INTEL® OPTANE™ SSD PERFORMANCE ANALYSIS ON ANDROID*

Shyjumon Nankandiyil

May 23-24, 2019, Bangalore

SNIA, Storage Developer Conference - 2019

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Performance results are based on testing as of the date set forth in the configuration.

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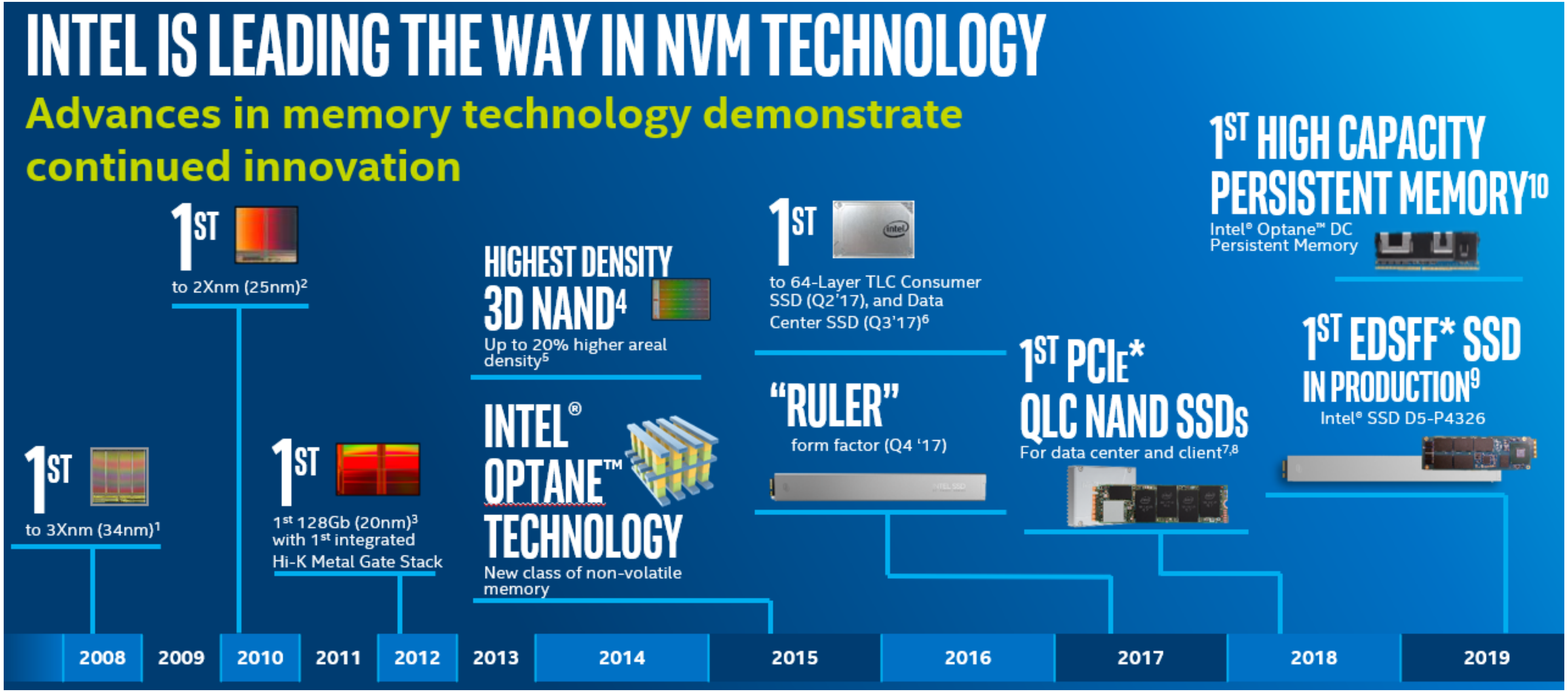
Agenda

- Introduction
- Software Stack
- Performance Analysis
- Conclusions & Recommendations

