Flash Memory Summit

Enterprise Flash Storage Annual Update

Flash, It's not just for tier 0 anymore

Or

Flash is the new black

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Santa Clara, CA
August 2018

Your not so Humble Speaker

- 30+ years of consulting & writing for trade press
- Occasional blogger at TechTarget
- Chief Scientist DeepStorage, LLC.
  - Independent test lab and analyst firm
- Cohost Greybeards on Storage podcast

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Agenda

- A brief history lesson
- The shift from SSD to NVMe
- NVMe over fabrics the new lingua franca
- A look in the crystal ball

A Decade of Enterprise Flash

2007

- Rackmount SSDs
- Texas Memory
- Violin Memory
- Fast but niche

2010

- SSDs in DISK arrays
- High cost
- Endurance fears
- Hybrids emerge

2014

- Flash understood
- All Flash Arrays
- Costs close

2018

- Flash is mainstream
- Full data services & data reduction
- Cost effective for most applications

Flash is just the default

- All flash ~$8bil/yr w/12% projected growth
- Disk is still cheaper
  - But being reserved for:
    - Secondary
    - Rich media
- Users are over endurance & deduplication fears
- Shift back to full featured arrays from purpose built AFA

The Great Flash Shortage of 2016-7

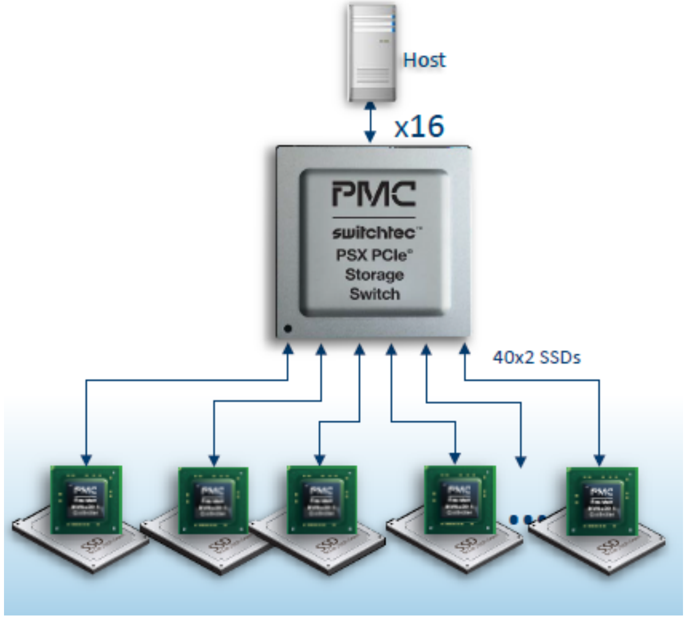
- 2008-2015 SSD $/GB −30%/yr
- 2016-2018 maybe 30% total
- Last year I said “Relief to come late 2018/19”
- Supply is easing
  - 96 layer QLC
  - Process improvements
  - New fabs
- Expect 30+% CAGR

Enterprise SSD Evolution

- Further fragmentation
  - Optane/Samsung Z-NAND NVMe
  - 100TB 6gbps SATA
- U.2 across server vendors
  - New form factors:
    - Samsung NGSFF
    - Intel Ruler

Solid State Drive to Solid State Device

- Dropping the HDD form factor
  - M.2 for boot
  - Ruler/NGSFF for hot-swap
  - Better cooling and density
- PCIe replaces SAS/SATA
- PCIe Switch chips vs SAS Expanders
- NVMe replaces SCSI as lingua franca
  - Over PCIe locally
  - Over fabrics



