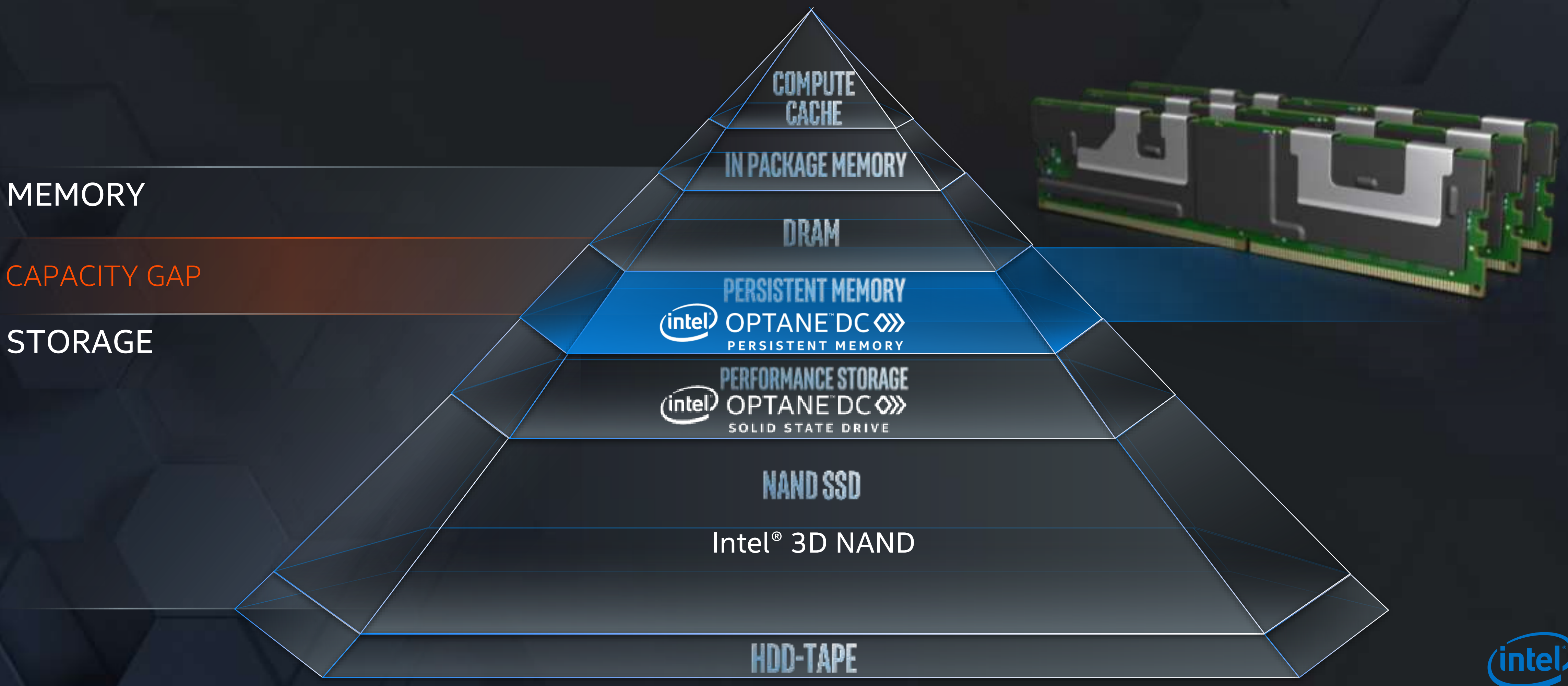
ComSys2019

INTRODUCING OPTANE DC PERSISTENT MEMORY

Techinical Solution Specialist
Fumiyasu Ishibashi

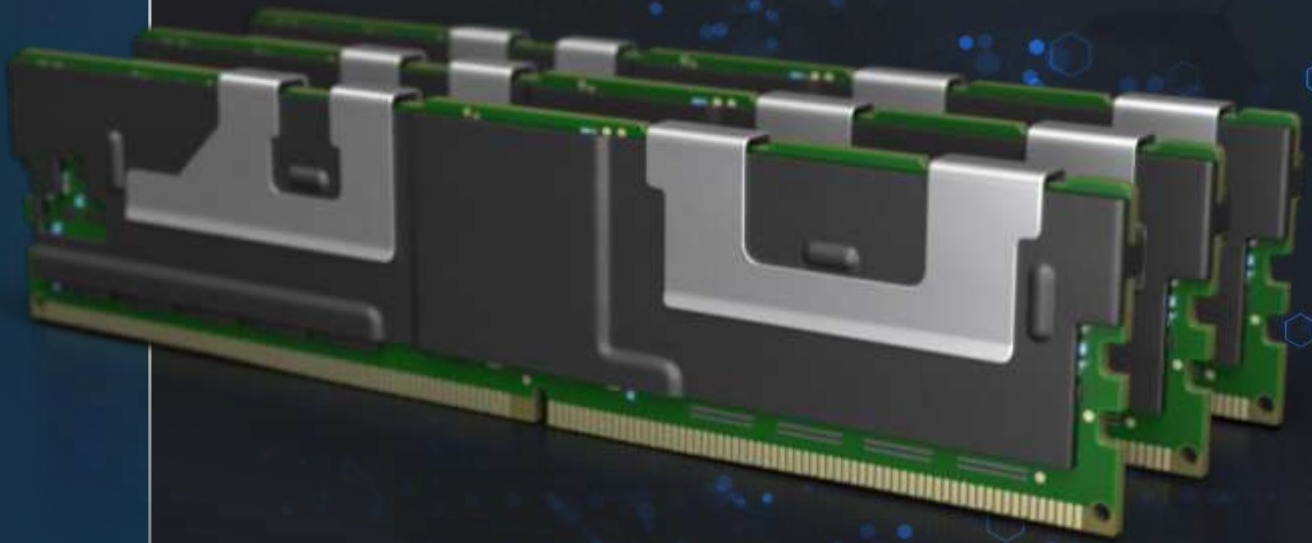
MEMORY AND STORAGE HIERARCHY GAPS

THE CAPACITY GAP



intel OPTANE™ DC
PERSISTENT MEMORY

- **BIG AND AFFORDABLE MEMORY**
  128, 256, 512GB MODULES
  DDR4 PIN COMPATIBLE
- **BYTE ADDRESSABLE**
  DIRECT LOAD/STORE ACCESS
- **HIGH PERFORMANCE STORAGE**
  NATIVE PERSISTENCE
- **HIGH RELIABILITY AND SECURITY**
- **TWO OPERATIONAL MODES**



INTEL® OPTANE™ MEDIA TECHNOLOGY

High Resistivity – '0'
Low Resistivity – '1'

Attributes

- + Non-volatile
- + Potentially fast write
- + High density
- + Non-destructive fast read
- + Low voltage
- + Integrate-able w/ logic
- + Bit alterable

First Generation Capacities:

