INTEL® OPTANE™ DC

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Benchmark results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown". Implementation of these updates may make these results inapplicable to your device or system.

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.

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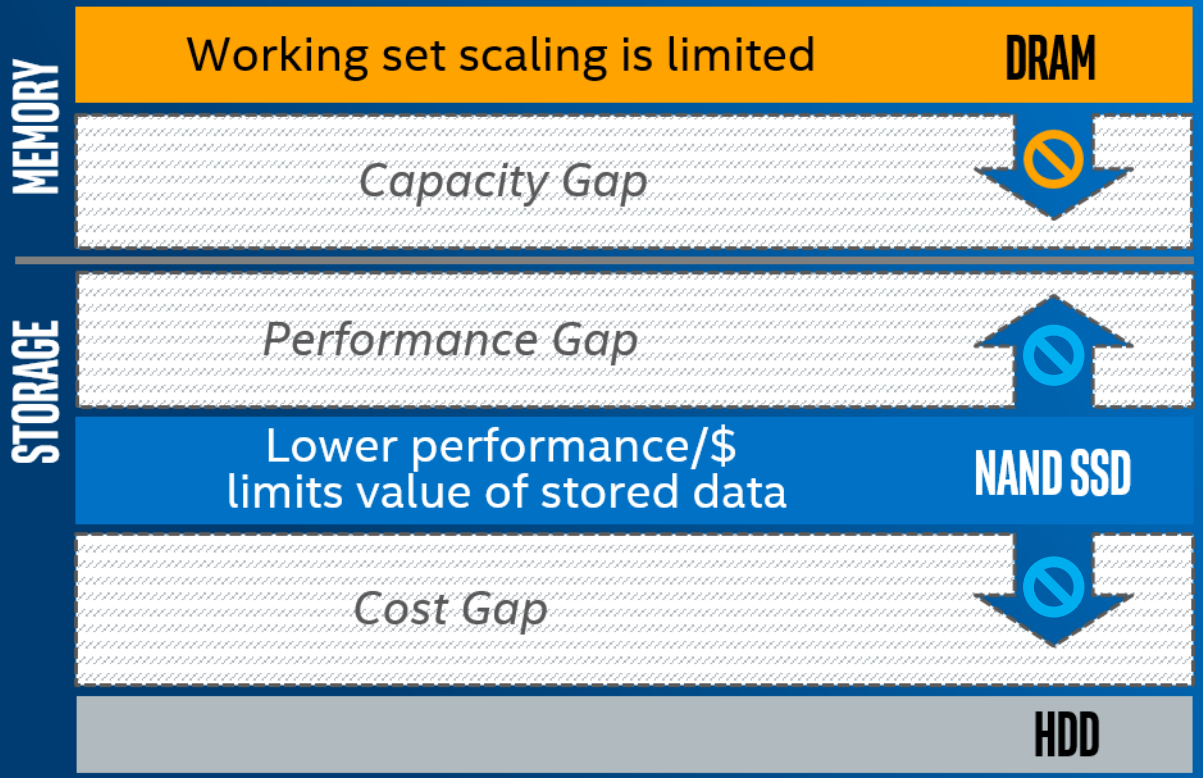
CHANGING DATA NEEDS HAVE EXPOSED STORAGE & MEMORY GAPS