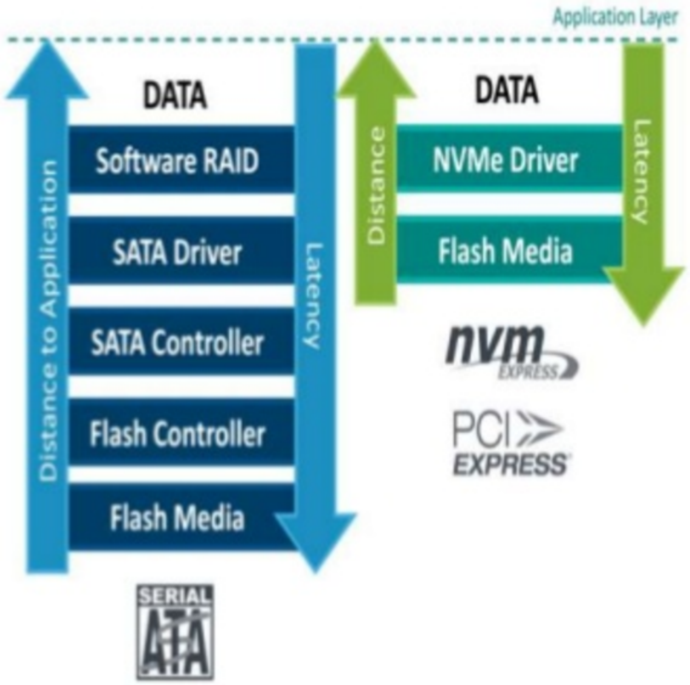
PCIe Advances

- PCIe 4.0
  - Doubles bandwidth/lane to 2GBps
  - Driven by 100Gbps Ethernet & NVMe
  - Power systems shipping now
  - x86 Next server chipset release
- PCIe 5.0 close on its heals
  - .7 version issued May 2018
  - Adoption planned Q1 2019
  - 400Gbps Ethernet ≅ x16 slot
  - Servers and such 2020?

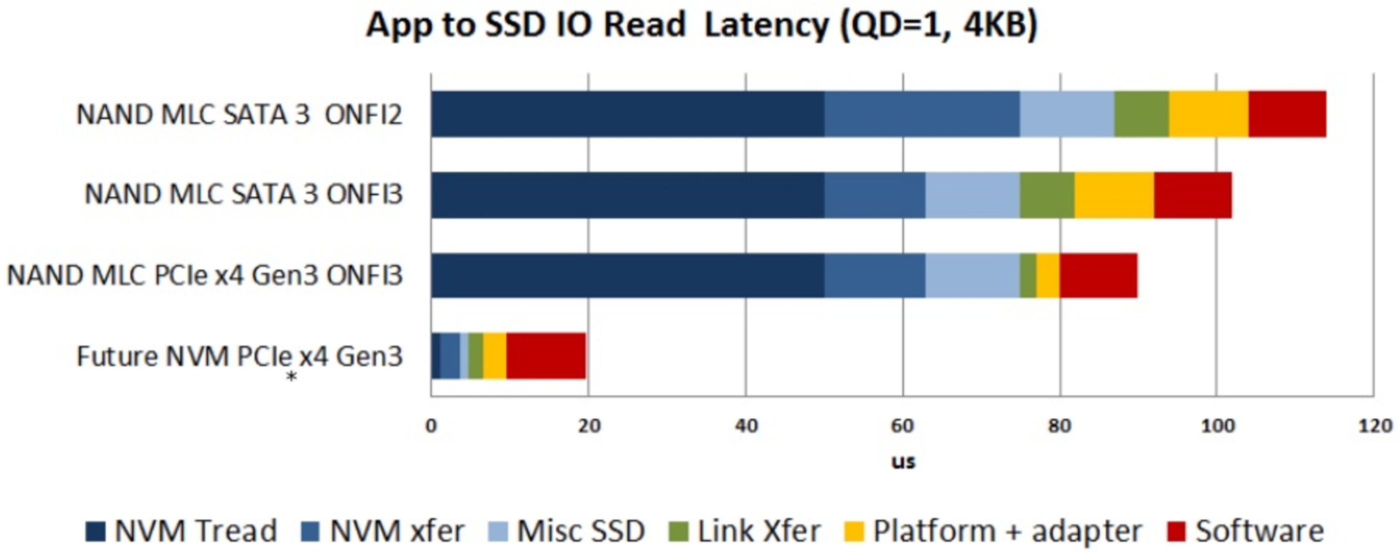
	Spec Date	Raw	Bandwidth per lane	x8 Gbps
PCIe 1	2003	2.5GT/s	250MB/s	16
PCIe 2	2007	5.0GT/s	500MB/s	32
PCIe 3	2010	8.0GT/s	984MB/s	64 (63.04)
PCI	201	16GT	1969M	126

NVMe 101

- Gen1 and 2 PCI SSDs
  - ACHI (SATA command set)
  - Propreatary (Fusion-IO, Verident) with heavy software
- Enter NVM Express
  - A new software protocol for non-volatile memory access
- Lower compute overhead than SCSI
- 64K queues of 64K entries vs SCSI 1 queue of 32 entries



