SOFTWARE INNOVATION IN THE AGE OF MEMORY AND STORAGE TRANSFORMATION

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Vice President & General Manager
Data Center Product Management and Storage
SPDK, PMDK, VTUNE™ AMPLIFIER SUMMIT 2019

- Keynotes
- Meet the expert session
- Demos
- Technical deep dive sessions
- Hands on lab
- Networking events

(intel logo)
NEW TECHNOLOGY ADOPTION TAKES TIME

HOW DO WE ACCELERATE THE TRANSITION?
Using software to rewrite DECADES of design...
Because the paradigm has fundamentally changed

ACCELERATING TECHNOLOGY ADOPTION

VTune Amplifier
SPDK
PMDK
2019 DATA-CENTRIC PORTFOLIO
THE FOUNDATION FOR DATA-CENTRIC INNOVATION

A new class of performance leadership
BREAKTHROUGH PERFORMANCE + WORKLOAD SPECIALIZED PROCESSORS

Advanced intelligence for high-density edge solutions
INTEL® XEON® D-1600 PROCESSORS

Flexible Hardware Acceleration
INTEL® AGILEX™ FPGA

Accelerating workloads with lower latency and more throughput
INTEL® ETHERNET 700 & 800 SERIES ADAPTERS

Groundbreaking memory and storage innovation
INTEL STORAGE SOLUTIONS

Delivering high data availability and unprecedented data density
INTEL® SSD D5-P4326 E1.L

Multi-Tenant Data Protection
QUICKASSIST TECHNOLOGY

Multi-Tenant Data Protection
INTEL® SECURITY LIBRARIES BUILT-IN ENCRYPTION + ACCELERATORS

DELIVERING FASTER TIME TO VALUE
Intel® Software

DATA-CENTRIC
DELIVERING
FABRICATION
INTEL CORPORATION.
BREAKTHROUGH INNOVATION FOR MEMORY AND STORAGE

MEMORY

PERSISTENT MEMORY

STORAGE

IMPROVING SSD PERFORMANCE

DELIVERING EFFICIENT STORAGE

PROVIDING SUSTAINABLE VALUE ACROSS VECTORS

DRAM

HOT TIER

INTEL® QLC 3D NAND SSD

HDD / TAPE - COLD TIER

INTEL OPTANE DC™ PERSISTENT MEMORY

INTEL OPTANE DC™ SOLID STATE DRIVE

Intel® QLC 3D NAND SSD providing sustainable value across vectors. Improving SSD performance and delivering efficient storage.
DECREASING HARDWARE LATENCY

Lower is better

Idle Latency

75 µs

Storage with NAND SSD

10 µs

Storage with Intel® Optane™ DC SSD

Really Close to Zero!*

memory subsystem with intel® optane™

100 ns

Hardware Latency

Storage with Intel® Optane™ DC Persistent memory

100 ns

1 Source: Intel-tested: Average read latency measured at queue depth 1 during 4k random write workload. Measured using FIO 3.1, comparing Intel Reference platform with Optane™ SSD DC P4800X 375GB and Intel® SSD DC P4600 1.6TB compared to SSDs commercially available as of July 1, 2018. Performance results are based on testing as of July 24, 2018 and may not reflect all publicly available security updates.

2 App Direct Mode, NeonCity, LBG B1 chipset, CLX 80 2B Core (QDF QQYZ), Memory Conf 192GB DDR4 (per socket) DDR 2666 MT/s, Intel® Optane™ DC Persistent Memory 128GB, BIOS 561.D09, BKC version WW48.5 BKC, Linux OS 4.18.8-100.fc27, Spectre/Meltdown Patched (1,2,3, 3a)
INDUSTRY INNOVATION

HARDWARE INNOVATION
- 100 GbE
- Persistent Memory
- FPGAs
- Accelerators
- NVMe-oF
- SmartNICs

SOFTWARE INNOVATION
- SPDK
- VTune™ Amplifier
- OCF
- DPDK
- PMDK
- ISA-L
SOFTWARE PERFORMANCE REVOLUTION

SPDK
5X
FIO FOR NVME

OCF
5X
CEPH WORKLOAD, OCF WITH OPTANE CACHE

PMDK
8X
CASSANDRA WITH NATIVE PERSISTENCE

INTEL® VTUNE™ AMPLIFIER
2.2X
NETFLIX GBE

Configurations: (3 – slide 28 4 - slide 29 5 – slide 30-32)
For more complete information about performance and benchmark results, visit www.intel.com/benchmarks
SPDK IS STORAGE