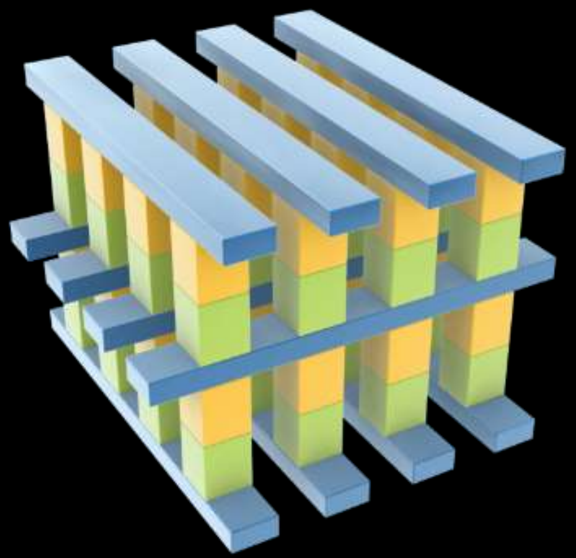
128 GB
256 GB
512 GB

Cross-Point Structure

Selectors allow dense packing
And individual access to bits

Breakthrough Material Advances

Compatible switch and memory cell materials



Scalable

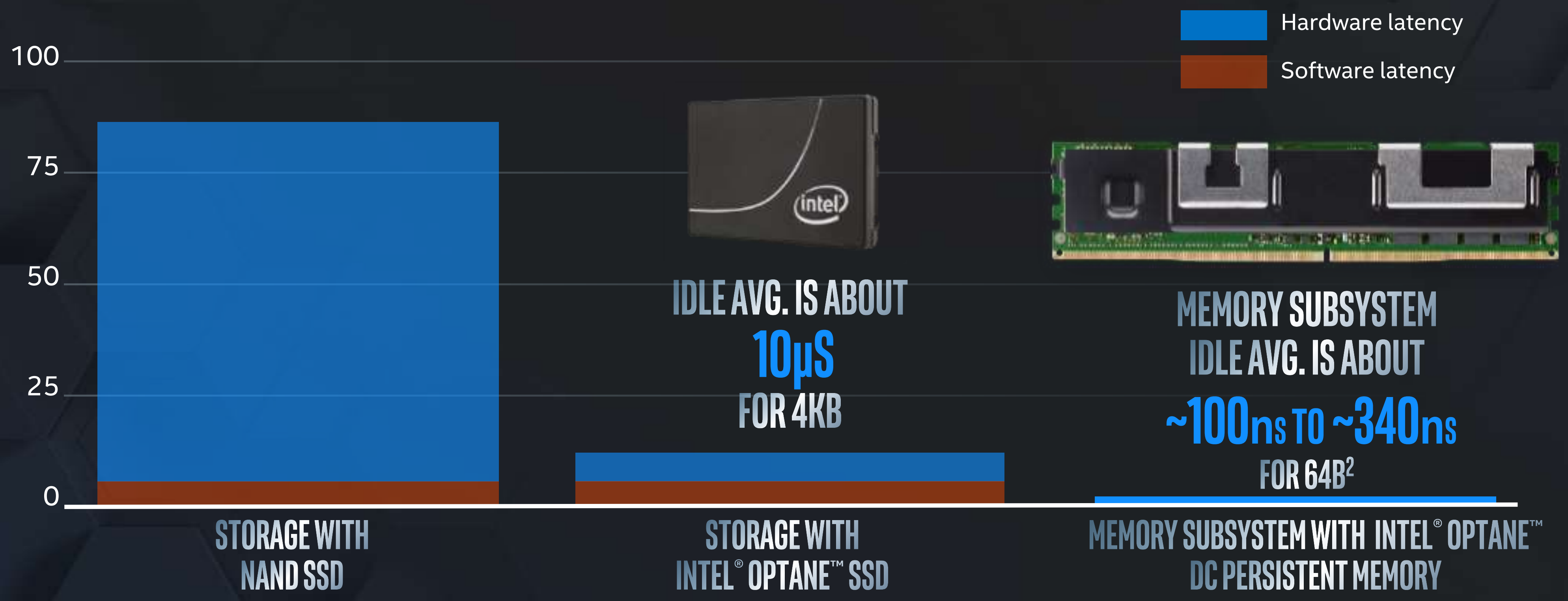
Memory layers can be stacked in a 3D manner

High Performance

Cell and array architecture that can switch fast

MORE TO BE GAINED BY BEING ON MEMORY BUS

IDLE AVERAGE RANDOM READ LATENCY[1]

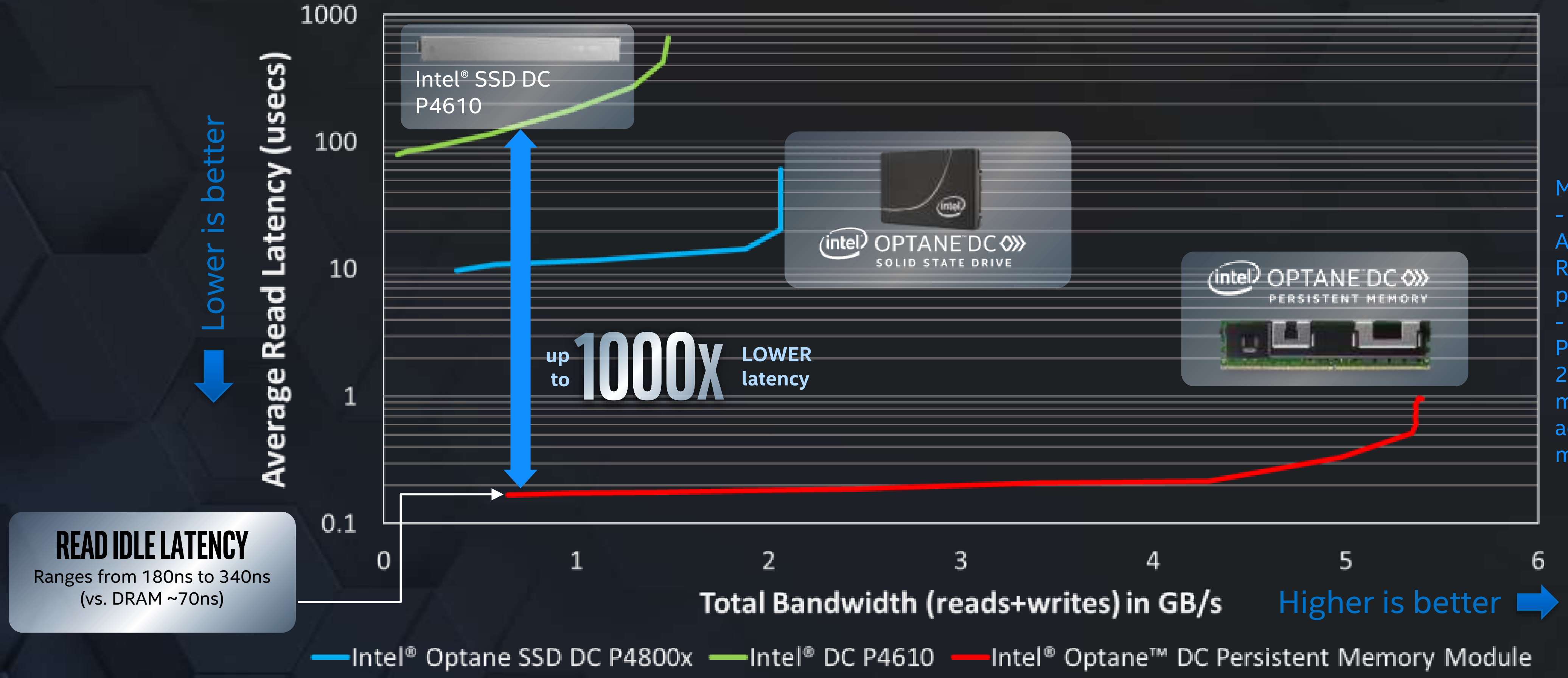


See Aopendix J
Performance results are based on testing as of July 24, 2018 set forth in the configurations and may not reflect all publicly available security updates. See configuration disclosure for details. No product can be absolutely secure.
For more complete information about performance and benchmark results, visit www.intel.com/benchmarks.

PERFORMANCE

Latency vs. Load

(70Read/30Write Random, 4kB for SSD and 256B for Memory)



Measurement notes:
- For SSDs Random 4KB Accesses over entire SSD, Read latency measured per 4kB access
- For Intel® Optane™ DC Persistent Memory Random 256B accesses Over entire module 256B random accesses w/ read latency measured per 64B access

See Appendix K

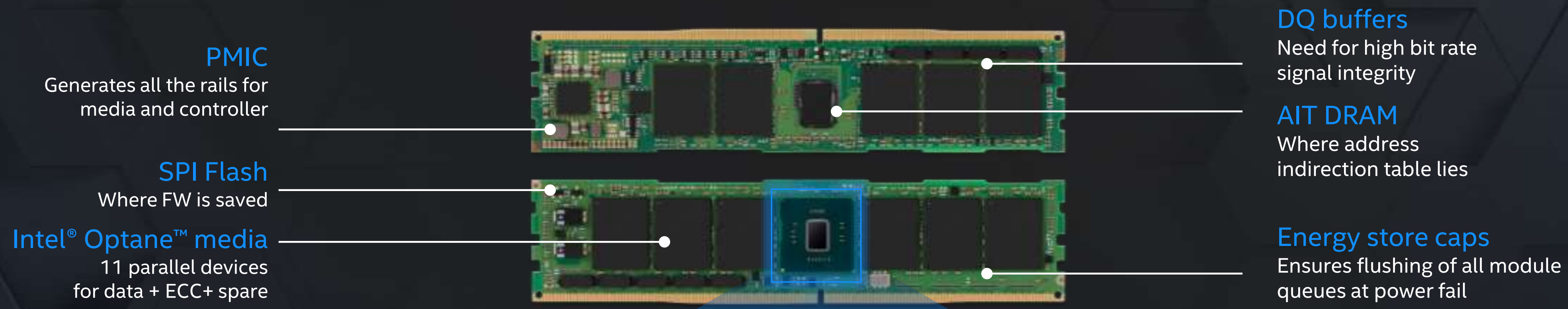
Performance results are based on testing as of February 22, 2019 set forth in the Configurations and may not reflect all publicly available security updates. See configuration disclosure for details. No product can be absolutely secure.
For more complete information about performance and benchmark results, visit www.intel.com/benchmarks.

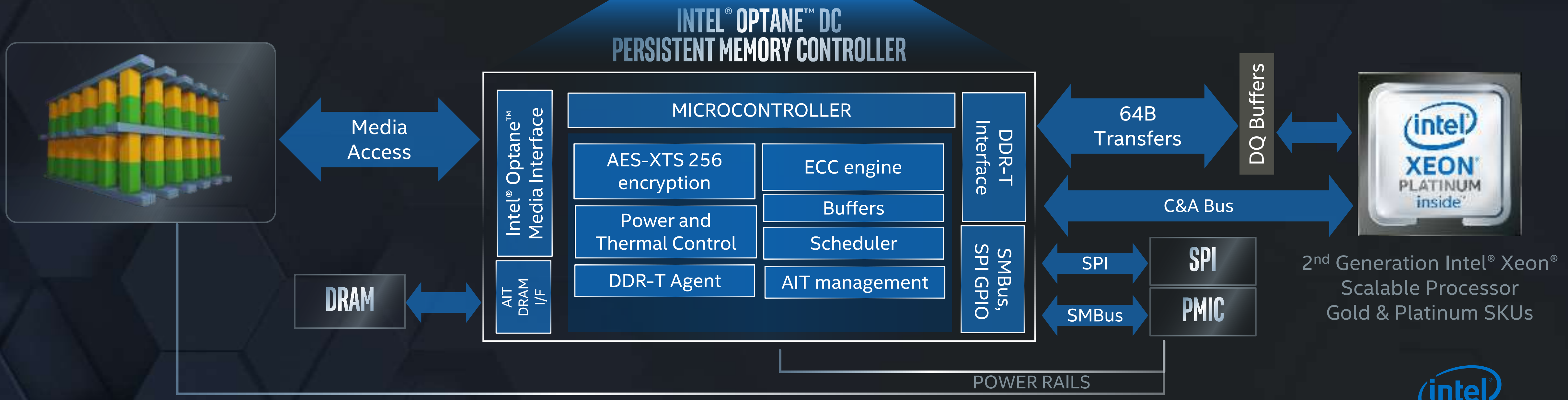
PERFORMANCE DETAILS

- Intel® Optane™ DC persistent memory is programmable for different power limits for power/performance optimization
  - 12W – 18W, in 0.25 watt granularity - for example: 12.25W, 14.75W, 18W
  - Higher power settings give best performance
- Performance varies based on traffic pattern
  - Contiguous 4 cacheline (256B) granularity vs. single random cacheline (64B) granularity
  - Read vs. writes