INTEL® OPTANE™ TECHNOLOGY + INTEL® QLC TECHNOLOGY FILL THE GAPS

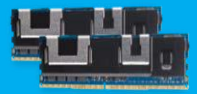
DRAM

MEMORY

Enable new insights with **bigger, more affordable memory**

extended memory

INTEL® OPTANE™ DC PERSISTENT MEMORY



STORAGE

Break through bottlenecks to increase value of storage data

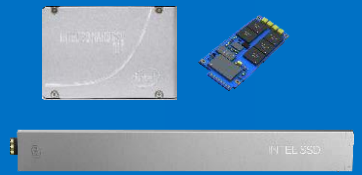
working

INTEL® OPTANE™ SSD DC P4800X

Cost-optimized SSDs enable **storage consolidation and acceleration**

capacity

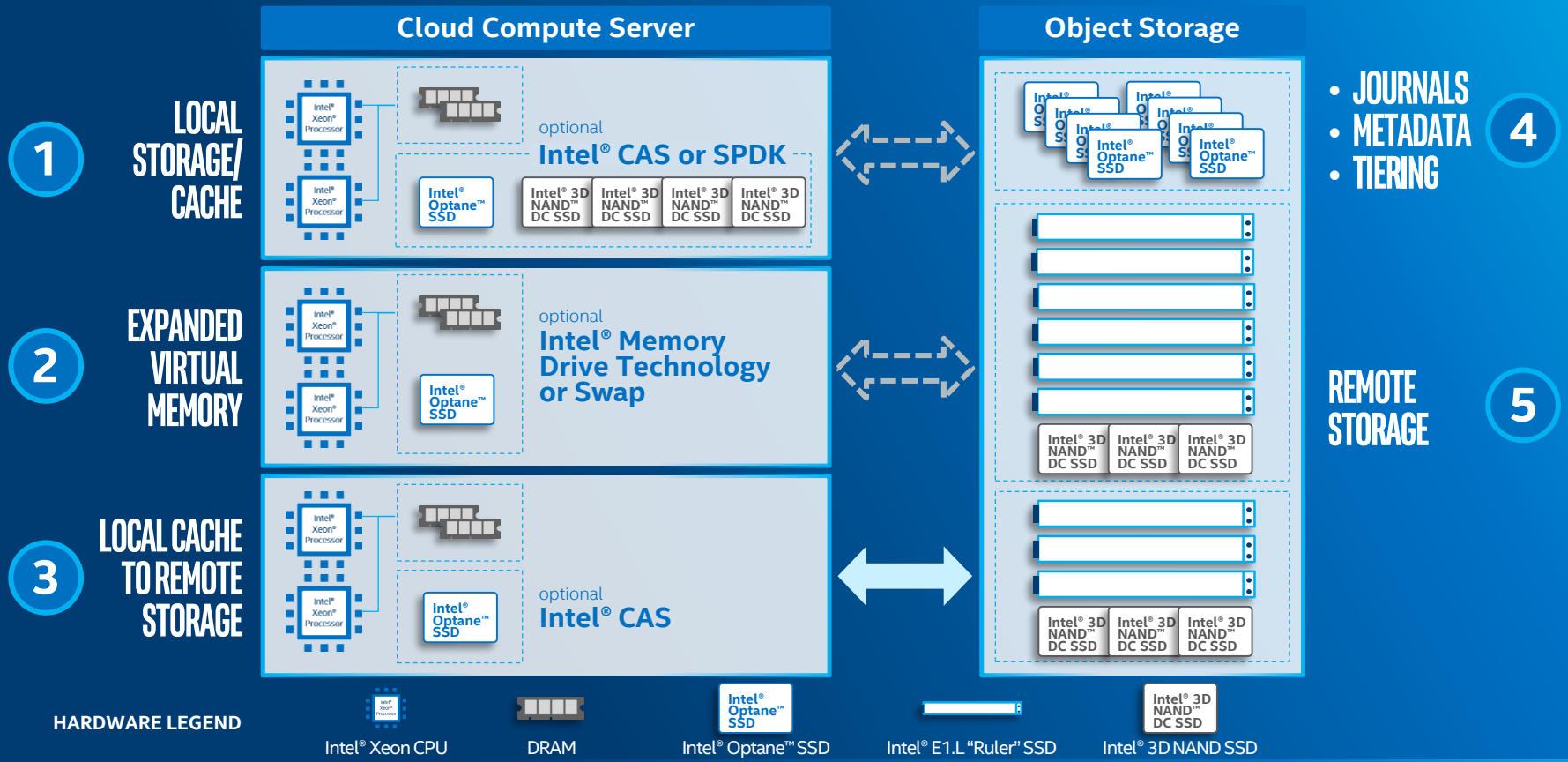
INTEL® QLC 3D NAND SSD



HDD

Products not shown to actual scale.

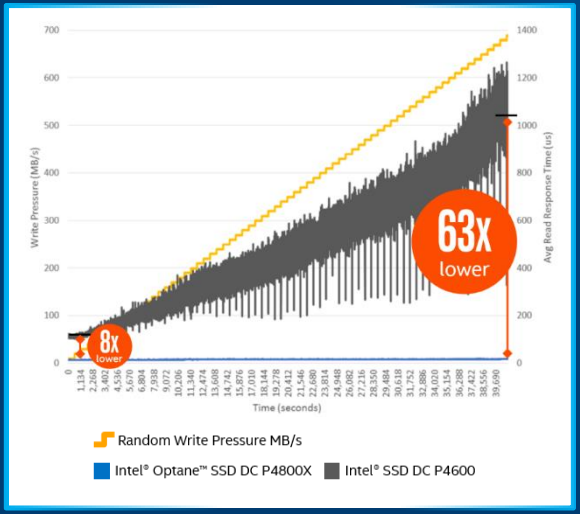
RECOMMENDED DATA CENTER CONFIGURATION WITH INTEL DATA CENTER SSDs.



INTEL® OPTANE™ SSD DC P4800X. THE IDEAL CACHING SOLUTION.

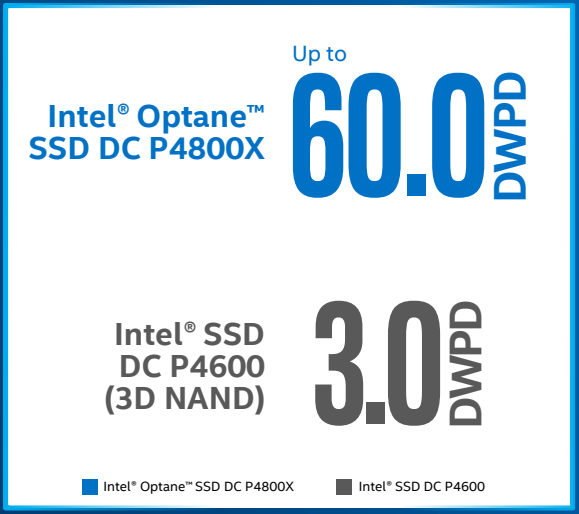
LOWER & MORE CONSISTENT LATENCY

Average Read Latency under Random Write Workload[1]



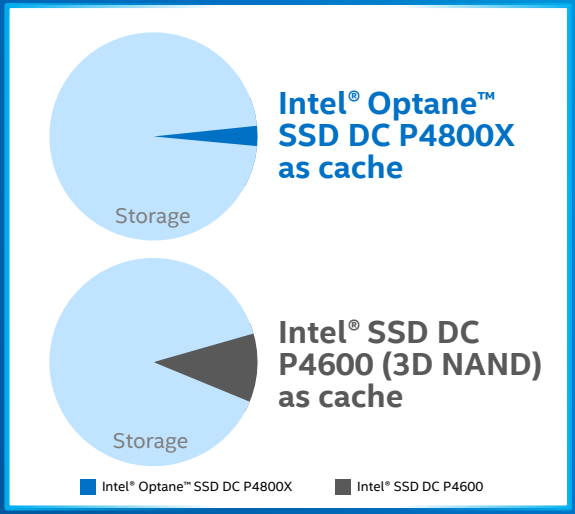
HIGHER ENDURANCE

Drive Writes Per Day (DWPD)[2]



