Intel Innovations
Re-Imagining Data Center Storage and Memory
March 2018
Greg Matson, Director of SSD Strategic Planning and Product Marketing
Legal Disclaimer

Intel may make changes to specifications and product descriptions at any time, without notice. Designers must not rely on the absence or characteristics of any features or instructions marked “reserved” or “undefined”. Intel reserves these for future definition and shall have no responsibility whatsoever for conflicts or incompatibilities arising from future changes to them. The information here is subject to change without notice. Do not finalize a design with this information.

The products described in this document may contain design defects or errors known as errata which may cause the product to deviate from published specifications. Current characterized errata are available on request.

Intel technologies’ features and benefits depend on system configuration and may require enabled hardware, software or service activation. Performance varies depending on system configuration. No computer system can be absolutely secure. Check with your system manufacturer or retailer or learn more at intel.com.

Intel disclaims all express and implied warranties, including without limitation, the implied warranties of merchantability, fitness for a particular purpose, and non-infringement, as well as any warranty arising from course of performance, course of dealing, or usage in trade.

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.

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.

Intel does not control or audit the design or implementation of third party benchmark data or Web sites referenced in this document. Intel encourages all of its customers to visit the referenced Web sites or others where similar performance benchmark data are reported and confirm whether the referenced benchmark data are accurate and reflect performance of systems available for purchase.

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

© 2018 Intel Corporation. All rights reserved.

*Other names and brands may be claimed as the property of others.
Re-Imagining Data Center Storage and Memory with Intel Innovations

YESTERDAY

Network
Compute  Storage
Compute  Storage
Compute  Storage
Compute  Storage
Compute  Storage
Compute  Storage
Compute  Storage

Rack

TODAY

Network
Compute
Compute
Compute
Compute
Compute
Compute
Compute

Bulk Storage
Bulk Storage
Bulk Storage

Rack

Scalable Server Racks Enabled by Intel Innovation
Intel® Storage and Memory Innovations
A Range of Solutions for Today’s OCP Platforms

Intel® SSD DC P4510
15mm U.2 1TB, 2TB, 4TB, 8TB, 16TB*

Intel® SSD DC P4511
110mm m.2 1TB, 2TB, 4TB*

Lightning™
Based on OCP Lightning v1.0 specification
http://www.opencompute.org/wiki/Storage

Tioga Pass™
1
AVA Carrier

Yosemite/Twinlakes™
1
Glacier Point Carrier

Intel® Optane™ SSD
110mm m.2*

Intel® SSD DC P4511
110mm m.2 1TB, 2TB, 4TB*

Intel® Optane™ SSD
110mm m.2*

Intel® Optane™ Technology

TODAY
Network

Compute

Compute

Compute

Compute

Compute

Cache

Bulk Storage

Bulk Storage

Bulk Storage

Rack

1Tioga Pass and Glacier Point – Based on OCP Yosemite V.2 specification 0.4 http://files.opencompute.org/oc/public.php?service=files&t=837133ef9167e70d79ba57450eccb826

2Lightning – Based on OCP Lightning v1.0 specification http://www.opencompute.org/wiki/Storage

* Product available at a later date. Check Intel roadmap for more details.
Intel Storage and Memory Innovations
Building Blocks for Next Generation OCP Platforms

Platform Connected
- Manage more efficiently at scale
- Accelerate apps
- Simplify systems

Intel® 3D NAND Technology
- Industry leading areal density\(^1\)
- Massive, cost effective capacities

EDSFF 1U Long and 1U Short
- Space, thermal, operationally efficient
- Ready for PCIe* 4.0 and 5.0

FUTURE
Network
Compute
Compute
Compute
Compute
Compute
Compute
Bulk Storage
Bulk Storage
Bulk Storage

“Apache Pass” DIMMs
- Big, affordable, persistent memory
- Available on future Intel® Xeon® processor based platforms

Intel® Optane™ SSDs
- Massive, affordable memory extension
- Breakthrough cache bottleneck

\(^1\)Comparing areal density of Intel measured data on 512Gb 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.

*Other names and brands may be claimed as the property of others.
Intel® Optane™ SSD
Most Responsive Data Center SSD in the World

Breakthrough Performance

Predictably Fast Service

Responsive Under Load

✔️ 5-8x faster at low QD

✔️ up to 60x better at 99% QoS

✔️ up to 40x faster response under workload

1, 2, 3, 4 See Appendix for specific configurations.
Polar DB* @Alibaba

Breaking the Bottleneck with Intel® Optane™ SSD

Workload Description
Alibaba is the largest e-commerce business in China and a rapidly growing cloud service provider. PolarDB* is their in-house-designed transactional database.

Solution
Alibaba designed a SDS scale-out system to journal on fast/low latency Intel® Optane™ SSDs, data on low cost/high capacity Intel NVMe* SSDs.

Customer Value
This storage node solution reduces software and OS overhead, accelerating database performance to improve Alibaba’s customer shopping experience.

Additional Info
- Solution consists of 3 replicas with one set for both read & write, and the other two set as read-only
- Previous solutions collocated journal and data on NAND-based Intel® SSD DC P3600
- 6x improvement*: 1 million QPS and 130K TPS, 120 seconds (vs 70 hours) for creating read-only replica, 360 seconds for fail-overs

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.