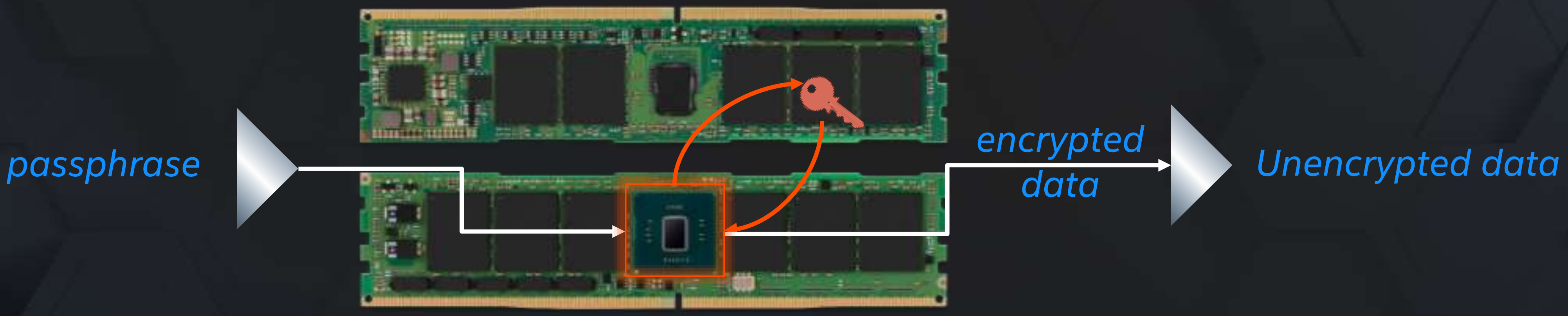
Granularity	Traffic	Module	Bandwidth
256B (4x64B)	Read	256GB, 18W	8.3 GB/s
256B (4x64B)	Write		3.0 GB/s
256B (4x64B)	2 Read/1 Write		5.4 GB/s
64B	Read		2.13 GB/s
64B	Write		0.73 GB/s
64B	2 Read/1 Write		1.35 GB/s

COMPLETE SYSTEM ON A MODULE





DESIGNED TO PROVIDE DATA AT REST SECURITY



intel OPTANE DC
PERSISTENT MEMORY

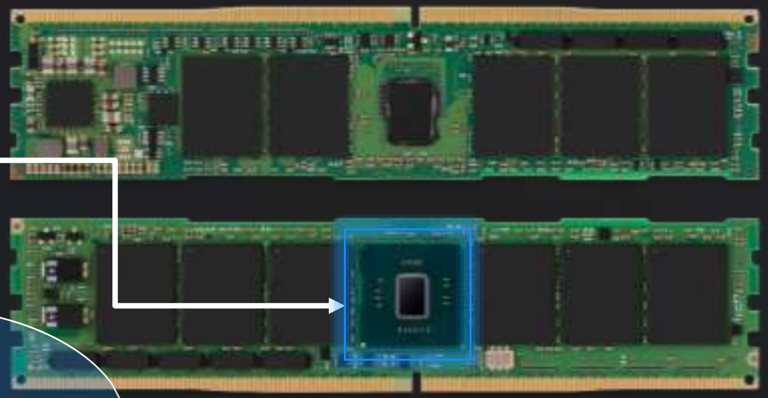
HARDWARE-ENCRYPTED MEMORY

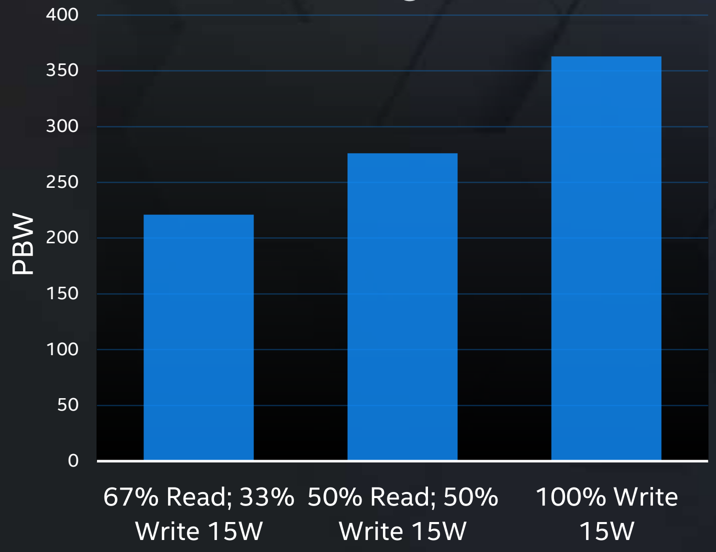
- Full module protection using 256b AES-XTP encryption engine on board
- Security keys are stored on module in hardware
- Secure cryptographic erase and module over-write for secure repurposing or discard
- Firmware authentication and integrity

intel

MEMORY LEVEL ENDURANCE

Endurance targets are spec'd in
Petabytes Written (PBW)





Let's do the math:

PBW for 100%wr

= BW*%write*3600s/hr*24hr*356days/yr*5years/1e6

= 2.3*3600*24*356*5

= 353.72PBW

ENDURANCE FOR THE ENTERPRISE

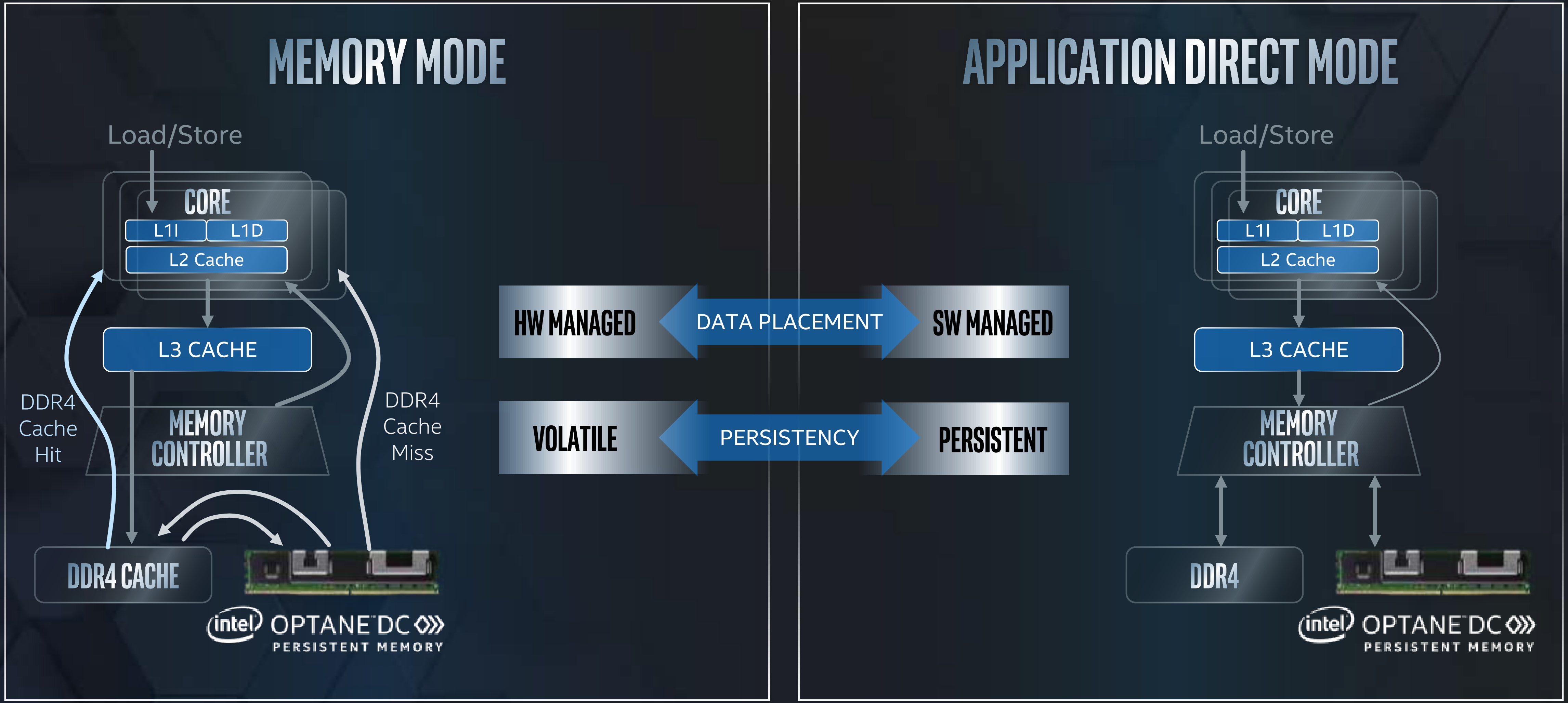
Usage reporting through SMART registers

5-year product warranty

BANDWIDTH 100% READ 15W 256B	**6.8 GB/s**
BANDWIDTH 100% WRITES 15W 256B	**2.3 GB/s**
BANDWIDTH 100% READ 15W 64B	**1.75 GB/s**
BANDWIDTH 100% WRITES 15W 64B	**0.58 GB/s**