MORE EFFICIENT

Cache as a % of Storage Capacity[3]



Low Latency + High Endurance = **Greater SDS System Efficiency**

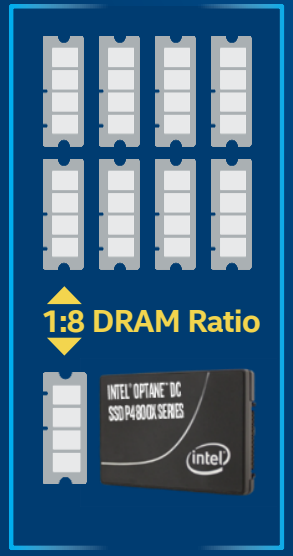
1. Source – Intel-tested: Average read latency measured at queue depth 1 during 4k random write workload. Measured using FIO* 2.15. Common Configuration - Intel 2U Server System, OS CentOS 7.5, kernel 4.17.6-1.el7.x86_64, CPU 2 x Intel® Xeon® 6154 Gold @ 3.0GHz (18 cores), RAM 256GB DDR @ 2666MHz. Configuration – Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P4600 1.6TB. Latency – Average read latency measured at QD1 during 4K Random Write operations using fio*-2.15. System BIOS: 00.01.0013; ME Firmware: 04.00.04.294; BMC Firmware: 1.43.91f76955; FRUSDR: 1.43. The benchmark results may need to be revised as additional testing is conducted. Performance results are based on testing as of July 2018 and may not reflect all publicly available security updates. See configuration disclosure for details. No product can be absolutely secure.
2. Source – Intel: Endurance ratings available at https://www.intel.com/content/www/us/en/solid-state-drives/optane-ssd-dc-p4800x-brief.html
3. Source – Intel: General proportions shown for illustrative purposes.

DATABASE: DRAM-LIKE PERFORMANCE FOR LESS IN MYSQL*

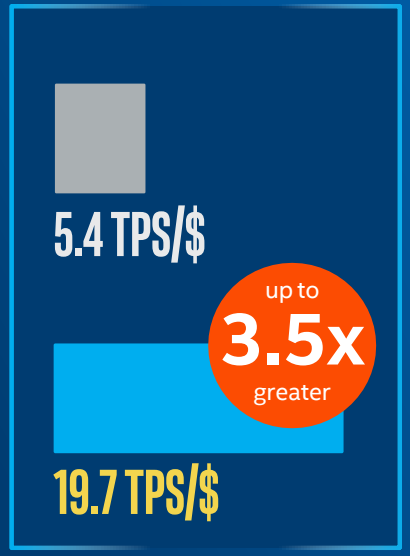
ALL-DRAM:
2048 MB

LOW-DRAM:
256 MB DRAM
+ Intel® Optane™ SSD DC P4800X

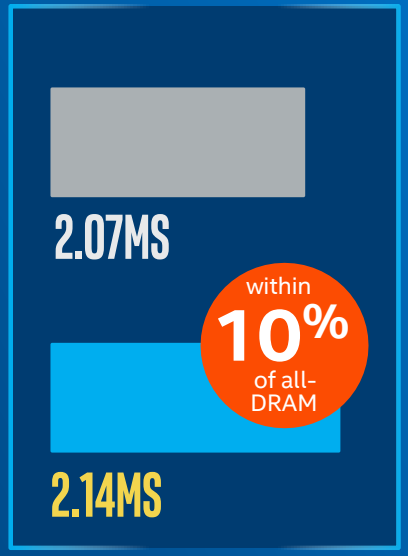
DB Size
~1850MB



TPS/$[1]
(Higher is better)



P99 Latency (ms)[1]
(Lower is better)



Greatly-improved Price/Performance and Near-DRAM Latency for the **World's Most Popular Open Source Database**[2]

[1] Configuration: 2S Intel® Xeon® Gold 6142 (32 total cores, 2.6 GHz), 192GB DDR4, 750GB Intel® Optane™ SSD DC P4800X, hosted at Packet.net* on Ubuntu 16.04.4 LTS. MySQL 5.7 installed in a Docker container (v. 18.03.1-ce) with 2 cores (4 vCPUs) and 8GB maximum DRAM available with Sysbench 1.0.15 70/30 read/write OLTP test conducted. Results averaged across 10 separate containers run concurrently once each with All-DRAM configuration and once each with Low-DRAM configuration (20 total runs). DRAM cost of $4.84/GB/month and Intel Optane SSD cost of $0.93/GB/month based on June 4, 2018 check of 128GB IBM Cloud* bare metal server pricing. Cost calculated as storage cost for size of database on Intel Optane SSD plus cost of DRAM.
Performance results are based on testing as of August 2, 2018 and may not reflect all publicly available security updates. See configuration disclosure for details. No product can be absolutely secure.
[2] Source – MySQL https://www.mysql.com/
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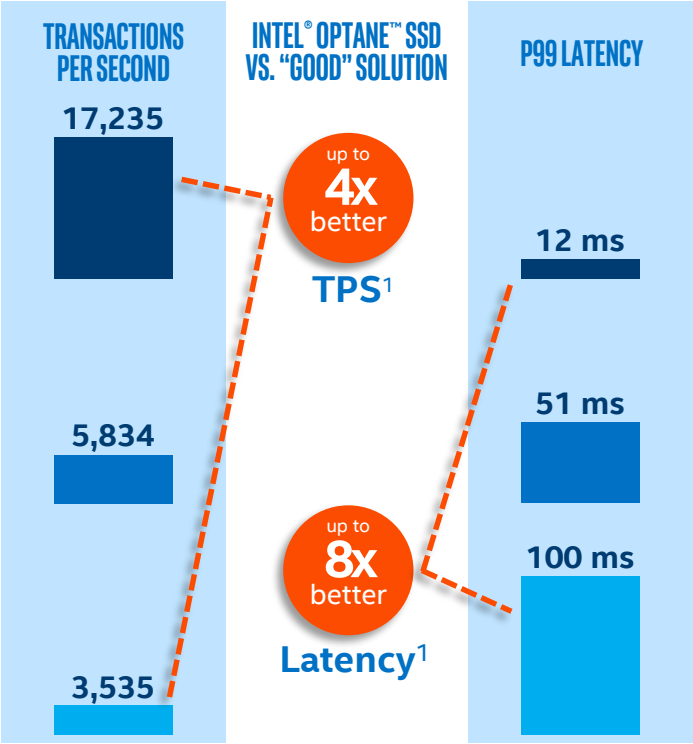
MySQL* 5.7 SYSBENCH BENCHMARK

