFLOPS

1077 TPS (transactions per second)

DRAM + Intel® Optane™ SSD + Intel® Memory Drive Technology

2605 GFLOPS

870 TPS

faster matrix multiplication with optimized data locality

up to 1.1x

up to 80% of the TPS in MySQL OLTP workloads

Performance varies by workload

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 Possibilities

All DRAM

DRAM + Intel® Optane™ SSD + Intel® Memory Drive Technology

3TB vs. 24TB up to 8x more capacity

12TB vs. 48TB up to 4x

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. Xeon E5v4 All-DRAM memory configuration hardware limited up to 3TB (assumes 24 DIMM x 128GB). Intel® Memory Drive Technology software supports in 2 socket configuration up to 24TB addressable space, while DRAM as a cache is only 3TB. 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.
Broad and Growing Ecosystem

Intel® Optane™ SSD DC P4800X

End Users

ISVs

OEMs

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