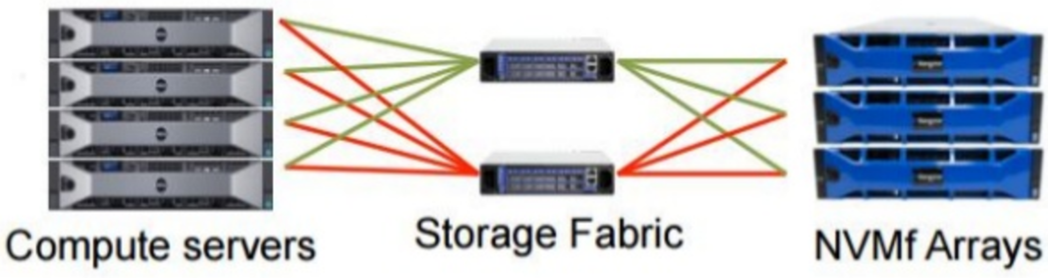
NVMe = Lower Overhead & Latency



- By 2016 NVMe is leading from desktop M.2 to the datacenter
- But limited to internal SSDs

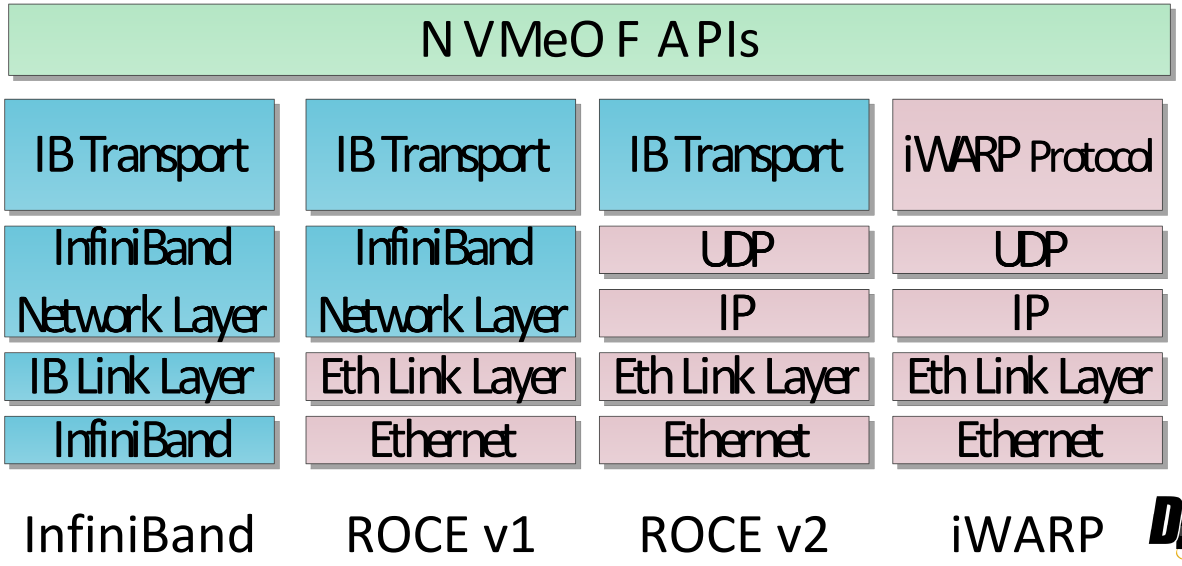
NVMe Over Fabrics (NVMEoF)

- Extends/encapsulates NVMe semantics over
  - Ethernet with RMDA
  - Fibre Channel
  - Infiniband (no products yet announced)
  - TCP
- Adds name spaces and discovery
- 10-50µsec protocol and network overhead



NVMeOF Ethernet Options

- RDMA over Converged Ethernet (ROCE)
- iWARP (Internet Wide-area RDMA Protocol)
- RNICs generally support ROCE or iWARP



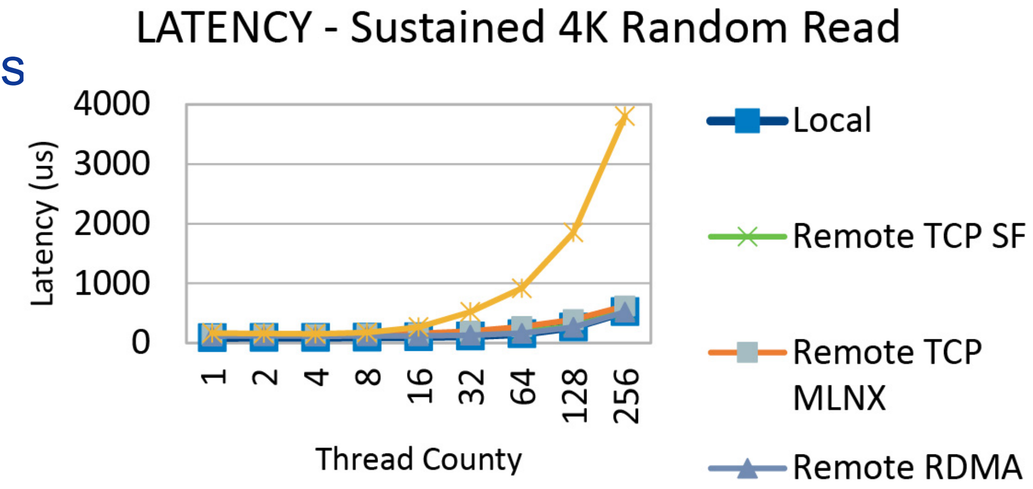
NVMeOF APIs			
IB Transport	IB Transport	IB Transport	iWARP Protocol
InfiniBand Network Layer	InfiniBand Network Layer	UDP	UDP
		IP	IP
IB Link Layer	Eth Link Layer	Eth Link Layer	Eth Link Layer
InfiniBand	Ethernet	Ethernet	Ethernet
InfiniBand	ROCE v1	ROCE v2	iWARP