What is P99 Latency?
This represents latency being in the 99th percentile or 99% of the requests are faster than the given latency.

		STORAGE	CPU	MEMORY
BEST	Lowest latency of the configurations shown and most efficient use of cores.	Intel® Optane™ SSD	Intel® Xeon® v4 (44 core)	DRAM 256GB
BETTER	2x better latency than "good" configuration with the benefits of NVMe*.	Intel® SSD DC P4500	Intel® Xeon® v4 (44 core)	DRAM 256GB
GOOD	Highest latency of shown configurations. Not able to transfer the IO load to the storage as effectively as NVMe*.	Intel® SSD DC S3520	Intel® Xeon® v4 (44 core)	DRAM 256GB



1.System configuration: Server Intel® Server System R2208WT2YS, 2x Intel® Xeon® E5 2699v4, 384 GB DDR4 DRAM, boot drive- 1x Intel® SSD DC S3710 Series (400 GB), database drives- 1x Intel® SSD DC P3700 Series (400 GB) and 1x Intel® Optane™ SSD DC 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. Estimated results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown". Implementation of these updates may make these results inapplicable to your device or system.

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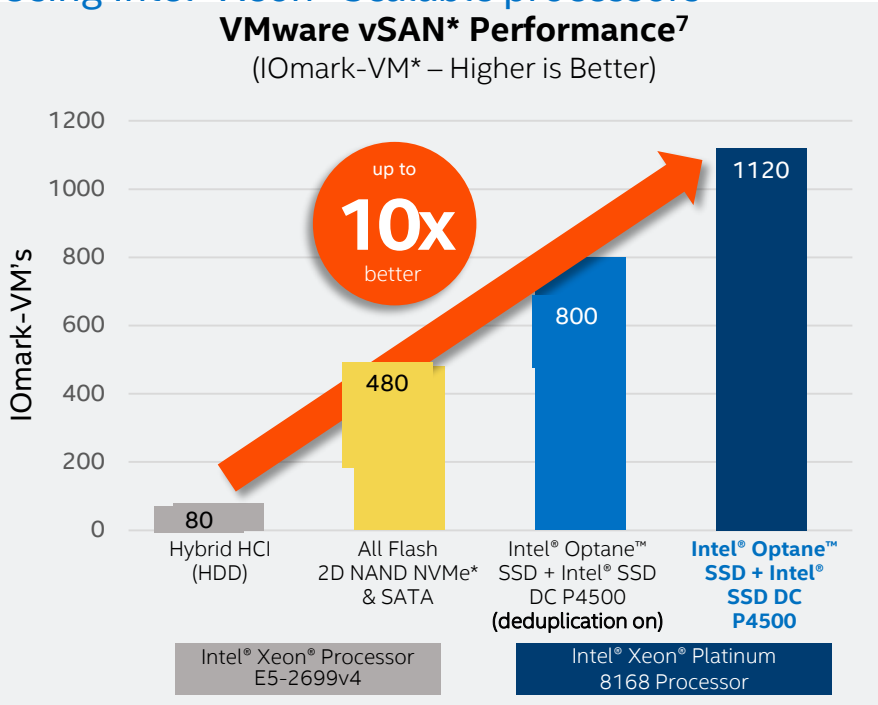
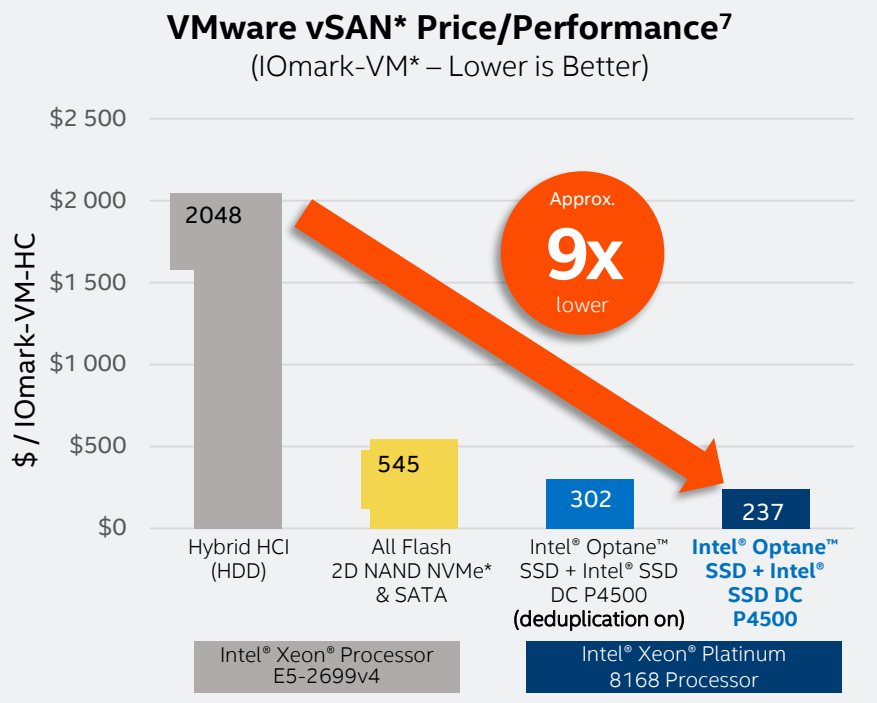
THE CLEAR ADVANTAGE OF ADDING INTEL® OPTANE™ TECHNOLOGY