Introduction



See Appendix 1 for footnotes.
Milestones highlighted are based on that point in time only and do not reflect current technology on the market today.
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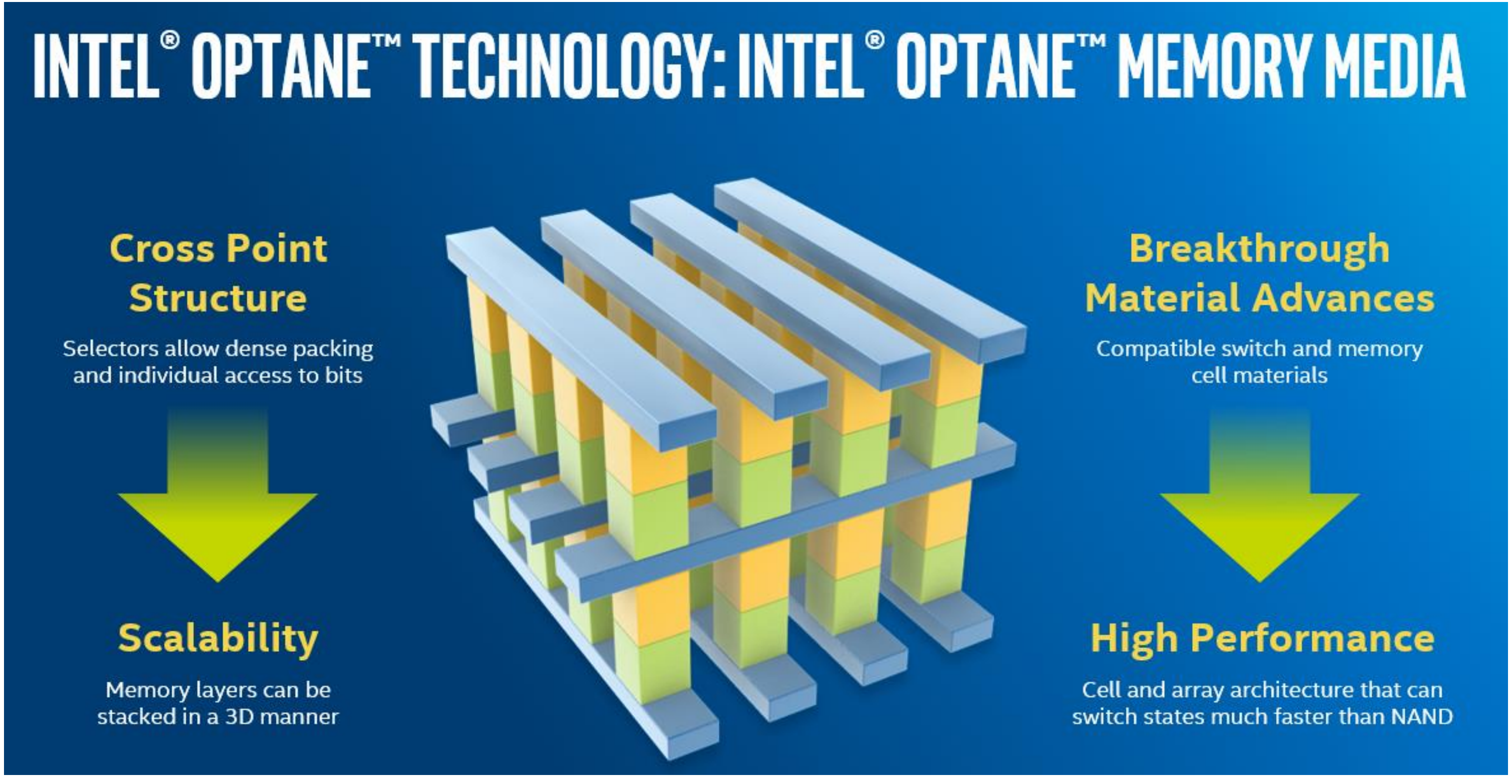
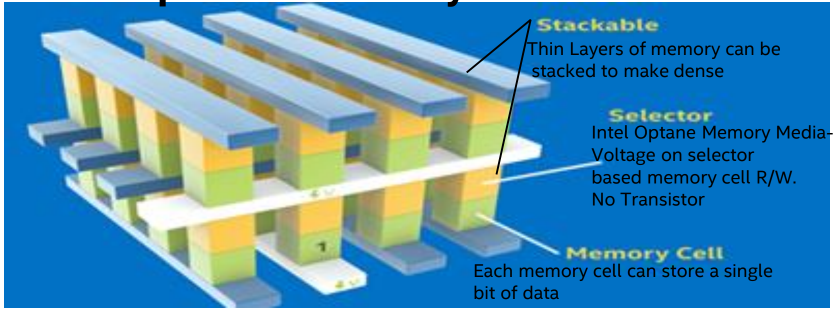
Hardware Media



Hardware Media Comparison

Intel® Optane™ Memory Media



Intel® Optane™ Technology	NAND	DRAM
Intel Optane Memory Media + Intel Controller => Intel® Optane™ SSD	3D NAND/TLC/MLC/SLC	DRAM
Bit/Byte wise. Block Emulation also.	Block wise	Bit/byte wise
Uses a bulk material property change, of the material itself to store a bit as 0 or 1	Stores electrons trapped on a floating gate	Stores electrons on a capacitor
NVMe*/DIMM	NVMe/SAS/SATA	DIMM
No Firmware. ASIC based HW programmable. No internal DRAM	Firmware and Internal DRAM	NA