- Services
- Protocols
- Drivers
- Virtualization
INNOVATIONS WITH SPDK

NVMe-oF  SmartNICs  Open Channel & Zoned Namespace SSDs  Virtualization

SPDK IS GROWING FAST!!!!
AliCloud* sees 4X improvement in IOPS and latency

AliCloud deploys Intel Xeon Scalable with SPDK and Intel® Optane

TOTAL GMV
RMB ¥213.5 BILLION
(USD $30.8 BILLION)

ALI CLOUD* SEES 4X IMPROVEMENT IN IOPS AND LATENCY^

https://mp.weixin.qq.com/s?__biz=MzIzOTU0NTQ0MA==&mid=2247488607&idx=1&sn=19e53786933d0c106fa5db842d10ce36&chksm=e9292950de5ea046f0502473454f1111a94c8bcf21a83030a5a62466f49abd6653aaaa2f2a0ad&mpshare=1&scene=1&srcid=1106CKDVSKvZ5zXPYwka6Ox&pass_ticket=yf7pdcGSGOEYx5tRe5EW3RIVz5jirZcnDC8FEMy9xZLPHiEFJ0TO3ZY333McXotrd
https://mp.weixin.qq.com/s?__biz=MzIzOTU0NTQ0MA==&mid=2247488807&idx=1&sn=54f87fa7bdf4ee901103895767db36328&chksm=e9292828de5e13ef922dd608d8eba474981139164e27ca61deddc476daa2ad6ed94974&scene=0&pass_ticket=rxfiYB3z4dV7qzdOkFzBjE%2ByJYxw41KcJwzI09I%2FXT9izHB5p824xpWgS1Oluy#rd
INTEL® CAS IS NOW OPEN!

OPEN SOURCE INNOVATION
FLEXIBLE INTEGRATION
INTEL® CAS CACHING ENGINE
INTEL® OPTANE DC SSD

UP TO 5X PERFORMANCE IMPROVEMENT

Configurations referenced on slide 29.
For more complete information about performance and benchmark results, visit www.intel.com/benchmarks
The **Open CAS Framework** is ready for action!

Integrate into your storage stack today!

[https://github.com/Open-CAS](https://github.com/Open-CAS)
PMDK IS

Faster TTM

Persistence at Native Hardware Latencies

Vendor neutral

Libraries and Tools

```python
n = 10000
t0 = time.time()
for i in range(n):
    myfast()
t1 = time.time()
```
ACCELERATING CASSANDRA WITH PMDK

8.2X READS
8.0X WRITES
10X 80/20 READ/UPDATE

WITH A NATIVE PERSISTENT MEMORY STORAGE ENGINE

Configurations describe on slides 30–32.
For more complete information about performance and benchmark results, visit www.intel.com/benchmarks.
INTEL® VTUNE™ AMPLIFIER OPTIMIZES

Configuration

Memory Performance

Storage Performance
“Intel® VTune™ Amplifier helped us detect a memory paging problem. We resolved the issue with Intel® Optane™ DC persistent memory which allowed us to scale to significantly larger datasets.”

Paul Cao
Ph. D. Performance and Solution Technologist
HP Enterprise
ISA-L IS DATA

Protection

Hashing

Compression

Integrity

Encryption
ISA-L GENERATIONAL INNOVATIONS

Compression

Hashing

Erasure Coding

3x SMALL BLOCK VERSES ZLIB 6x

3x GEN TO GEN

2x GEN TO GEN

06d80e7 b0C50bs 49a509t b49f249 24e8c8o 05x84q4

Configurations: Slide 33.
For more complete information about performance and benchmark results, visit www.intel.com/benchmarks
**COMMUNITY 2018 REVIEW**

2 SPDK Summits (Totaling >330 Attendees)

2 Developer Labs

1 Developer Meetup (Hosted by NetApp)

>70 Companies

>1000 Github followers

Up 40% YoY

+250%

+31%

+34%

Unique Daily Visitors: 2016, 2017, 2018

Committers: 2016, 2017, 2018

External Patches: 2016, 2017, 2018
SPDK Project Considering Open Governance

Open Governance Membership Benefits

• Open governance and level playing field for all participants
• Proliferate community by:
  – Shared Community events planning
  – Opportunities for community operated infrastructure
  – Shared voice in project direction
  – Shared marketing opportunities
• Provide support for any trademark or other legal issues

Please let us know your thoughts during the summit
IF WE MOVE TO OPEN GOVERNANCE, WHAT IS NOT CHANGING?