Using Intel® Xeon® Scalable processors





New Intel® Technologies Deliver a Significant vSAN* Price/Performance Advantage

Source – Evaluator Group: https://www.intel.com/content/www/us/en/storage/evaluator-group-storage-paper.html. See full configurations in Appendix. Estimated results were obtained prior to implementation of recent software patches and firmware updates intended to address exploits referred to as "Spectre" and "Meltdown". Implementation of these updates may make these results inapplicable to your device or system.

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Evaluator Group

APPENDIX FOR VMWARE VSAN PROOF POINT

Intel® Optane™ SSDs with Intel® XEON® Scalable Processor for VMware vSAN*

7. Storage Configuration for Column 1 (1 SSD + 4 HDD)
   - IOmark-VM-HC validated configuration.
   - Storage: Media: 1 x Intel® SSD DC S3700 + 4 Seagate* 1 TB 10K HDD
   - Performance: 80 IOmark-VM-HC
   - Price / Performance: $2048 / IOmark-VM-HC
- Storage Configuration for Column 2 (2 NVMe + 6 SSD + 1 NVMe)
  - IOmark-VM-HC validated configuration.
  - Storage: Media: 3x Intel® SSD DC P3700 + 6x Intel® SSD DC S3700
  - Performance: 480 IOmark-VM-HC
  - Price / Performance: $545 / IOmark-VM-HC
- Server and Software Configuration for Columns 1 and 2
  - The configuration consisted of a cluster of 4 physical server nodes running VMware ESXi* 6.2 with vSAN 6.2. The Hyperconverged systems used for testing included the following CPU, memory and network configuration. The storage media utilized changed for each configuration as noted.
  - Intel® Server System S2600 W2 Servers
  - CPU: 2x Xeon E5-2699v4 CPU (22 core, 2.2Ghz) w/ hyper threading
  - Memory: Tested with 256 GB DRAM, priced for comparison at 512 GB DRAM
  - NIC : Tested with 40 GbE XL710, price configured with onboard 10 GbE X-540 AT2
  - Hyperconverged Software: VMware ESXi 6.0U2, VMware vSAN* 6.2
  - Benchmark Software: IOmark-VM (I/O equivalent to VMmark 2.5), IOmark-VM-HC requires Hyperconverged configurations verified with reported VMware VMmark results

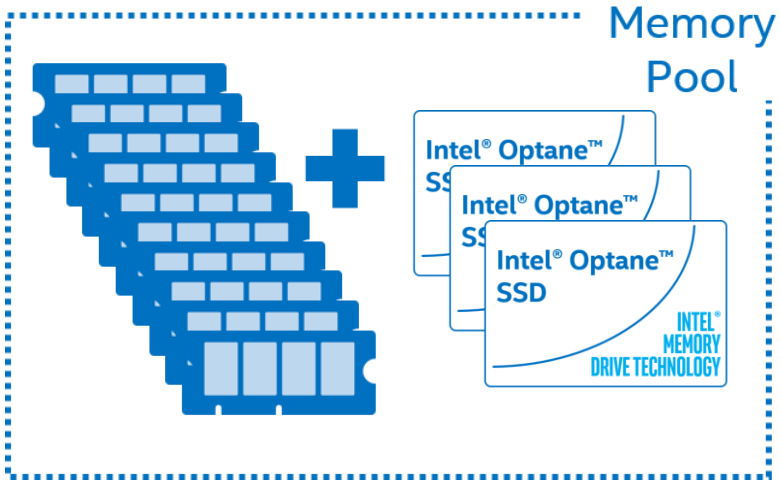
Intel® Optane™ SSDs Deliver Benefits for VMware* vSAN Deployments