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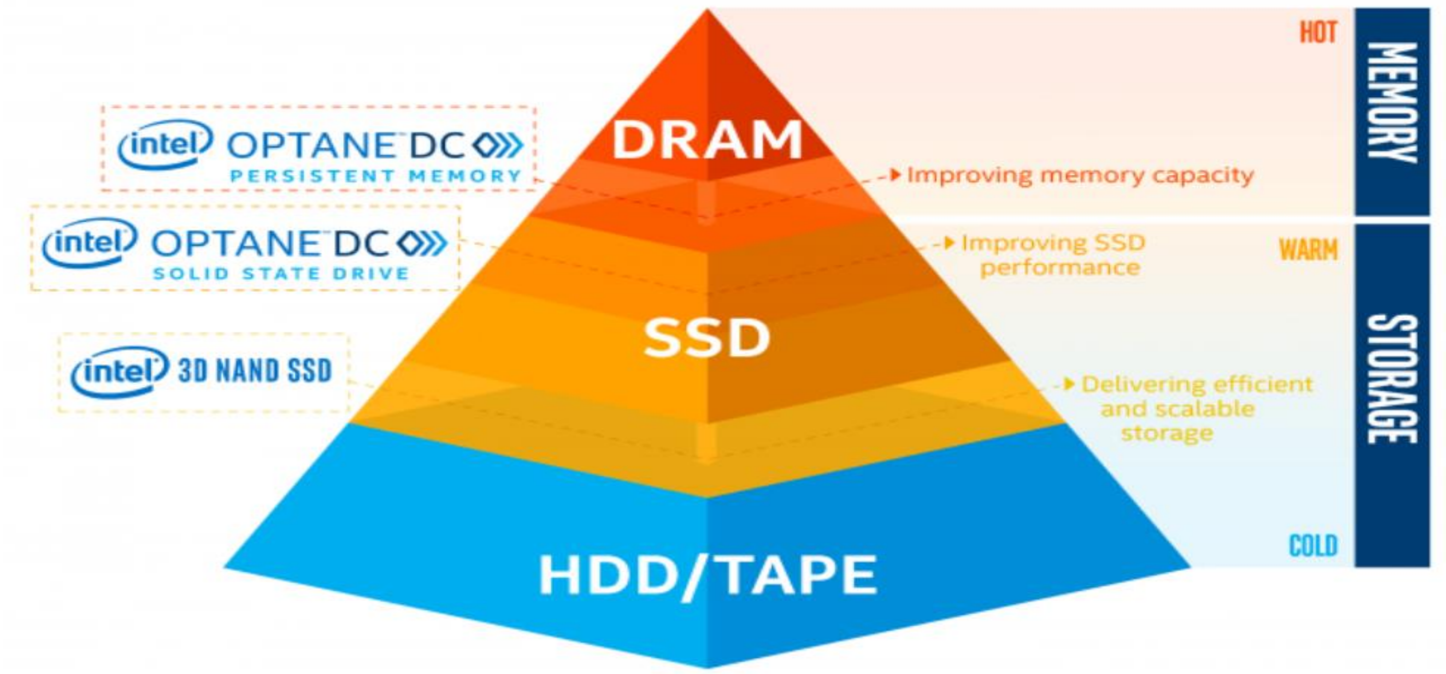
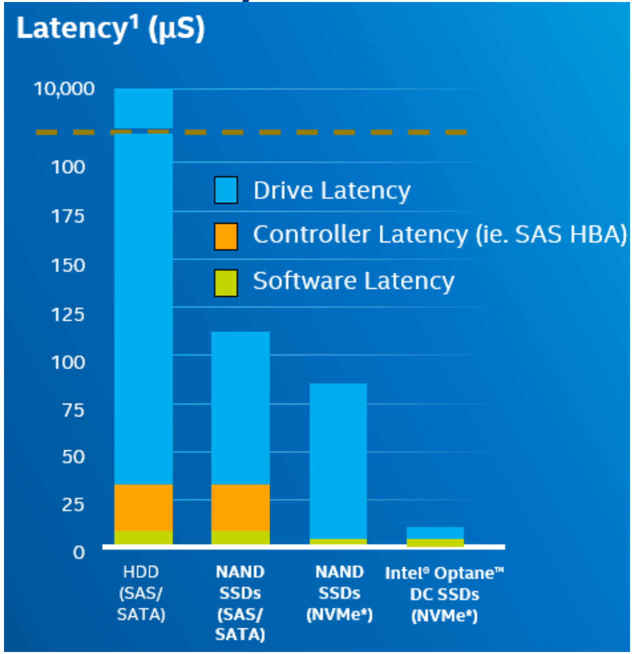
Memory & Storage Hierarchy Intel® Optane™ technology inclusive



