INTEL® OPTANE™ SSD PERFORMANCE ANALYSIS ON ANDROID*

Shyjumon Nankandiyil
May 23-24, 2019, Bangalore
SNIA, Storage Developer Conference - 2019
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Agenda

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

INTEL IS LEADING THE WAY IN NVM TECHNOLOGY

Advances in memory technology demonstrate continued innovation

1st to 3Xnm (34nm)¹

1st to 2Xnm (25nm)²

1st 128Gb (20nm)³ with 1st integrated Hi-K Metal Gate Stack

HIGHEST DENSITY 3D NAND⁴
Up to 20% higher areal density²

INTERNET OPTANE™ TECHNOLOGY
New class of non-volatile memory

1st to 64-Layer TLC Consumer SSD (Q2’17), and Data Center SSD (Q3’17)⁶

“RULER” form factor (Q4 ‘17)

1st PCIe* QLC NAND SSDs
For data center and client⁶

1st EDSFF* SSD in Production⁹
Intel® SSD DS-P4326

1st High Capacity Persistent Memory¹⁰
Intel® Optane™ DC Persistent Memory

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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INTEL® OPTANE™ TECHNOLOGY: INTEL® OPTANE™ MEMORY MEDIA

Cross Point Structure
Selectors allow dense packing and individual access to bits

Breakthrough Material Advances
Compatible switch and memory cell materials

Scalability
Memory layers can be stacked in a 3D manner

High Performance
Cell and array architecture that can switch states much faster than NAND
# Hardware Media Comparison

## Intel® Optane™ Memory Media

- Thin Layers of memory can be stacked to make dense memory.
- Each memory cell can store a single bit of data.
- Voltage on selector based memory cell R/W. No Transistor.

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

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Memory & Storage Hierarchy Intel® Optane™ technology inclusive
Latency Trends

- 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

1Source – 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: 1.43.9176955; 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.

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Software Stack

Intel® Optane™ SSD

Intel® Optane™ PMEM

No Page Cache
**Android* IO Stack**

- **DBMS (SQLite)**
- **File System**
- **I/O Daemons**
- **I/O Scheduler**

### 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

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†Excluding Metadata and Journal accesses

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System configuration: Tested September, 26, 2018
Android* Version : 8.0 Oreo
*Other names and brands may be claimed as the property of others
Switching to an Intel® Optane™ Memory M10 showed 70% improvement in Read and 50% in Write on QD4

See slides 19-20 for footnotes and configurations.

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Android Version : 8.0 Oreo
FIO Performance Analysis

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

See slides 19-20 for footnotes and configurations.

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See slides 19-20 for footnotes and configurations.
Switching to an Intel® Optane™ Memory M10 shows 90% Improvement. App Launch time ~30% Better

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Boot time Analysis

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

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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.
Shrout Research Data

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This paper was commissioned by Intel [https://static1.squarespace.com/static/57fdb580ff7c50274b138ef7/59f24b308e7b0f2fb05e73f3/1509051187047/IntelOptaneSSD900p_Performance_Testing_Methodology_v10.pdf](https://static1.squarespace.com/static/57fdb580ff7c50274b138ef7/59f24b308e7b0f2fb05e73f3/1509051187047/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

- Massive in-memory database
- Fast system recovery
- Low latency
- High endurance

End User Possibilities:
- Gaming
- High fidelity pattern recognition
- Genomics
Appendix 1

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

3. **1st 128GB with 1st integrated Hi-K Metal Gate Stack** - [https://www.pcmag.com/article2/0,2817,2397287,00.asp](https://www.pcmag.com/article2/0,2817,2397287,00.asp)
6. **1st to 64 layer TLC** - [http://www.storagereview.com/intel_shows_off_new_tech_ships_1st_64layer_3d_nand_for_data_center](http://www.storagereview.com/intel_shows_off_new_tech_ships_1st_64layer_3d_nand_for_data_center)
### Storage Workload used

#### FIO* Performance Analysis (Slide 11 & 12)

<table>
<thead>
<tr>
<th>Drive Prepare</th>
<th>Command</th>
</tr>
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<tbody>
<tr>
<td>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</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Random Read</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>sync &amp; echo 3 &gt; /proc/sys/vm/drop_caches &amp; fio --name=rand_read --rw=randread --size=256m --bs=4k --iodepth=8 --ioengine=mmap --directory=/data/local/tmp --numjobs=1/2/4</td>
<td></td>
</tr>
</tbody>
</table>

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<th>Command</th>
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<td></td>
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<table>
<thead>
<tr>
<th>Sequential Read</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>sync &amp; echo 3 &gt; /proc/sys/vm/drop_caches &amp; fio --name=seq_read --rw=read --size=1024m --bs=128k --iodepth=128 --ioengine=mmap --directory=/data/local/tmp --numjobs=1/2/4</td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Sequential Write</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>sync &amp; echo 3 &gt; /proc/sys/vm/drop_caches &amp; fio --name=seq_write --rw=write --size=1024m --bs=128k --iodepth=128 --ioengine=mmap --directory=/data/local/tmp --numjobs=1/2/4</td>
<td></td>
</tr>
</tbody>
</table>

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DDR: 4 GB, Kingston, 2133 MHz (SODIMM, DDR4)


Android Version: 8.0 Oreo
# Analysis Environment

## Performance Analysis (Slide 11 - 14)

### System Configuration

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

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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/

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THANK YOU