- Storage Configuration for Column 3 (Intel® Optane™ SSD + P4500 Deduplication On)
  - IOmark-VM-HC validated configuration.
  - Storage: Media: 2 x Intel® Optane™ SSD DC P4800x+ 4 x Intel® SSD DC P4500 SSD's
  - Performance: 800 IOmark-VM-HC
  - Price / Performance: $293 / IOmark-VM-HC
- Storage Configuration for Column 4 (Intel® Optane™ SSD + NVMe)
  - Not IOmark-VM-HC validated (Insufficient processing)
  - Storage: Media: 2 x Intel® Optane™ SSD DC P4800x + 4 x Intel® SSD DC P4500
  - Performance: 1,120 IOmark-VM's (Note: Measured as a storage system, not Hyperconverged)
  - Price / Performance: $237 / IOmark-VM (Note: Measured as a storage system, not Hyperconverged)
- Server and Software Configuration for Columns 3 and 4
  - The configuration consisted of a cluster of 4 physical server nodes running VMware ESXi* 6.5.0d with vSAN 6.6. The Hyperconverged systems used for testing included the following CPU, memory and network configuration. The storage media utilized changed for each configuration as noted.
  - Intel® Server System R2208WF, with 4 U.2 NVMe accessible slots
  - CPU: 2 x Intel® Xeon® processor 8168 CPU (24 cores @ 2.7 Ghz w/ hyper threading)
  - Memory: Tested with 256 GB DRAM, priced for comparison at 768 GB DRAM
  - NIC : Tested with 40 GbE XL710, price configured with onboard 10 GbE X-540 AT2
  - Hyperconverged Software: VMware ESXi 6.5.0d, VMware vSAN* 6.6, VMware vCenter* 6.5.0d
  - Benchmark Software: IOmark-VM (I/O equivalent to VMmark 2.5), IOmark-VM-HC requires Hyperconverged configurations verified with reported VMware VMmark results

INTEL® MEMORY DRIVE TECHNOLOGY DELIVERS BIG, AFFORDABLE MEMORY

use case 1

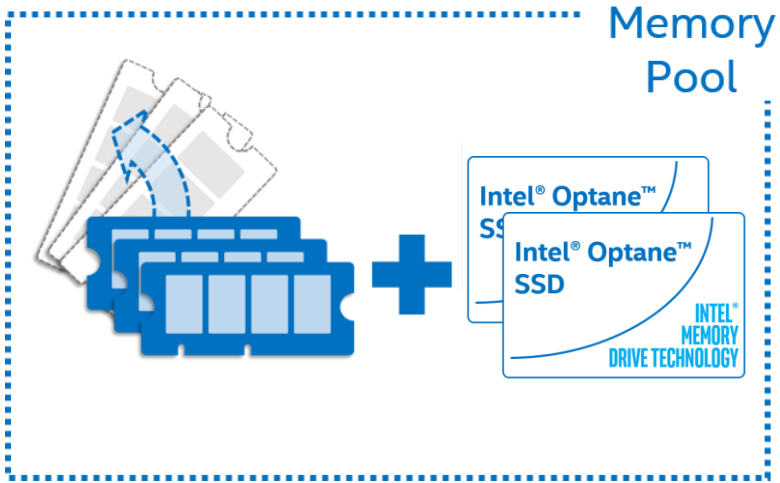
EXPAND BEYOND LIMITED DRAM CAPACITY



Expand Insights with Massive Data Pools

use case 2

DISPLACE DRAM WITH AFFORDABLE SSDs

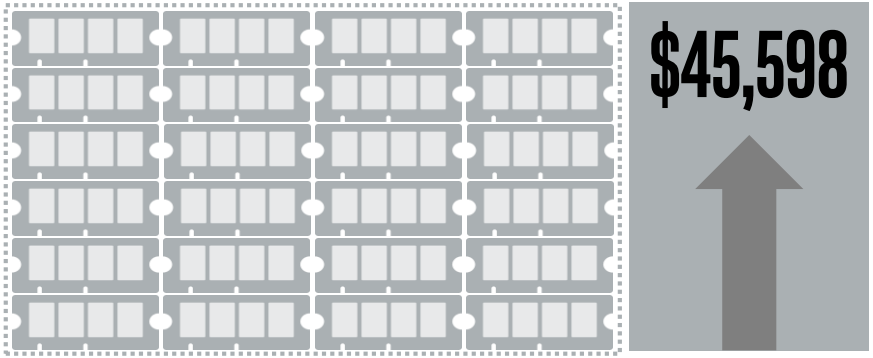


Reduce High-capacity DRAM CAPEX Expenditures

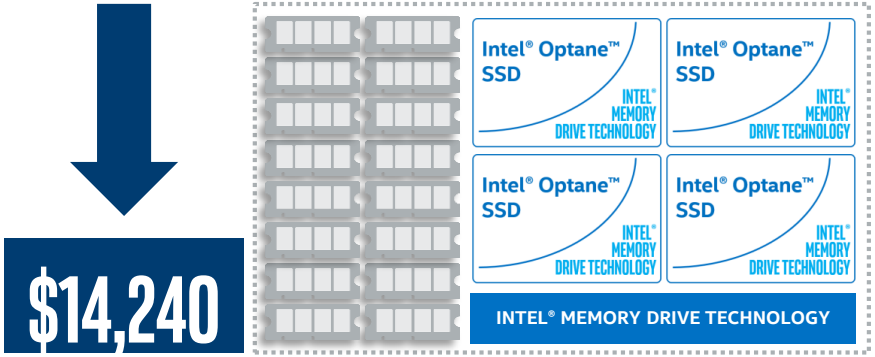
Intel® Memory Drive Technology supports Linux* x86_64 (64-bit), kernels 2.6.32 or newer.
*Other names and brands may be claimed as the property of others

DISPLACE COSTLY DRAM WITH INTEL® MEMORY DRIVE TECHNOLOGY

COST FOR 3TB OF DRAM-ONLY MEMORY



COST FOR 3TB OF INTEL® MEMORY DRIVE TECHNOLOGY



Memory Configuration used:

Item	Qty	$/ea	Total
128GB DDR4-2400 RDIMM	24	$1899[1]	$45,598

Memory Configuration used:

Item	Qty	$/ea	Total
32GB DDR4-2400 RDIMM	8	$273[2]	$2184
16GB DDR4-2400 RDIMM	8	$147[2]	$1176
Intel® Memory Drive Technology 640GB	4	$2720[3]	$10880