Latency Trends

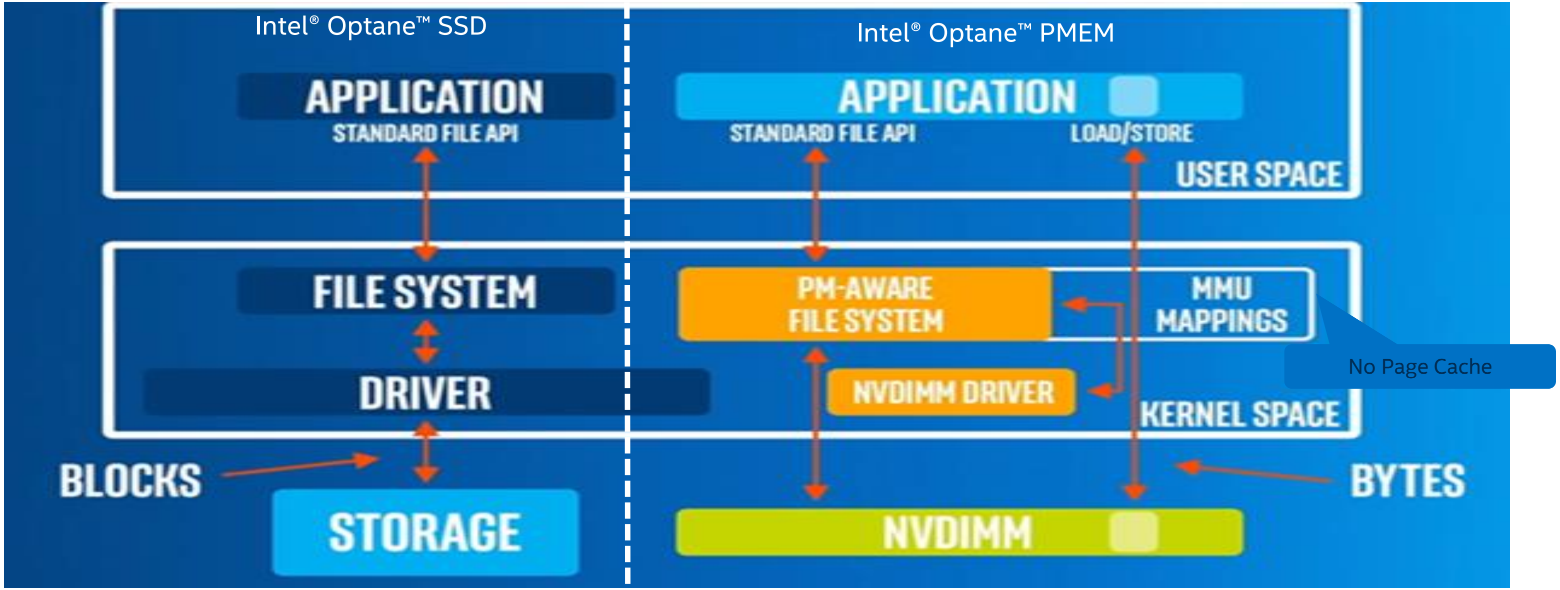


(Lower is better)

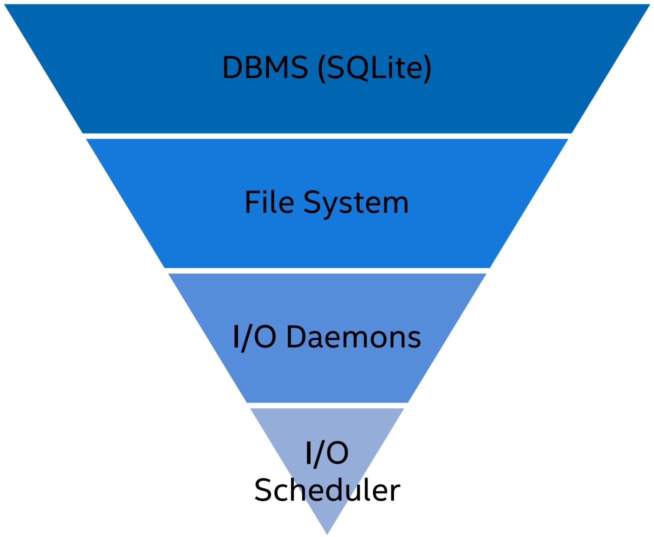
- SSD NAND technology offers ~100x reduction in latency versus HDD1
- NVMe* eliminates ~ 20 µs of latency today
- Intel® Optane™ Memory Media reduces NVM latency, offering ~ 10x reduction in latency versus NAND SSD1

[1]Source – Intel-tested: Average read latency measured at queue depth 1 during 4k random write workload. Measured using FIO 3.1. 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 DDR4 @ 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 3.1. Intel Microcode: 0x2000043; System BIOS: 00.01.0013; ME Firmware: 04.00.04.294; BMC Firmware: 1.43.91f76955; FRUSDR: 1.43. SSDs tested were commercially available at time of test. Performance results are based on testing as of July 24, 2018 and may not reflect all publicly available security updates. See configuration disclosure for details. No product can be absolutely secure. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more complete information visit www.intel.com/benchmarks.