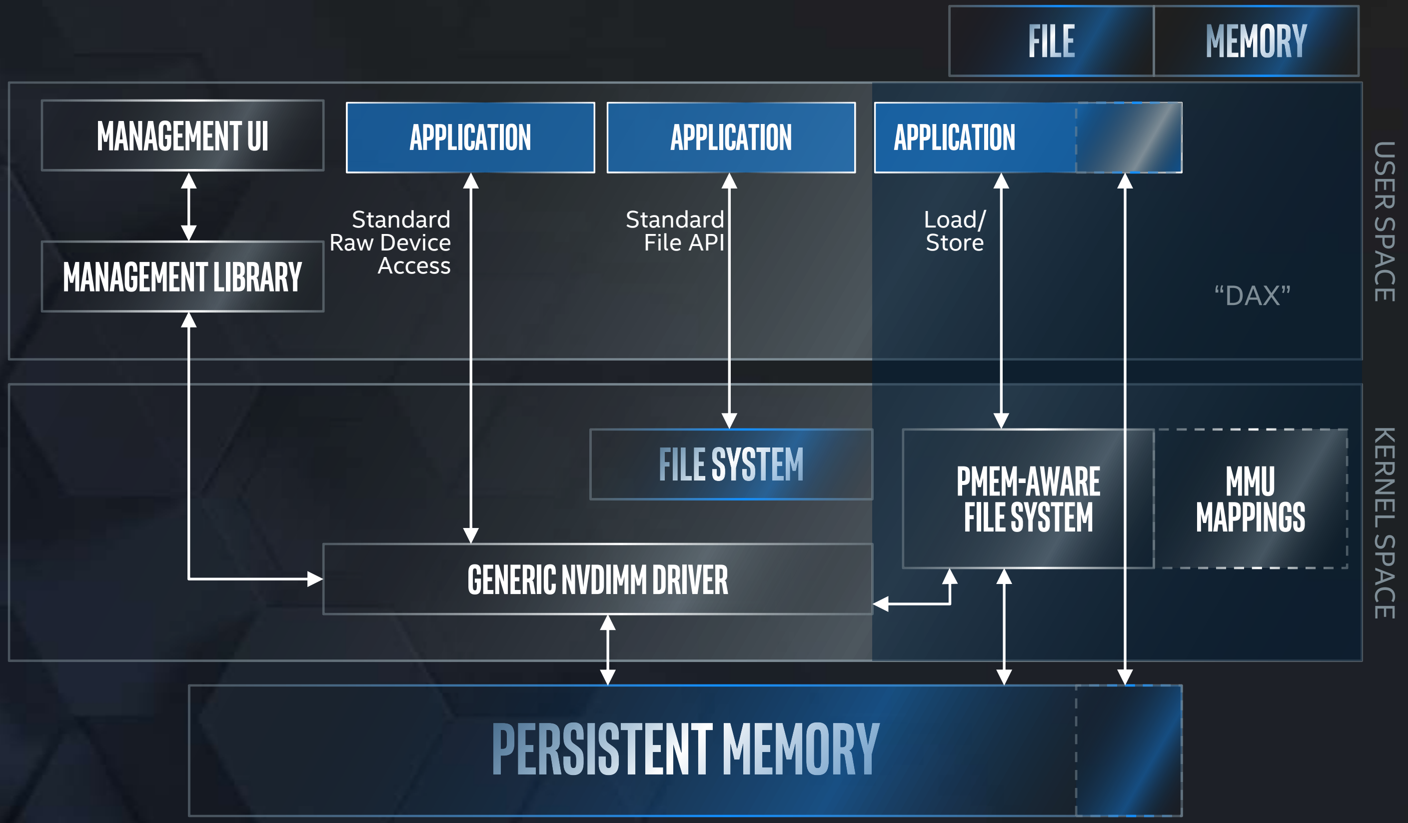
From Datasheet

TWO OPERATIONAL MODES

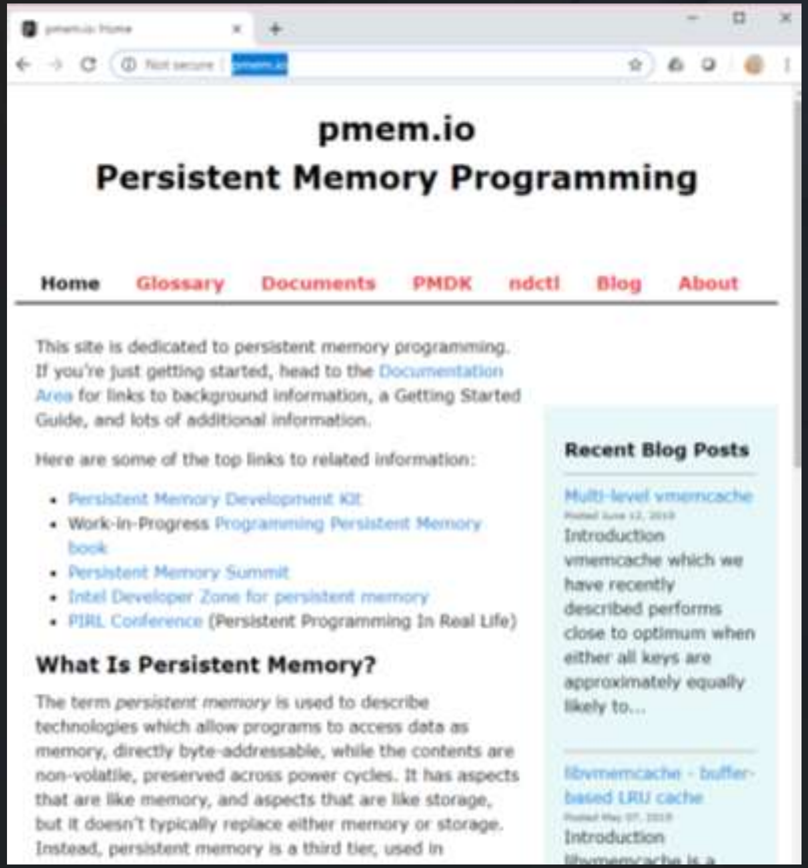


PERSISTENCY: EARLY ENGAGEMENT WITH INDUSTRY

PERSISTENT MEMORY PROGRAMING MODEL
developed through SNIA



PERSISTENT MEMORY DESIGN KIT (PMDK)
available on http://pmem.io



INTRODUCING SECOND GENERATION INTEL® XEON® SCALABLE PROCESSORS

PROCESSOR SKU STRUCTURE

INTEL® XEON® PLATINUM # 2 # # α α PROCESSOR

PROCESSOR LEVEL
9 PLATINUM
8 PLATINUM
6 GOLD
5 GOLD
4 SILVER
3 BRONZE

PROCESSOR GENERATION
2 SECOND GENERATION
1 FIRST GENERATION

PROCESSOR SKU
E.G. 20, 34, ...

PROCESSOR OPTIONS
L LARGE DDR MEMORY TIER SUPPORT (UP TO 4.5TB)
M MEDIUM DDR MEMORY TIER SUPPORT (UP TO 2.0TB)
N NETWORKING & NFV SPECIALIZED (INCL. SST-BF)
S SEARCH VALUE SPECIALIZED
T THERMAL & LONG-LIFE CYCLE SUPPORT
V VM DENSITY VALUE SPECIALIZED
Y INTEL® SPEED SELECT TECHNOLOGY (SST-PP, "3 CPUS IN 1")

NFV: NETWORK FUNCTION VIRTUALIZATION
SST-BF: INTEL® SPEED SELECT TECHNOLOGY-BASE FREQUENCY)
SST-PP: INTEL® SPEED SELECT TECHNOLOGY-PERFORMANCE PROFILE

SECOND GENERATION INTEL® XEON® SCALABLE PROCESSORS

CUSTOMER OBSESSED & WORKLOAD OPTIMIZED

- INTEL® XEON® PLATINUM 9200 PROCESSORS
- INTEL® XEON® PLATINUM 8200 PROCESSORS
- INTEL® XEON® GOLD 6200 & 5200 PROCESSORS
- INTEL® XEON® SILVER 4200 PROCESSORS
- INTEL® XEON® BRONZE 3200 PROCESSORS