[1] Source – Servers4less* - Price as of October 26, 2017, Samsung M386AAK40B40-CUC4* 128GB PC4-19200 DDR4-2400MHz ECC Registered CL17 288-Pin Load Reduced DIMM
[2] Source – Trendforce* - Server DRAM Price Report Sep 2017 (Market Price)
[3] Source – Colfax Direct* - Combined pricing for Intel® Optane™ SSD DC P4800X 750GB and Intel® Memory Drive Technology http://www.colfaxdirect.com/store/pc/showsearchresults.asp?pageStyle=M&resultCnt=10&keyword=p4800x
*Other names and brands may be claimed as the property of others

INTEL® MEMORY DRIVE TECHNOLOGY WORKLOAD AND APPLICATION PERFORMANCE EXAMPLES

MEMCACHED

speed up dynamic web apps by alleviating database load

See more at:
https://www.intel.com/content/www/us/en/software/memcached-optimization-technology-brief.html

In-Memory Databases

leading enterprise in-memory databases for both OLAP and OLTP

redis

in-memory database and caching engine

See more at:
https://www.intel.com/content/www/us/en/products/docs/memory-storage/memory-drive-technology/imdt-for-redis-performance-evaluation-guide.html

APACHE Spark™

a fast and general engine for large-scale data processing

See more at:
https://www.intel.com/content/www/us/en/software/apache-spark-optimization-technology-brief.html
And:
https://vimeo.com/274692917

China Unicom
http://www.cnii.com.cn/incloud/2017-11/14/content_2012143.htm

Selectel
https://habrahabr.ru/company/selectel/blog/345306/

KVM

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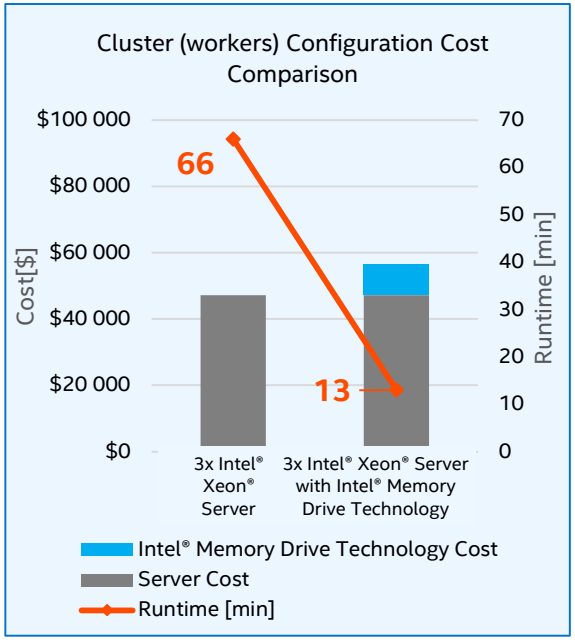
IMPROVE APACHE SPARK* AND TCO WITH INTEL® MEMORY DRIVE TECHNOLOGY



	3x Intel® Xeon® Servers	3x Intel Xeon Servers **+ Intel Memory Drive Technology**
Run time	*baseline*[1]	up to **5X** faster[2]
Run time/$	*baseline*[1]	up to **83.5%** better[2]

"Spark adoption is booming. Its community is growing, and all major big data platforms make a point of interoperating with Spark." ZDNet*, Nov 2017

https://www.zdnet.com/article/the-future-of-the-future-spark-big-data-insights-streaming-and-deep-learning-in-the-cloud/

[1] Source – Intel, System Configuration for Management Node: S2600WFT Intel White Box, 2 sockets, Intel® Xeon® Gold 6140 CPU @ 2.30GHz, 18 cores per socket / 2 threads per core (total 72 vcores), 192GB DDR4, CentOS 7.4* distribution with 4.15.12 kernel, HortonWorks* Data Platform 2.6.4, Spark 2.2.0*. Performance results are based on testing as of July 2018 and may not reflect all publicly available security updates. See configuration disclosure for details. 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. No product can be absolutely secure.

[2] Source – Intel, System Configuration for Data Node(s): Same as above plus 2x NVMe* PCIe* Intel® Optane™ SSD DC P4800X 375GB per system, 2x NVMe* PCIe* Intel® SSD DC P4500 3.7 TB per system

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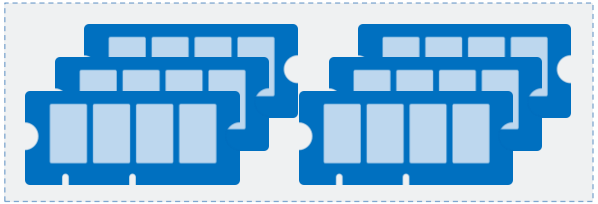
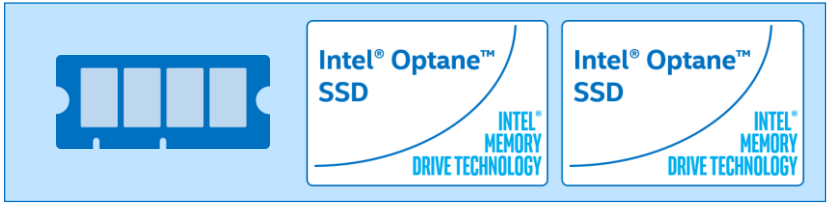
MS SQL SERVER* AND INTEL® MEMORY DRIVE TECHNOLOGY

384GB All-DRAM
(377GB total available memory)



3,380,127 TPM
(new order transactions per minute)

Intel® Memory Drive Technology
+ 128GB DRAM (377GB total available memory)