Software Stack



Android* IO Stack



EXT4 Writes

- 50% of writes are for EXT4 Journal* updating
- 60-80% of the writes are random†

4KB IO

- More than 50% of the writes are synchronous
- 4KB IO accounts for 70% of all writes

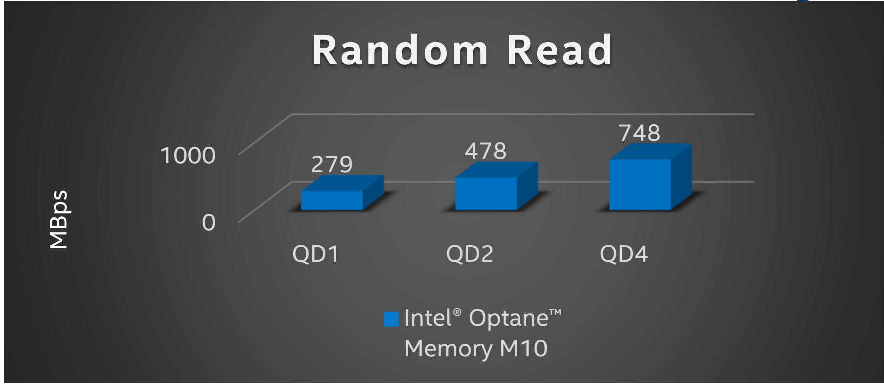
Impact

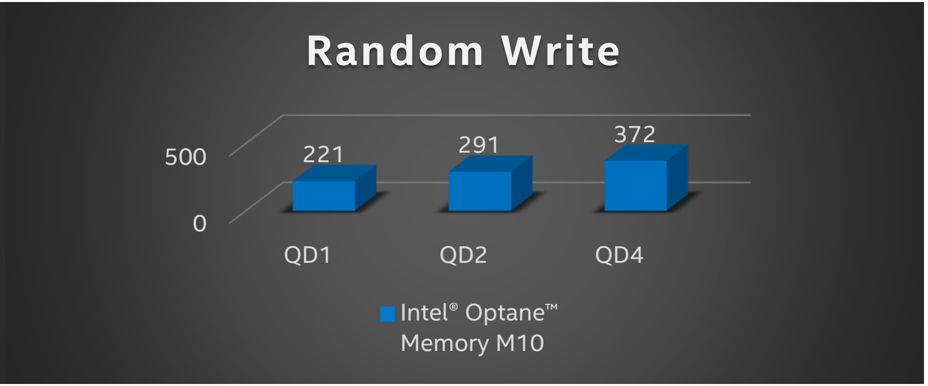
- Most of the IO operations uses SQLite* and EXT4 combined
- This generate excessive write operations to the NAND-based storage
- Degrade IO performance & Reduces life time

†Excluding Metadata and Journal accesses

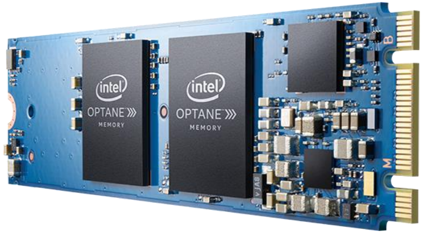
System configuration: Tested September, 26, 2018 Source – Intel: Model Specification: https://www.intel.com/content/www/us/en/products/boards-kits/nuc/kits/nuc7i7bnh.html DDR: 4 GB, Kingston*, 2133 MHz (SODIMM, DDR4). https://ark.intel.com/content/www/us/en/ark/products/135531/intel-optane-memory-m10-series-64gb-m-2-80mm-pcie-3-0-20nm-3d-xpoint.htmlAndroid* Version : 8.0 Oreo

FIO Performance Analysis





- Switching to an Intel® Optane™ Memory M10 showed 70% improvement in Read and 50% in Write on QD4