ADVANCED PERFORMANCE

SKU	CORES	TURBO	BASE	CACHE	TDP
9242	48	3.8	2.3	71.5	350
9222	32	3.7	2.3	71.5	250
9221	32	3.7	2.3	71.5	250

OPTIMIZED FOR HIGHEST PER-CORE SCALABLE PERFORMANCE

SKU	CORES	TURBO	BASE	CACHE	TDP		
8280	28	4.0	2.7	38.5	205	SUPPORT FOR OPTANE DC	2.0TB & 4.5TB DDR4 MEMORY CAPACITY SUPPORT SKUs AVAILABLE
8270	26	4.0	2.7	35.75	205	SUPPORT FOR OPTANE DC	
8268	24	3.9	2.9	35.75	205	SUPPORT FOR OPTANE DC	
8256	4	3.9	3.8	16.5	105	SUPPORT FOR OPTANE DC	
6254	18	4.0	3.1	24.75	200	SUPPORT FOR OPTANE DC	
6246	12	4.2	3.3	24.75	165	SUPPORT FOR OPTANE DC	
6244	8	4.4	3.6	24.75	150	SUPPORT FOR OPTANE DC	
6242	16	3.9	2.8	22	150	SUPPORT FOR OPTANE DC	
6234	8	4.0	3.3	24.75	130	SUPPORT FOR OPTANE DC	
6226	12	3.7	2.7	19.25	125	SUPPORT FOR OPTANE DC	
5222	4	3.9	3.8	16.5	105	SUPPORT FOR OPTANE DC	
5217	8	3.7	3.0	16.5	115	SUPPORT FOR OPTANE DC	
5215	10	3.4	2.5	16.5	85	SUPPORT FOR OPTANE DC	2.0TB & 4.5TB DDR4 MEMORY CAPACITY SUPPORT SKUs AVAILABLE
4215	8	3.5	2.5	16.5	85	SUPPORT FOR OPTANE DC	

SCALABLE PERFORMANCE

SKU	CORES	TURBO	BASE	CACHE	TDP		
8276	28	4.0	2.2	38.5	165	SUPPORT FOR OPTANE DC	2.0TB & 4.5 TB DDR4 MEMORY CAPACITY SUPPORT SKUs AVAILABLE
8260	24	3.9	2.4	35.7	165	SUPPORT FOR OPTANE DC	2.0TB & 4.5TB DDR4 MEMORY CAPACITY SUPPORT SKUs AVAILABLE
8253	16	3.0	2.2	35.7	165	SUPPORT FOR OPTANE DC	
6252	24	3.7	2.1	35.75	150	SUPPORT FOR OPTANE DC	
6248	20	3.9	2.5	27.5	150	SUPPORT FOR OPTANE DC	
6240	18	3.9	2.6	24.75	150	SUPPORT FOR OPTANE DC	2.0TB & 4.5TB DDR4 MEMORY CAPACITY SUPPORT SKUs AVAILABLE
6238	22	3.7	2.1	30.25	140	SUPPORT FOR OPTANE DC	2.0TB & 4.5TB DDR4 MEMORY CAPACITY SUPPORT SKUs AVAILABLE
6230	20	3.9	2.1	27.5	125	SUPPORT FOR OPTANE DC	
5220	18	3.9	2.2	24.75	125	SUPPORT FOR OPTANE DC	
5218	16	3.9	2.3	22	125	SUPPORT FOR OPTANE DC	
4216	16	3.2	2.1	16.5	100		
4214	12	3.2	2.2	16.5	85		
4210	10	3.2	2.2	13.75	85		
4208	8	3.2	2.1	11	85		
3204	6	1.9	1.9	8.25	85		

FEATURING INTEL® SPEED SELECT TECH-PERFORMANCE PROFILE (SST-PP, "3 IN 1")

SKU	CORES	TURBO	BASE	CACHE	TDP	
8260Y	24	3.9	2.4	35.75	165	SUPPORT FOR OPTANE DC
6240Y	18	3.9	2.6	24.75	150	SUPPORT FOR OPTANE DC
4214Y	12	3.2	2.2	16.5	85	

NETWORKING/NFV SPECIALIZED (INCL. INTEL® SPEED SELECT TECH-BF)

SKU	CORES	TURBO	BASE	CACHE	TDP	
6252N	24	3.6	2.3	35.75	150	SUPPORT FOR OPTANE DC
6230N	20	3.5	2.3	27.5	125	SUPPORT FOR OPTANE DC
5218N	16	3.9	2.3	22	105	SUPPORT FOR OPTANE DC

VM DENSITY VALUE SPECIALIZED

SKU	CORES	TURBO	BASE	CACHE	TDP	
6262V	24	3.6	1.9	33	135	SUPPORT FOR OPTANE DC
6222V	20	3.6	1.8	27.5	115	SUPPORT FOR OPTANE DC

LONG-LIFE CYCLE AND NEBS-THERMAL FRIENDLY

SKU	CORES	TURBO	BASE	CACHE	TDP	
6238T	22	3.7	1.9	30.25	125	SUPPORT FOR OPTANE DC
6230T	20	3.9	2.1	27.5	125	SUPPORT FOR OPTANE DC
5220T	18	3.9	1.9	24.75	105	SUPPORT FOR OPTANE DC
5218T	16	3.8	2.1	22	105	SUPPORT FOR OPTANE DC
4209T	8	3.2	2.2	11	70	

SEARCH APPLICATION VALUE SPECIALIZED

SKU	CORES	TURBO	BASE	CACHE	TDP	
5220S	18	3.9	2.7	24.75	125	SUPPORT FOR OPTANE DC

AVAILABLE PROCESSOR OPTIONS

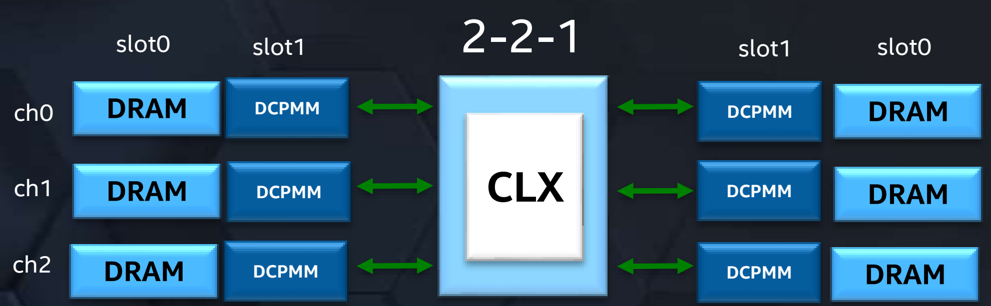
L	LARGE DDR MEMORY TIER SUPPORT (UP TO 4.5TB)
M	MEDIUM DDR MEMORY TIER SUPPORT (UP TO 2TB)
N	NETWORKING & NFV SPECIALIZED (INCL. SST-BF)
S	SEARCH VALUE SPECIALIZED
T	THERMAL & LONG-LIFE CYCLE SUPPORT
V	VM DENSITY VALUE SPECIALIZED
Y	INTEL® SPEED SELECT TECHNOLOGY-PP ("3 IN 1")
TURBO	MAXIMUM INTEL® TURBO BOOST TECHNOLOGY 2.0 FREQUENCY (IN GHz)
BASE	BASE FREQUENCY (IN GHz)
CACHE	PROCESSOR CACHE (IN MB)
TDP	THERMAL DESIGN POWER (IN WATTS)
SST-PP	INTEL® SPEED SELECT TECH-PERFORMANCE PROFILE
SST-BF	INTEL® SPEED SELECT TECH-BASE FREQUENCY
RCP	RECOMMENDED CUSTOMER PRICING ($ US DOLLARS)
NFV	NETWORK FUNCTION VIRTUALIZATION
VM	VIRTUAL MACHINE
NEBS	NETWORK EQUIPMENT-BUILDING SYSTEM

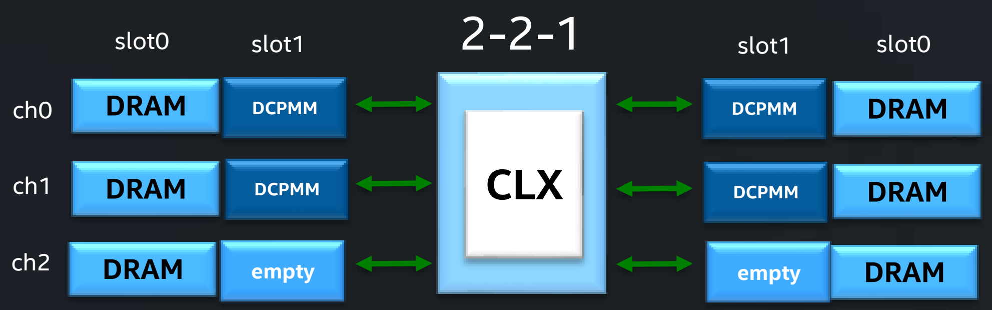
INTEL PERSISTENT MEMORY RECOMMENDATIONS

Population Guidelines				Max Capacity	
Ratio	Population	DCPMM	DRAM	AD	MM
4:1	2-2-2	512GB x 6	128GB x 6	3.77 TB	3 TB
		256GB x 6	64GB x 6	1.84 TB	1.5 TB
		128GB x 6	32GB x 6	960 GB	768 GB
5.3:1	2-2-1	512GB x 4	64GB x 6	2.43 TB	2 TB
		256GB x 4	32GB x 6	1.22 TB	1 TB
		128GB x 4	16GB x 6	608 GB	512 GB
8:1	2-2-2	512GB x 6	64GB x 6	3.38 TB	3 TB
		256GB x 6	32GB x 6	1.69 TB	1.5 TB
		128GB x 6	16GB x 6	864 GB	768 GB
10.7:1	2-2-1	512GB x 4	32GB x 6	2.24 TB	2 TB
		256GB x 4	16GB x 6	1.12 TB	1 TB
16:1	2-2-2	512GB x 6	32GB x 6	3.26 TB	3 TB
		256GB x 6	16GB x 6	1.63 TB	1.5 TB

- All Modes:
  - Max 1 DCPMM per channel
- Memory Mode (MM):
  - Min 1 DRAM DIMM + 1 DCPMM per IMC
  - 8:1; 5.3:1; 4:1 DCPMM to DRAM populated
  - DCPMM total capacity counted ONLY. DRAM used as cache.