NVMe Over Fibre Channel

- Fibre Channel
  - Zero copy vs RDMA
  - Flow and congestion control
- Gen5 (16) and Gen6 (32Gbps) Fibre Channel
- One fabric for SCSI and NVMe
- Keeps storage network in storage domain
- The safe move in enterprise

NVMe over TCP

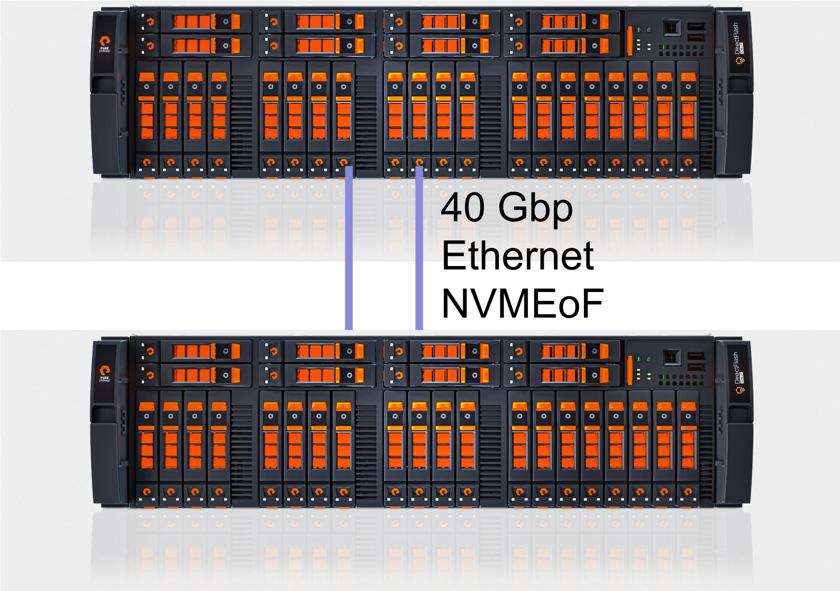
- Encapsulates NVMe verbs in TCP
- Relies on TCP low control
- NIC offload optional
- No switch config requirements
- Nominal latency addition
- Supporters:
  - SolarFlare
  - Cavium
  - Toshiba
- Greybeards on Storage



NVMeOF Pioneers

- Apeiron – 40Gbps Ethernet switch in JBOF
- E8 – Dual controller array – basic services
- Mangstor – x86 NVMEoF target
- Excellero – Low CPU SDS, RDMA

Pure FlashArray//x

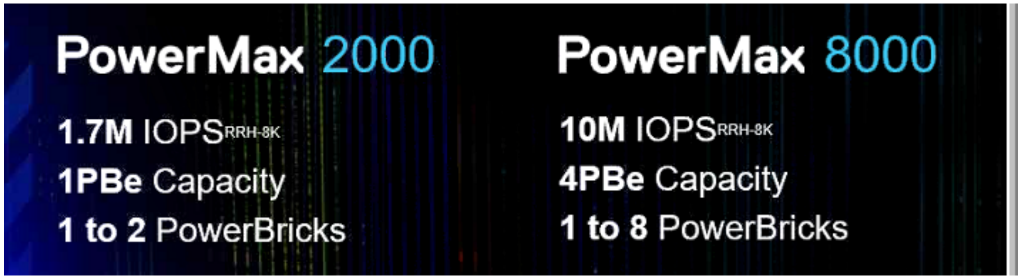


40 Gbp
Ethernet
NVMEoF

- Replaces //m SAS SSDs with NVMe flashmodules
- Expansion via SAS or NVMEoF JBOF
- NVMEoF target on 40Gbps Ethernet
- Full services