Intel® Optane™ Memory M10 64GB PCIe* 3.0 x2, NVMe*

See slides 19-20 for footnotes and configurations.
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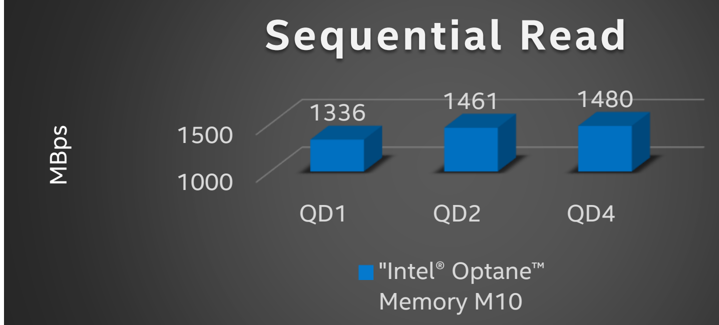
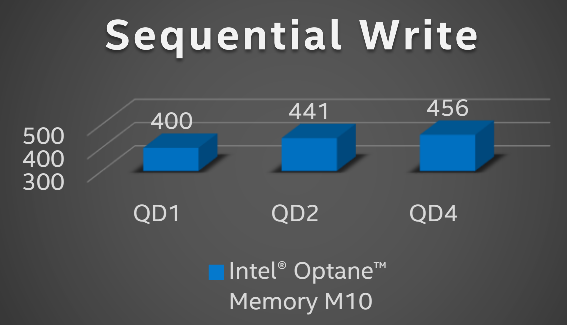
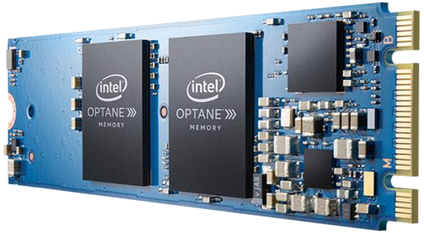
DDR: 4 GB, Kingston, 2133 MHz (SODIMM, DDR4). Comparison done with Third party at par spec. PCIe* 3.0 x2 NVMe drives.
https://ark.intel.com/content/www/us/en/ark/products/135531/intel-optane-memory-m10-series-64gb-m-2-80mm-pcie-3-0-20nm-3d-xpoint.htmlAndroid Version : 8.0 Oreo

FIO Performance Analysis





- Switching to an Intel® Optane™ Memory M10 shown at par performance



Intel® Optane™ Memory M10 64GB PCIe* 3.0 x2, NVMe*

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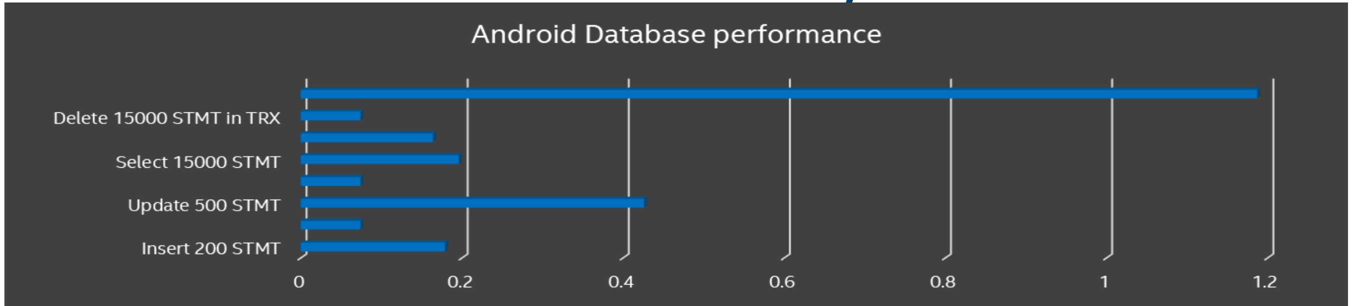
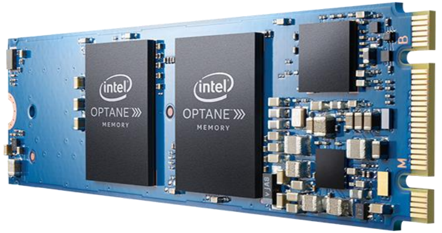
DBMS Performance Analysis



	Insert 200 STMT	Insert 15000 STMT in TRX	Update 500 STMT	Update 15000 STMT in TRX	Select 15000 STMT	Delete 200 STMT	Delete 15000 STMT in TRX	overall Avg QPS
Intel® Optane™ Memory M10	0.179	0.074	0.426	0.074	0.196	0.164	0.074	1.187



Intel® Optane™ Memory M10 64GB PCIe* 3.0 x2, NVMe*

- Switching to an Intel® Optane™ Memory M10 shows 90% Improvement. App Launch time ~30% Better

See slides 19-20 for footnotes and configurations.