- App Direct Mode (AD):
  - Min 1 DCPMM anywhere on platform
  - DRAM and DCPMM additive for total capacity.





Sample Cascade Lake (CLX) Platinum/Gold Socket with Apache Pass (DCPMM)

A STRONG MEMORY & STORAGE FUTURE

TODAY — FUTURE →

intel XEON PLATINUM inside	2ND GEN INTEL XEON SCALABLE (CASCADE LAKE)	COOPER LAKE / ICE LAKE	SAPPHIRE RAPIDS	FUTURE INTEL XEON PROCESSOR
intel OPTANE DC PERSISTENT MEMORY	APACHE PASS	BARLOW PASS	3RD GEN DC PERSISTENT MEMORY	4TH GEN DC PERSISTENT MEMORY
intel OPTANE DC SOLID STATE DRIVE	Intel® SSD DC P4800X (COLDSTREAM)	ALDER STREAM	NEXT GENERATION	NEXT GENERATION
INTEL® 3D NAND SSD	INTEL® SSD DC P46XX/P45XX	CLIFFDALE-R/ARBORDALE + (96-L, 144-L)	NEXT GENERATION	NEXT GENERATION

For each processor above, Intel® Optane™ DC Persistent Memory will be supported on select SKUs

GROWING GLOBAL ECOSYSTEM FOR intel OPTANE™ DC PERSISTENT MEMORY

SOFTWARE

Apache CASSANDRA
APACHE Spark
Microsoft
CLOUDERA
NetApp
AsiaInfo
AEROSPIKE
TRANSWARP 星环科技
SAP
sas
SUSE
MySQL
redis
ORACLE
redhat
FORMULUS BLACK
宝信软件 BAOSIGHT
MEMCACHED
ubuntu
GIGASPACES
vmware
Qwilt
kx

CSPS & COSPS

Alibaba Group 阿里巴巴集团
Microsoft Azure
Google Cloud
海鑫科金 HISIGN TECHNOLOGY
平安云
Baidu 百度
BONC 东方国信
packet
Tencent Cloud
SK telecom
快手 KUAISHOU TECHNOLOGY
人大金仓 Kingbase
Kingsoft Cloud
中国航信 TravelSky

OEMS & SIS

QINGCLOUD
CDW
DELLEMC
ORACLE
Hewlett Packard Enterprise
ZTE
scalar
accenture
inspur
cisco
Lenovo
Capgemini
SUPERMICRO
Atos
PENGUIN COMPUTING
FUJITSU
Inventec
QCT
H3C
World Wide Technology
intel

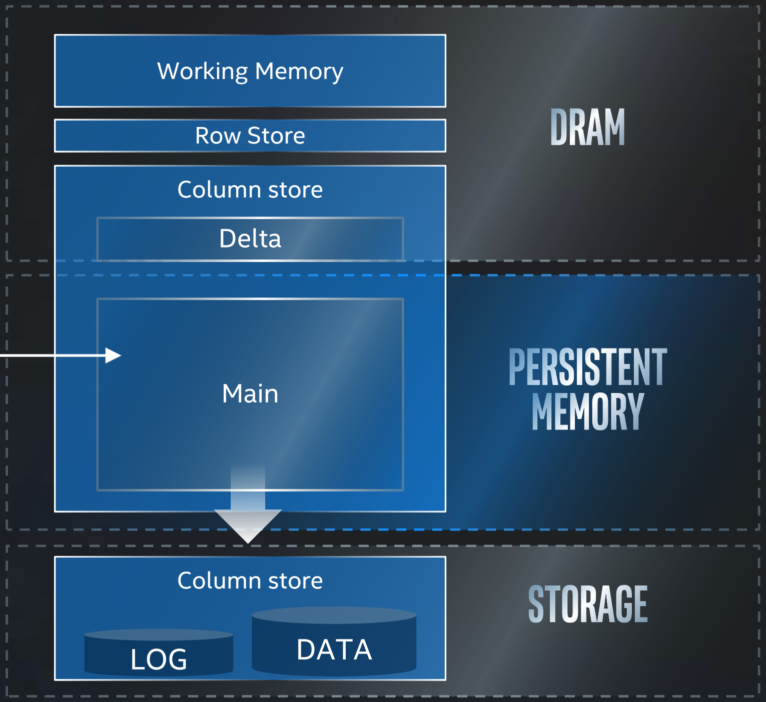
USECASE-DATABASE

SAP HANA

FASTER RESTART TIMES

INCREASED MEMORY CAPACITY

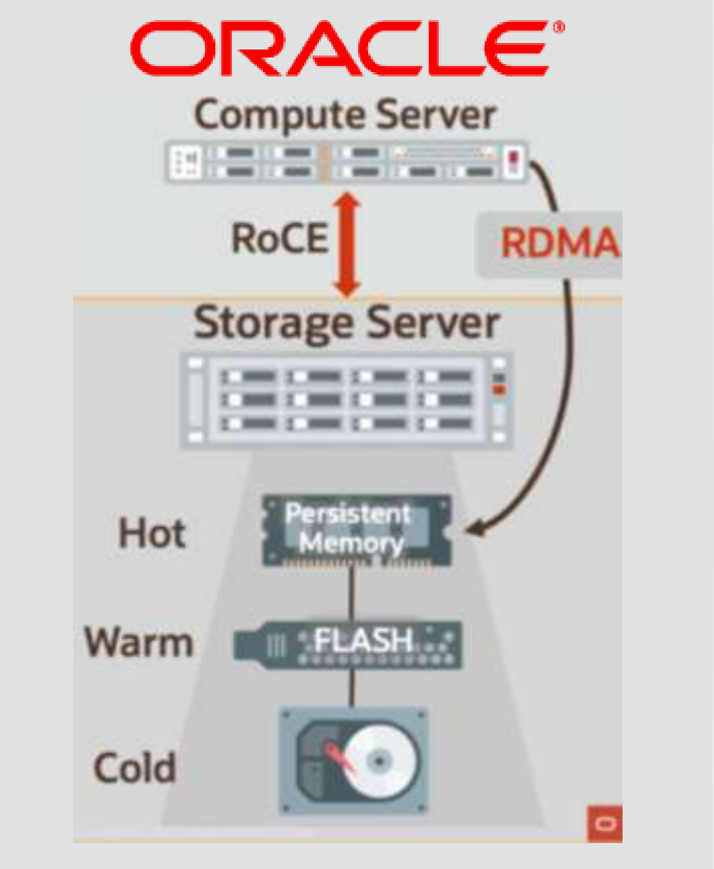
SAP HANA Main Store relocated to larger persistent memory to achieve lower TCO



- Volatile data structures remain in DRAM
- Column Store Main moves to Persistent Memory
  - DIMM form-factor, replacing DRAM
  - Could be configured for each table, partition, or column
  - Loading of tables into memory at startup becomes obsolete
  - Lower TCO, larger capacity
- No changes to the persistence

SAP HANA CONTROLS WHAT IS PLACED IN PERSISTENT MEMORY AND WHAT REMAINS IN DRAM

ORACLE EXADATA : PERSISTENT MEMORY ACCELERATOR FOR OLTP



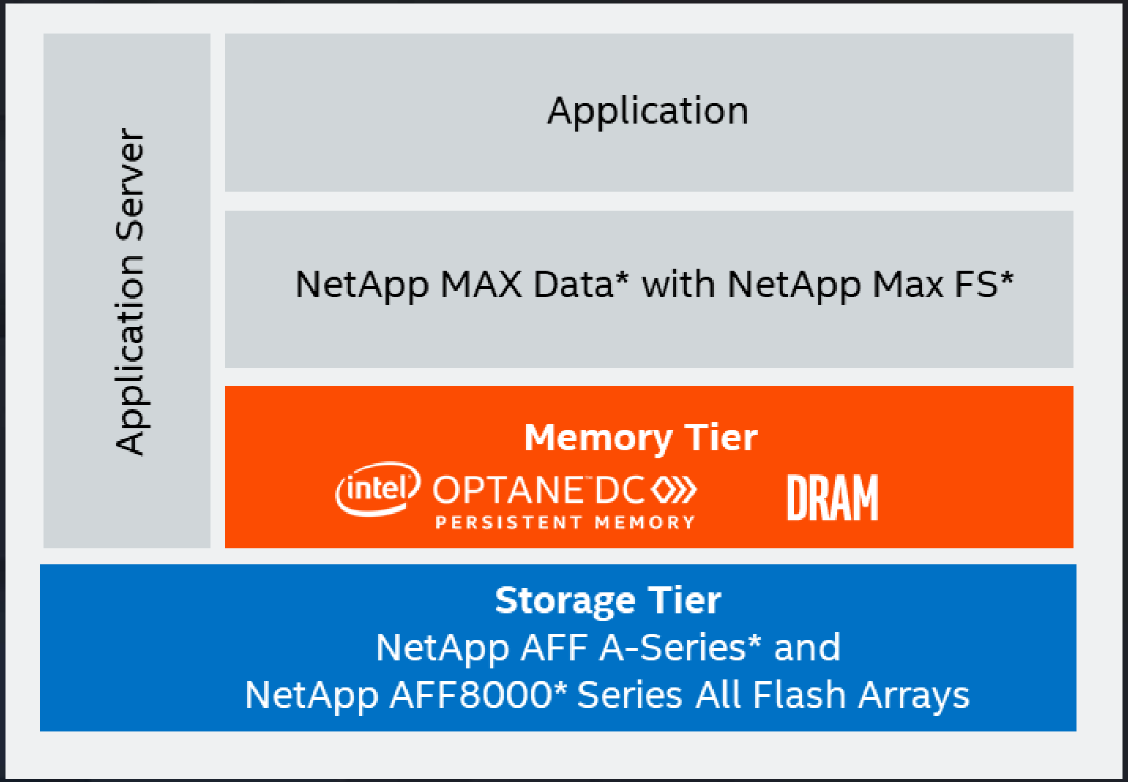
Slide courtesy of Oracle

- Exadata Storage Servers will add Persistent Memory Accelerator in front of Flash memory
- **RDMA** bypasses the software stack, giving 10X faster access latency to remove Persistent Memory
- Persistent Memory mirrored across storage servers for fault-tolerance
- Persistent memory used as a shared cache effectively increases its capacity 10X vs using it directly as expensive storage
- Log Writes will use RDMA to achieve super fast commits