- SPDK remains a fully open source project
- Anybody can contribute
- Anybody can use and remain proprietary
- There are no fees
- Tools and Process remains the same
Use SPDK, PMDK, VTune™, OCF

Interact with the community

Contribute

LOTS OF WAYS TO ENGAGE

THANK YOU FOR BUILDING THE COMMUNITY
NOTICES AND DISCLAIMERS

• 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 product or component 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. For more complete information about performance and benchmark results, visit http://www.intel.com/benchmarks.
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• Intel® Advanced Vector Extensions (Intel® AVX)* provides higher throughput to certain processor operations. Due to varying processor power characteristics, utilizing AVX instructions may cause a) some parts to operate at less than the rated frequency and b) some parts with Intel® Turbo Boost Technology 2.0 to not achieve any or maximum turbo frequencies. Performance varies depending on hardware, software, and system configuration and you can learn more at http://www.intel.com/go/turbo.
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• 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 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.
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Hardware Configuration for System Level Performance

SSDs
Intel-tested: 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 P4610 3.2TB. Intel Microcode: 0x2000043; System BIOS: 00.01.0013; ME Firmware: 04.00.04.294; BMC Firmware: 1.43.91f76955; FRUSDR: 1.43.

Intel® Optane™ DC Persistent Memory

<table>
<thead>
<tr>
<th>Component</th>
<th>Single DIMM Config</th>
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<tr>
<td>Test by</td>
<td>Intel</td>
</tr>
<tr>
<td>Test date</td>
<td>02/20/2019</td>
</tr>
<tr>
<td>Platform</td>
<td>NeonCity</td>
</tr>
<tr>
<td>Chipset</td>
<td>LBG B1</td>
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<tr>
<td>CPU</td>
<td>CLX B0 28 Core (QDF QQYZ)</td>
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<tr>
<td>DDR Speed</td>
<td>2666 MT/s</td>
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<tr>
<td>AEP</td>
<td>QS Tranche3, 256GB, 18W</td>
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<td>Memory Config</td>
<td>32GB DDR4 (per socket)</td>
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<td></td>
<td>128GB AEP (per socket)</td>
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<td>AEP FW</td>
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<td>4.20.4-200.fc29</td>
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<td>Spectre/Meltdown</td>
<td>Patched (1,2,3, 3a)</td>
</tr>
<tr>
<td>Performance Turning</td>
<td>QoS Disabled, IODC=5(AD)</td>
</tr>
</tbody>
</table>

The benchmark results may need to be revised as additional testing is conducted. Performance results are based on testing as of November 15, 2018 and may not reflect all publicly available security updates. See configuration disclosure for details. No product can be absolutely secure.
SPDK SYSTEM CONFIGURATION

- Performance results are based on testing by Intel as of 2/26/2019 and may not reflect all publicly available security updates. See configuration disclosure for details. No product or component 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.

- **Intel(R) Xeon(R) Platinum 8280L CPU @ 2.70GHz + P4610:** Tested by Intel on 4/12/2019, S2600WFT Platform with 12 x 16GB 2666MHz DDR4 (total 192GB), Storage: Intel® SSD DC S3700 800GB, Storage drives: 20x Intel® SSD DC P4610 (2TB), SPDK: (16x P4610s), URING: (4x P4610s), AIO: (2x P4610s), Bios: SE5C620.86B.0D.01.0250.112320180145, ucode: 0x4000010 (HT=ON, Turbo=ON), OS: Fedora 29, Kernel: 5.0.0-rc6+, Benchmark: bdevperf, QD= 32 (for SPDK), QD= 64 (for URING), QD=128 (for AIO), runtime = 300s, SPDK commit: b62dca930, SPDK compiled with LTO, PGO gcc compiler options, for URING (tuning: echo 0 > /sys/block/$dev/queue/iostats, echo 0 > /sys/block/$dev/queue/rq_affinity, echo 2 > /sys/block/$dev/queue/nomerge, echo 0 > /sys/block/$dev/queue/io_poll_delay)

  - Results: 4K 100% Random Reads (100%) SPDK = 8.15M IOPS
  - Results: 4K 100% Random Reads (100%) URING = 1.56M IOPS
  - Results: 4K 100% Random Reads (100%) AIO = 0.614M IOPS
OCF FOOTNOTES/SYSTEM CONFIGURATIONS

• 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 [www.intel.com/benchmarks](http://www.intel.com/benchmarks). 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.