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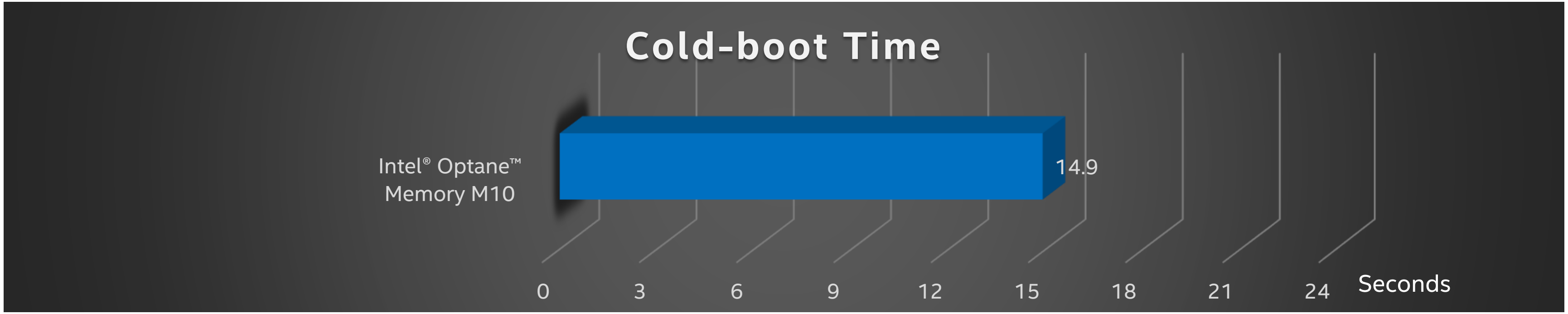
Boot time Analysis



- Switching to an Intel® Optane™ Memory M10 shows 20% better performance

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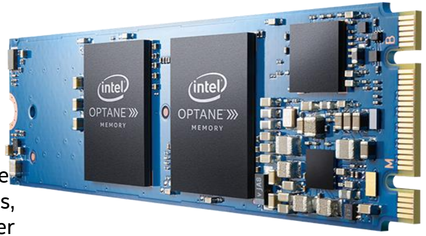
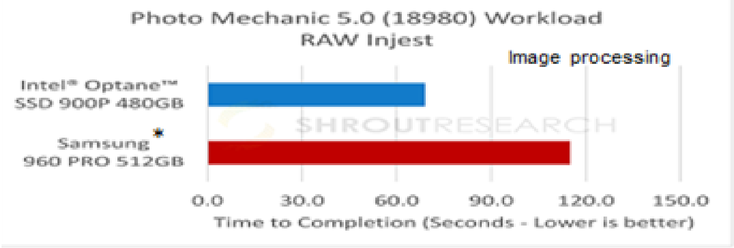
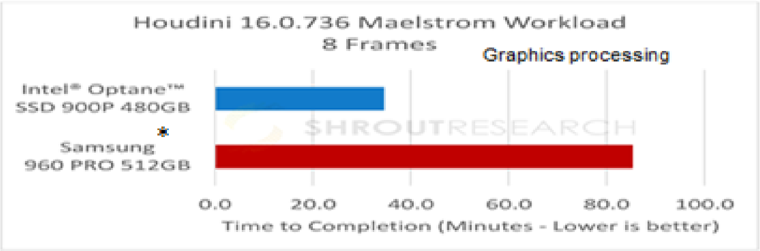


Intel® Optane™ Memory M10 64GB
PCIe* 3.0 x2, NVMe*

Shrout Research Data





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This paper was commissioned by Intel https://static1.squarespace.com/static/57fdb580ff7c50274b1387ef/t/59f24b308e7b0f2fb05e73f3/1509051187047/IntelOptaneSSD900p_Performance_Testing_Methodology_v10.pdf

Conclusions & Recommendations

- Intel® Optane™ technology is best suited for Data base workloads
- Android applications uses SQLite.
- Intel® Optane™ Memory Media & Intel Optane technology can provide higher performance in low power segments as well.
- All Android* Storage overheads improved with Intel® Optane™ technology

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Conclusions & Recommendations

Intel® Optane™ Memory Media Enables Future Applications

Appendix 1

Intel **is Leading the Way with NVM Technology (Slide 4)**

1. 1st to 3Xnm (34nm)- https://phys.org/news/2009-07-intel-industry-nanometer-nand-solid-state.html

2. 1st to 2Xnm (25nm)- https://www.intel.com/pressroom/archive/releases/2010/20100201comp.htm

3. 1st 128GB with 1st integrated Hi-K Metal Gate Stack - https://www.pcmag.com/article2/0,2817,2397287,00.asp

4. Highest Density 3D NAND – based on launch on March 26, 2015 comparing to other NAND die in production at that time https://newsroom.intel.com/news-releases/micron-and-intel-unveil-new-3d-nand-flash-memory/

5. Areal Density. Source – IEEE. Comparing areal density of Intel measured data on 512 Gb Intel 3D NAND to representative competitors based on 2017 IEEE International Solid-State Circuits Conference papers citing Samsung Electronics and Western Digital/Toshiba die sizes for 64-stacked 3D NAND component.