10X LOWER LATENCY

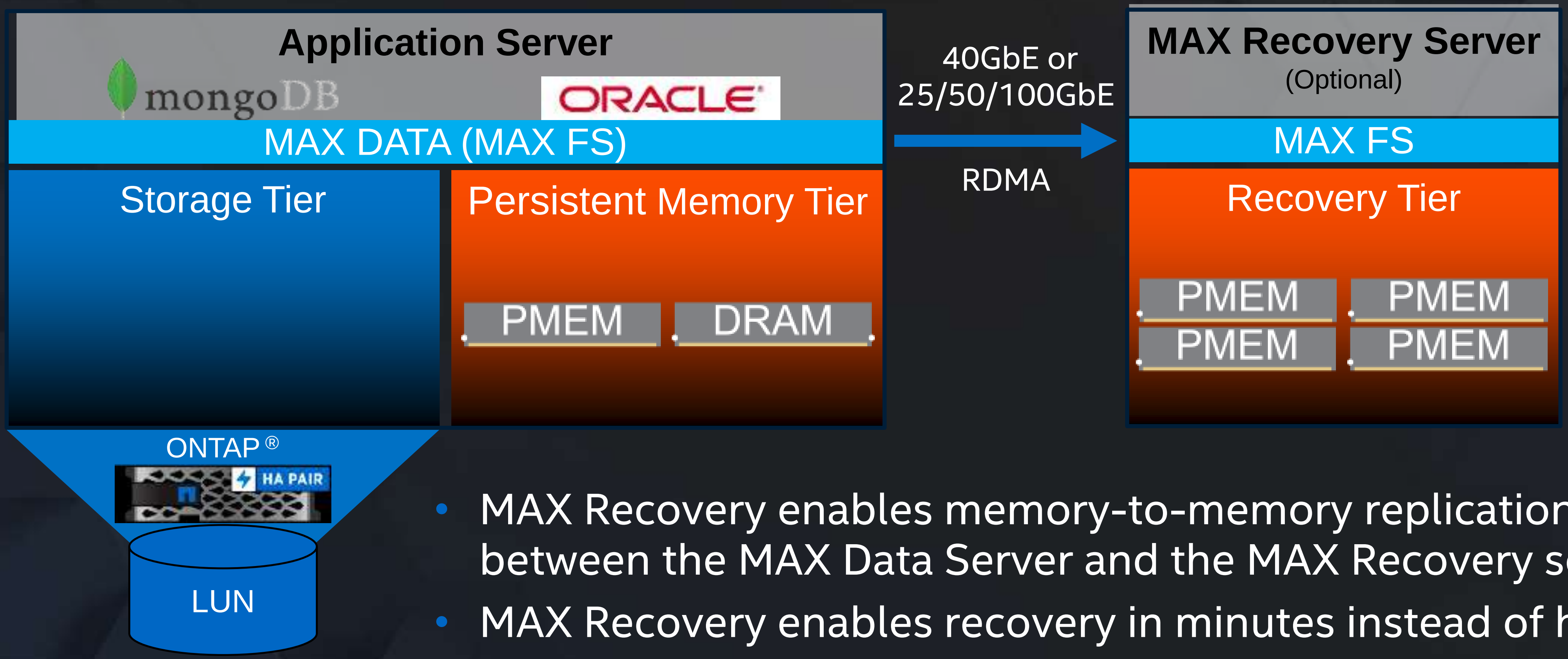
USECASE-STORAGE

NETAPP® MAX DATA



- **NetApp MAX Data** runs on servers equipped with 2nd Generation Intel® Xeon® Scalable processors and Intel Optane DC persistent memory
- **NetApp MAX File System* (FS) for Optane and auto tiering**
- Your applications **don't require any changes (App Direct mode)**

MAX RECOVERY HIGH-LEVEL ARCHITECTURE

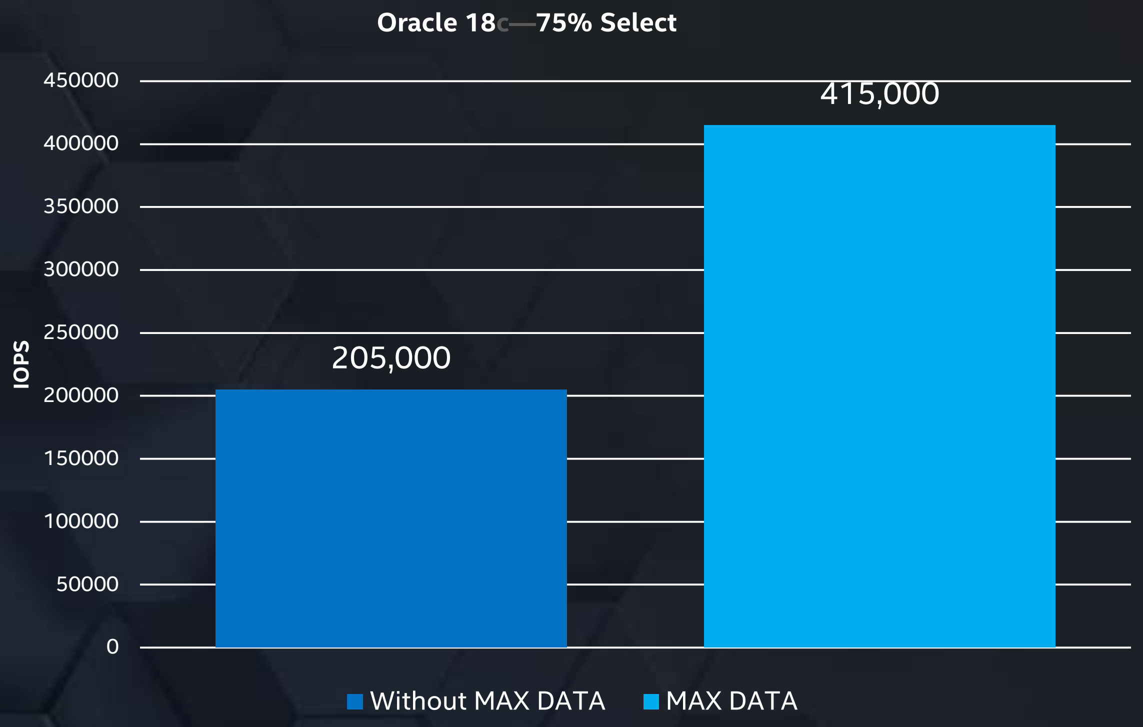


- MAX Recovery enables memory-to-memory replication between the MAX Data Server and the MAX Recovery server.
- MAX Recovery enables recovery in minutes instead of hours.
- Four MAX Data servers can replicate to a single MAX Recovery server.