4,076,536 TPM
(new order transactions per minute)

up to **1.2x**
Better Transactions Per Minute (TPM)[1]

Better Performance in MS SQL Server* for Linux with Lower TCO

[1] Source – Intel tested: Intel® Optane™ SSD + Intel Memory Drive Technology configuration – 2 x Intel® Xeon® Gold 6140 Processor @ 2.30Ghz, Intel® Server Board S2600WF, 128GB DDR4 + 2 x Intel® Optane™ SSD DC P4800X (SSDPED1K375GA), CentOS 7.4*.1708. All DRAM configuration – 2 x Intel® Xeon® Gold 6140 CPU @ 2.30Ghz, Intel® Server Board S2600WF, 384GB DDR4 CentOS 7.4.1708. Test – HammerDB tpcc OLTP transaction split using an auto sequence mode (used for providing user sequence i.e. 2 4 8 16 32 64) with a 8min ramp-up time and a 346GB database. TPM is new orders per minute not queries per second. The benchmark results may need to be revised as additional testing is conducted. Performance results are based on testing as of August 2018 and may not reflect all publicly available security updates. See configuration disclosure for details. No product can be absolutely secure.
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INTEL® OPTANE™ TECHNOLOGY

Intel® Optane™
SSD DC P4800X
PCIe* 3.0 x4, NVMe*

375GB
750GB
1.5TB

Intel® Optane™
DC Persistent Memory

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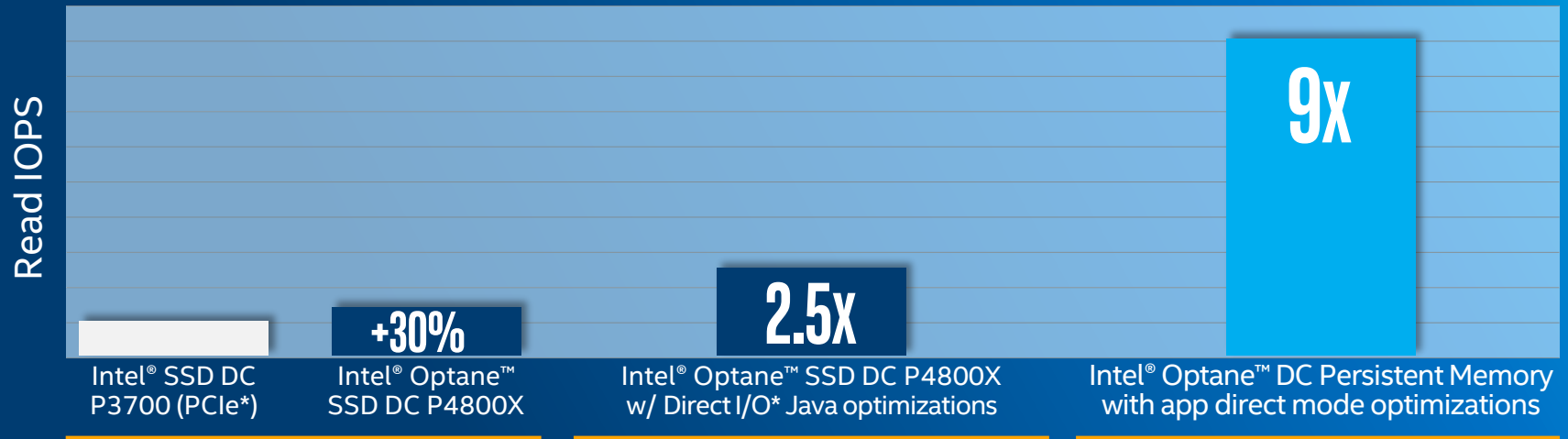
NEW DATA SOLUTIONS. SUPPORTING DATA CENTER DESIGN FLEXIBILITY.

DRAM	Bigger is Better	INTEL® OPTANE™ DC PERSISTENT MEMORY MODULE	INTEL® OPTANE™ SSD with software
◉	Capacity	●	○
○	Latency/ Bandwidth	●	◉
◉	Power	○	○
N	Persistency	Y	N

Graphical representation of product comparison is based on internal Intel analysis, and is provided here for informational purposes only. Any differences in system hardware, software or configuration may affect actual performance.

DATABASE. RE-ARCHITECT FOR APACHE CASSANDRA 4.0* GAINS.

IOPS performance vs. Comparable Server System with DRAM and NAND SSD



1 DEPLOY

available Intel® Optane™ DC SSDs

2 OPTIMIZE

with available software tools

3 EVOLVE

with next-generation memory technology

[1]System configuration: Server model: 2x Intel® Xeon® E5 2699 v4 @ 4. Ghz, Intel system board S2600WFWF, 384GB DDR4 @ 2667Mhz, 4x Intel® Optane DC SSD 375GB; CentOS 7.3.1611 (kernel 4.17.6) , Network is 10GbE. Apache Cassandra version 4.0-SNAPSHOT (DirectIO from Intel-based Java DirectIO Development team). Cassandra-stress tool used for benchmarking embedded into the Cassandra version build 4.0. Java heap size 64GB, Java Garbage collector G1GC, Java Version Oracle JDK 10.01 that embeds with Cassandra. Experimental release used for Optane Persistent Memory based system. Baseline nvme NAND Intel Drives – Intel SSD DC P4510. Baseline consists of Operating System OS page cache (not DirectIO) and best methods per Datastax and lead Companies of the Apache Cassandra Open Source version Project Management Committee. Performance results are based on testing as of July 2018 and may not reflect all publicly available security updates. See configuration disclosure for details. No product can be absolutely secure.

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