• System Configuration for slides titled “CAS + Intel® Optane™ SSD Accelerating MySQL” (pages 27-28) and for performance claim “MySQL up to 5.1X as fast w/CAS + Intel® Optane™ SSD” (pages 6, 8, 15) and for performance claim “MySQL* accelerated 5.11X” (pages 10, 26)

- System configuration – Red Hat Enterprise Linux 7.3, Kernal 3.10.0-514.el7.x86_64 #1 SMP Wed Oct 19 11:24:13 EDT 2016, Purley Silver Wolf Pass S2600WFQ, BIOS Version: SE5C620.86B.0X.01.0107.122220170349, BIOS Release Date: 12/22/2017, Skylake H0 (2 Processors)(24 cores each processor, hyper-threading is enabled in BIOS so thread count per processor is 48) Intel® Xeon® Platinum 8160T CPU @ 2.10GHz, Intel(R) Rapid Storage Technology enterprise PreOS Version : 5.3.0.1052, 256GB Physical RAM installed but set to 128GB in the grub2 configuration, Intel 82574L Gigabit Ethernet Adapter, VMD enabled in BIOS and VROC HW key (Premium) installed and activated, Package C-State set to C6(non retention state) and Processor C6 set to enabled in BIOS, P-States set to default in BIOS and SpeedStep and Turbo are enabled, BMC version: 1.43.33e8d6b4 ME version: 4.00.04.309 SDR Package version: 1.43, fio version: fio-3.5-86-gcefd2, (VROC) mdadm - v4.0 - 2017-09-22 Intel build: RSTe_5.3_WW38.5, kmod-md-rste-5.3-514_4.el7_3.x86_64

• System Configuration for slides “Accelerating Ceph* using HDD Backing Store” (page 33 - 34), performance claims “Ceph* Reads up to 4.9 X Faster with CAS + Intel® Optane™ SSD” and “Ceph* Writs up to 4.8 X Faster with CAS + Intel® Optane™ SSD” (pages 6, 8, 15) and “Ceph* reads 4.9X faster, Ceph writes 4.8X faster” (pages 12, 31)

- Baseline 4-Node Cluster: HDD OSD Drives with Journals on Intel S4600 SSD’s: 3x OSD 1x Mon/RGW Nodes: Server Intel S2600GZ (Grizzly Pass), CPUs 2x Intel® Xeon® Ivy Bridge E5-2660v2 @ 2.20GHz, 64GB Mem, SATA Boot SSD 1 x 800GB Intel® SSD DC S3700, OSD HDD 7 x 4TB WD* WDC_WD4003FZEX (excl. Mon/RGW), SATA Journal SSD 1 x 2TB Intel® SSD DC S4600, Network 2 x Intel® X540-AT2 10Gb eNICS; Ceph journal size: 10GB x 7. Value 4-Node Cluster: HDD OSD Drives with Journals on Optane, with/without CAS. Same as Baseline except NVMe Journal and cache x 375GB Intel P4800x Optane; Ceph Journal size: 10GB x 7, Cache Size: 320GB x 2. Software: Ceph Luminous v12.2.3, RHEL 7.4 Updated, COSBench 0.4.2.c4, Intel CAS 3.5.1 (Value)
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<thead>
<tr>
<th>Parameter</th>
<th>NVMe</th>
<th>DCPMM</th>
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<tr>
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<td>Intel/Java Performance Team</td>
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<tr>
<td># Nodes</td>
<td>1</td>
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</tr>
<tr>
<td># Sockets</td>
<td>2</td>
<td>2</td>
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<tr>
<td>CPU</td>
<td>8280L</td>
<td>8280L</td>
</tr>
<tr>
<td>Cores/socket, Threads/socket</td>
<td>28/56</td>
<td>28/56</td>
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<tr>
<td>ucode</td>
<td>0x4000013</td>
<td>0x4000013</td>
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<tr>
<td>HT</td>
<td>On</td>
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<tr>
<td>DCPMM BKC version</td>
<td>NA</td>
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<td>DCPMM FW version</td>
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<td>12 slots / 16GB / 2666</td>
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<tr>
<td>System DCPMM Config: slots / cap / run-speed</td>
<td>-</td>
<td>12 slots / 512GB</td>
</tr>
<tr>
<td>Total Memory/Node (DDR, DCPMM)</td>
<td>192GB, 0</td>
<td>192GB, 6TB</td>
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<tr>
<td>Storage - boot</td>
<td>1x Intel 800GB SSD OS Drive</td>
<td>1x Intel 800GB SSD OS Drive</td>
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<tr>
<td>Storage - application drives</td>
<td>4x P4610 1.6TB NVMe</td>
<td>12x512GB DCPMM</td>
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<tr>
<td>NIC</td>
<td>1x Intel X722</td>
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<td>Yes</td>
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<td>DCPMM mode</td>
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<td>Run Method</td>
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<td>5 minute warm up post boot, then start performance recording</td>
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<td>Iterations and result choice</td>
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<td>3 iterations, median</td>
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<td>Two 1.5 Billion Partitions (Insanity schema)</td>
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</tbody>
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PMDK - HARDWARE CONFIGURATION DIAGRAM