6. 1st to 64 layer TLC - http://www.storagereview.com/intel_shows_off_new_tech_ships_1st_64layer_3d_nand_for_data_center

7. Source: Intel. 1st PCIe* Intel QLC 3D NAND SSD. Based on Intel achieving PRQ status of Intel® SSD D5-P4320 on 13 July 2018.

8. 1st PCIe* QLC SSD for Client - https://www.tomshardware.com/reviews/intel-ssd-660p-qlc-nvme,5719.html

9. Intel announced on April 2, 2019 the Intel® SSD D5-P4326, the industry's first EDSFF compliant drive: https://newsroom.intel.com/news/fact-sheet-intel-unveils-new-technologies-accelerate-innovation-data-centric-world/#gs.bypjsd

10. Intel announced on April 2, 2019 the Intel Optane DC persistent memory, with up to 36TB of system-level memory capacity: https://newsroom.intel.com/image-archive/images-data-centric-innovation-products/#gs.byt5jb

Storage Workload used

FIO* Performance Analysis (Slide 11 & 12)

Drive Prepare	fio --ioengine=mmap --direct=1 --buffered=0 --size=100% --randrepeat=0 --fill_device=1 --norandommap --allow_mounted_write=1 --refill_buffers --log_avg_msec=1000 --group_reporting --filename=/dev/block/nvme0n1 sleep 1 fio --name=seq_write --rw=write --bs=128k --size=1024m --iodepth=128 --ioengine=mmap --numjobs=1
Random Read	sync && echo 3 > /proc/sys/vm/drop_caches && fio --name=rand_read --rw=randread --size=256m --bs=4k --iodepth=8 --ioengine=mmap --directory=/data/local/tmp --numjobs=1/2/4
Random Write	sync && echo 3 > /proc/sys/vm/drop_caches && fio --name=rand_write --rw=randwrite --size=256m --bs=4k --iodepth=8 --ioengine=mmap --directory=/data/local/tmp --numjobs=1/2/4
Sequential Read	sync && echo 3 > /proc/sys/vm/drop_caches && fio --name=seq_read --rw=read --size=1024m --bs=128k --iodepth=128 --ioengine=mmap --directory=/data/local/tmp --numjobs=1/2/4
Sequential Write	sync && echo 3 > /proc/sys/vm/drop_caches && fio --name=seq_write --rw=write --size=1024m --bs=128k --iodepth=128 --ioengine=mmap --directory=/data/local/tmp --numjobs=1/2/4

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Analysis Environment

Performance Analysis (Slide 11 - 14)

System Configuration	
Board	KBL-NUC NUC7i7BNH
Storage	**Optane Memory M10 Series (64GB, M.2 80mm PCIe* 3.0, 20nm) - MEMPEK1J064GAES**
	Intel e6000p 256GB SSD, NVMe*, 1570/540 (Seq/Rand)
RAM	4 GB, Kingston*, 2133 MHz (SODIMM, DDR4)
OS	Android* 8.0 (Oreo)

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Useful Resources

For information on how best to benchmark Intel® Optane™ SSDs, please refer to the [Evaluation Guide]

Open source Android Software Stack on Intel Architecture

https://01.org/projectceladon/

Celadon

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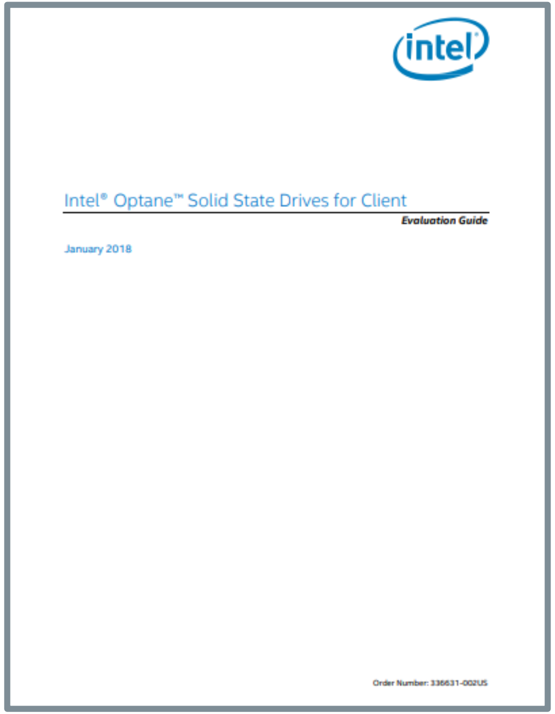
Intel® Optane™ Solid State Drives for Client

Evaluation Guide

January 2018

Order Number: 336631-002US

THANK YOU