*Alibaba-tested. (See Appendix for source link)

*Other names and brands may be claimed as the property of others.
Re-Imagining RAID
NVMe* RAID built into CPU

Intel® Virtual RAID on CPU
RAID Intel® SSD DC P4510

Unleash performance

Reduce cost and complexity

Up to 2x More IOPS in RAID 0
Up to 70% Cost Saving

Intel® VROC Stack

*Other names and brands may be claimed as the property of others.
6, 7, 8 See Appendix for Virtual RAID configuration and notes.
Re-Imagining the Data Center Form Factor
Enterprise Data Center SSD Form Factor (EDSFF)

Capacity Scaling.
up to 48 media sites 1U Long, 12 media sites 1U Short

Performance Scaling.
x4, x8, x16 support

Future Ready.
PCIe* 4.0 and 5.0 ready

Thermal efficiency.
up to 55% less airflow required than U.2 15mm

Solution Range.
1U Long, 1U Short, case, caseless designs.

1EDSFF 1U Short spec. Source – EDSFF.org. https://edsffspec.org/edsff-resources/
EDSFF 1U Short (SFF-TA-1006\(^1\))
Best of U.2 and M.2

- **Low power 6-12W operation**
- **Standard mounting holes for custom heatsinks, sleds**
- **111mm x 31.5mm fits in compute servers**
- **Fits 12 media (NAND) packages**
- **Full performance NVMe* controller**

SFF-TA-1002 Connector /w 6mm pin pitch, hot-plug

\(^1\)EDSFF 1U Short spec. Source – EDSFF.org. [https://edsffspec.org/edsff-resources/](https://edsffspec.org/edsff-resources/)

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

<table>
<thead>
<tr>
<th>Dense capacity</th>
<th>PCIe* M.2 flash card¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>System simplification</td>
<td>60TB (15 bays, 2 drives per bay, 2TB per drive)</td>
</tr>
<tr>
<td>Future-proof</td>
<td>PCIe 3.0 only</td>
</tr>
<tr>
<td>Thermal efficiency</td>
<td>Top/bottom heatsinks + TIMs req.</td>
</tr>
</tbody>
</table>

### PCIe* JBOF with M.2

- **EDSFF 1U Long**
  - 256TB – 1PB³ (32 slots, 8-32TB Intel® SSD DC P4510)
  - No cables, **Fully passive backplane, orthogonal connector**
  - PCIe 4.0, 5.0 ready
  - **Optimal airflow** (drives in front, horizontal mid-plane)
  - **Fully front serviceable**

¹Based on OCP Lightning v1.0 specification [http://www.opencompute.org/wiki/Storage](http://www.opencompute.org/wiki/Storage) ²Source – EDSFF.org, [https://edsffspec.org/edsff-resources/](https://edsffspec.org/edsff-resources/) ³Source – Intel. 256TB = 32 drives in 1U x 8TB Intel® SSD DC P4510. 1PB = 32 drives in 1U x 32 TB Intel® SSD DC P4510. 32TB drive available at a later date.

*Other names and brands may be claimed as the property of others.
Intel® Storage and Memory Innovations
Building Blocks for Next Generation OCP Platforms

Platform Connected
Intel® Volume Management Device
Intel® Virtual RAID on CPU

Intel® 3D NAND Technology

EDSFF 1U Long and 1U Short

FUTURE
Network

Compute
Intel® Optane™ Technology
Compute
Compute
Compute
Compute
Compute

Bulk Storage
Bulk Storage
Bulk Storage

Rack

“Apache Pass” DIMMs

Intel® Optane™ SSDs

Call to Action

Data Center Architects
• Explore bulk storage consolidation and TCO opportunities
• Identify opportunities to break through system bottleneck with Optane™ SSD

Software Developers
• Enable new data insights with larger hot data tier

Learn more
• http://www.opencompute.org/projects/storage/
• https://edsffspec.org/edsff-resources/
Appendix

1. **Most responsive SSD.** 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 Server System, 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 Write 4K latency using fio-2.15.

2. **Breakthrough performance.** Common Configuration - Intel 2U Server System, 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.

3. **Predictably fast service.** Common Configuration – Intel 2U Server System, 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.

4. **Responsive under load.** 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 Server System, 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.

5. **6x Faster. Source** – Alibaba-tested: Source document @ http://mp.weixin.qq.com/s/?__biz=MzA4NjI4MzM4MQ==&mid=2660194350&idx=2&sn=7b937d4363e0f28888a0ce07c31fd9007&chksm=84b0fd34b3c7742289b89bb09632f41d6a17646a626ecbceeeefac2815db3e87f3a9955feb&mpshare=1&scene=5&srcid=0921yeW6qPdiNB9MS8Vu5N6i#rd.


8. **Open source RAID.** RAID 0, 1, 5, 6, 10 support available on Red Hat Enterprise Linux 7.3* and Linux 7.4*. Intel UEFI drivers required for bootable RAID and enclosure management support.

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