Client running cassandra-stress

10Gb network

10Gb network

10Gb network

10Gb network

10Gbit switch

DRAM

Optane

PM

Intel Confidential

CLX Server

DRAM

Optane

PM

DRAM

Optane

PM

DRAM

Optane

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DRAM

Optane

PM

Intel Confidential-CNDA Required
PMDK - SOFTWARE CONFIGURATION DIAGRAM

Client 1
- cassandra-stress 1
- cassandra-stress 2

Client 2
- cassandra-stress 3
- cassandra-stress 4

Server 1
- Socket 1
  - Cassandra App 1
  - Database 1

- Persistent Memory Namespace or 2 NVME

- Socket 2
  - Cassandra App 2
  - Database 2

- Persistent Memory Namespace or 2 NVME
ISA-L FOOTNOTES/SYSTEM CONFIGURATIONS

CLX:
Intel(R) Xeon(R) Platinum 8280L, 28C, 2.7 GHz, H0, Neon City CRB, 12x16 GB DDR4 2933 MT/s ECC RDIMM, Micron MTA18ASF2G72PDZ-2G9E1TG, NUMA Memory Configuration, Red Hat Enterprise Linux Server 7.5 64-bit OS, kernel 3.10.0-957.1.3.el7.x86_64, BIOS ENERGY_PERF_BIAS_CFG: PERF, Disabled: P-States, Turbo, Speed Step, C-States, Power Performance Tuning, Isochronous, Memory Power Savings, ISA-L 2.25

CLX:
Intel(R) Xeon(R) Gold 6230, 20C, 2.1 GHz, H0, Neon City CRB, 12x16 GB DDR4 2933 MT/s ECC RDIMM, Micron MTA18ASF2G72PDZ-2G9E1TG, NUMA Memory Configuration, Red Hat Enterprise Linux Server 7.5 64-bit OS, kernel 3.10.0-957.1.3.el7.x86_64, BIOS ENERGY_PERF_BIAS_CFG: PERF, Disabled: P-States, Turbo, Speed Step, C-States, Power Performance Tuning, Isochronous, Memory Power Savings, ISA-L 2.25

SKX:
Intel(R) Xeon(R) Gold 6126, 12C, 2.6 GHz, H0, Neon City CRB, 12x16 GB DDR4 2666 MT/s ECC RDIMM, Micron MTA36ASF2G72PZ-2G6B1QJ, NUMA Memory Configuration, Red Hat Enterprise Linux Server 7.4 64-bit OS, kernel 3.10.0-693.21.1.el7.x86_64, BIOS ENERGY_PERF_BIAS_CFG: PERF, Disabled: P-States, Turbo, Speed Step, C-States, Power Performance Tuning, Isochronous, Memory Power Savings, ISA-L 2.23 vs ISA-L 2.25

BDX:
Intel(R) Xeon(R) E5-2650v4, 12C, 2.2 GHz, B0, Aztec City CRB, 8x8 GB DDR4 2400 MT/s ECC RDIMM, Samsung M393A1G43DB0, NUMA Memory Configuration, Red Hat Enterprise Linux Server 7.4 64-bit OS, kernel 3.10.0-693.21.1.el7.x86_64, BIOS ENERGY_PERF_BIAS_CFG: PERF, Disabled: P-States, Turbo, Speed Step, C-States, Power Performance Tuning, Isochronous, Memory Power Savings, ISA-L 2.23