ORACLE*, INTEL® OPTANE™ DC PERSISTENT MEMORY, AND NETAPP MAX DATA* PERFORMANCE SUMMARY

ORACLE®

IOPS 2X HIGHER THROUGHPUT[5]



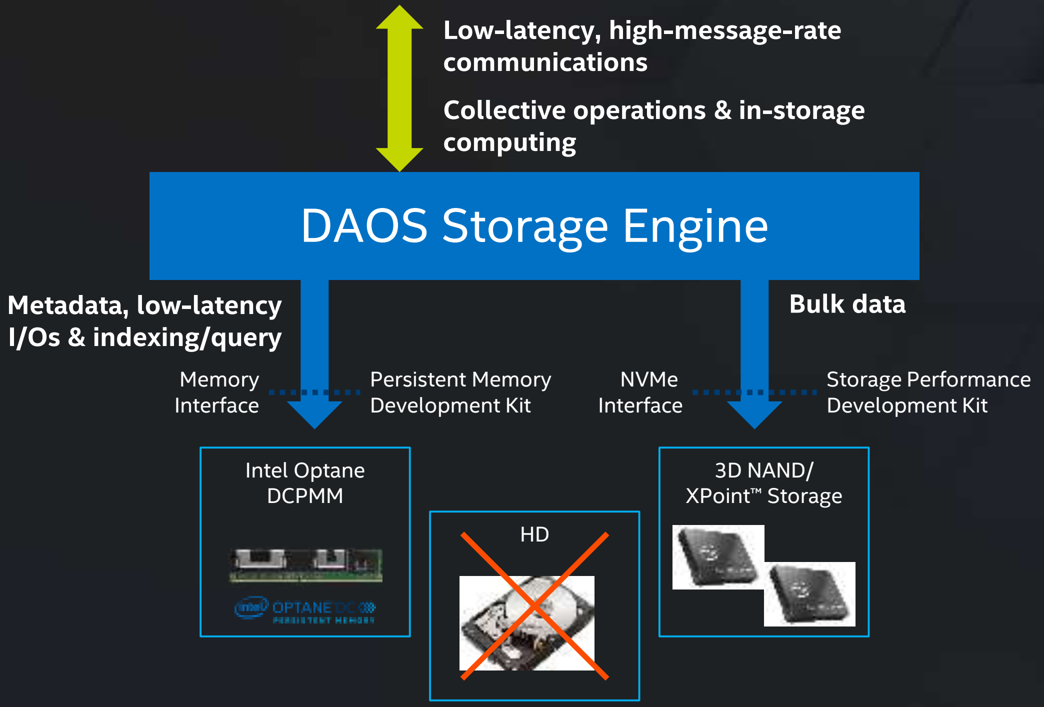
LATENCY 16X LOWER[5]

intel

DAOS: DISTRIBUTED ASYNCHRONOUS OBJECT STORAGE

A new open-source, high-performance storage software solution architected for DCPMM

- Small I/Os are stored in Intel Optane DC persistent memory
- Bulk I/Os go straight to the NVMe SSDs
- Built entirely in userspace



CUSTOMER SUCCESS STORY: EXASCALE HPC

Argonne NATIONAL LABORATORY

“What excites me most about exascale systems like Aurora is the fact that we now have, in one platform and one environment, the ability to mix simulation and artificial intelligence. This idea of mixing simulation and data-intensive science will give us an unprecedented capability, and open doors in research which were inaccessible before, like cancer research, materials science, climate science, and cosmology.”
Rick Stevens, associate laboratory director for computing, environment and life sciences at Argonne National Laboratory and professor of computer science at the University of Chicago

intel XEON PLATINUM inside

intel OPTANE DC PERSISTENT MEMORY

CRAY

Customer: Argonne National Laboratory supports about 3,500 researchers with a billion-dollar budget each year and spearheads scientific research in disciplines like physics, chemistry, genomics and more.

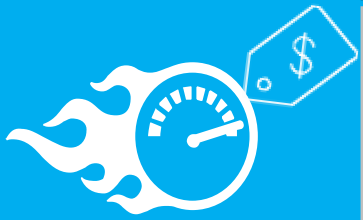
Challenge: Deploying Aurora, the first exascale supercomputer in the United States, represents an enormous undertaking. The complexity of next-generation research and engineering requires a system offering the prowess to tackle workloads involving massive data sets like advanced simulation and modeling, artificial intelligence and data science.

Solution: Working closely with Intel and Cray, the Argonne team collaborated to design and implement Aurora’s exascale architecture. Scheduled for deployment in 2021, Aurora will feature future Generation Intel® Xeon® Scalable processors, Intel’s X^{e} compute architecture, future Intel® Optane™ DC persistent memory and Intel® One API.

1 Source: https://newsroom.intel.com/news-releases/u-s-department-energy-intel-deliver-first-exascale-supercomputer/#gs.vsxk42

USECASE-VIRTUALIZATION

WHEN IS VM MEMORY EXPANSION A GOOD FIT FOR YOUR CUSTOMER?

GOOD FIT		NOT A GOOD FIT	
	When **CPU utilizations are low**, to **use untapped server potential**		If DRAM capacity not limiting app density (i.e. **small VM size**)
	**Read** versus **Write ratios are high**		Workloads that require **ultimate performance**
	Where **cost for performance** is a primary motivation		If higher **VM density (or more VM's) is not required**

VMWARE ESXI VMMARK FOR INCREMENTAL MEMORY

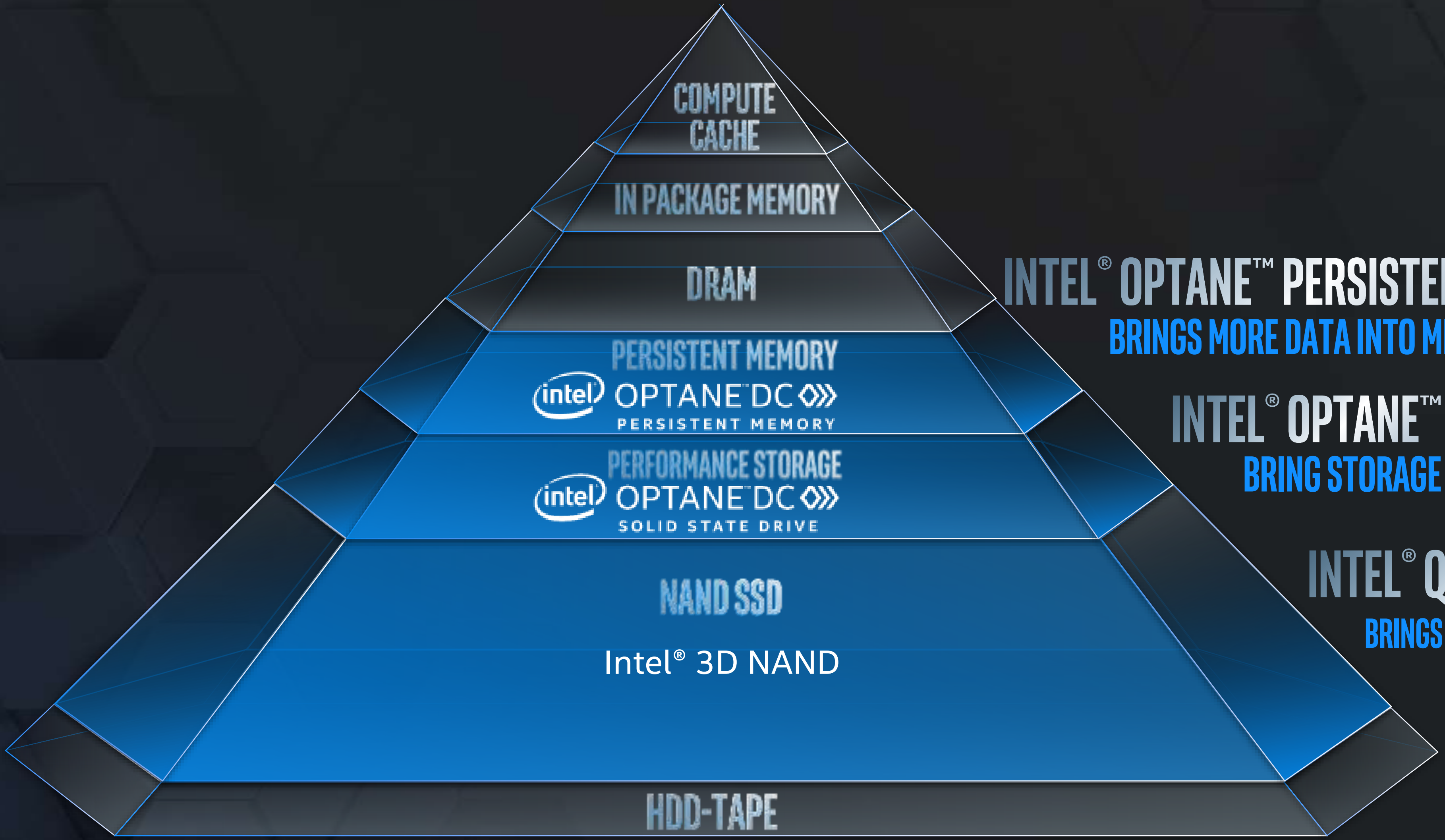
WORKLOAD – INCREASE VMs PER NODE

	DDR4 DRAM ONLY	DDR4 DRAM + Intel OPTANE DC PERSISTENT MEMORY — MEMORY MODE	
DO MORE	768 GB DDR4 DRAM	192 GB DDR4 DRAM +1 TB INTEL® OPTANE® DC PERSISTENT MEMORY	up to 33% more memory[1]
	152 VMs	190 VMs	25% more VMs per node[1,2]
SAVE MORE	~$80 USD	~$69 USD	up to 14% lower estimated HW cost per VM
	CPU: 2x Intel® Xeon® Gold 6252 Processor **MEMORY:** 768 GB DDR4 DRAM Memory	**CPU: 2x** Intel® Xeon® Gold 6252 Processor **MEMORY:** 192 GB DDR4 DRAM Memory + 1 TB Intel® Optane™ DC Persistent Memory	

MORE, AFFORDABLE MEMORY = LOWER COST PER VM

Performance results are based on testing as of 4/02/2019 and may not reflect all publicly available security updates. See configuration disclosure for details. No product can be absolutely secure. For more complete information about performance and benchmark results, visit www.intel.com/benchmarks. Configuration: See VMWare VMMark config slide

A COMPLETE HIERARCHY



INTEL® OPTANE™ PERSISTENT MEMORY
BRINGS MORE DATA INTO MEMORY

INTEL® OPTANE™ SSDs
BRING STORAGE CLOSER TO THE PROCESSOR

INTEL® QLC 3D NAND SSDs
BRINGS MORE DATA INTO SOLID STATE STORAGE

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