Dell/EMC PowerMAX

- Should end the “designed from scratch for flash” argument
- All the Symetrix/VMAX software goodness
- NVMe media
- NVMe over fabrics promised
- Scaleout x86 & FICON

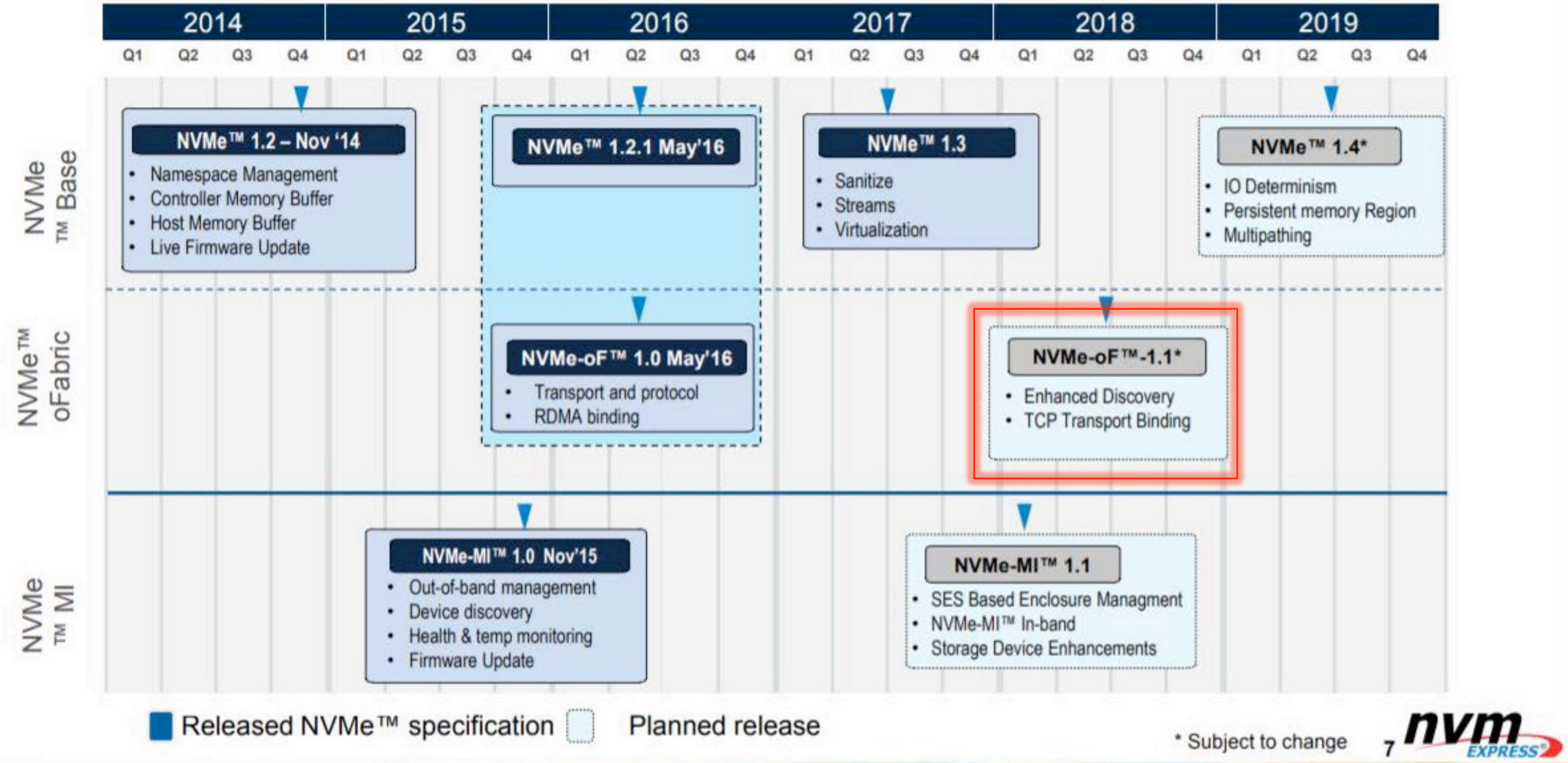


PowerMax 2000	PowerMax 8000
1.7M IOPS$_{\text{RRH-8K}}$	10M IOPS$_{\text{RRH-8K}}$
1PBe Capacity	4PBe Capacity
1 to 2 PowerBricks	1 to 8 PowerBricks

NetApp and IBM Go NVMEoFC

- IBM FlashSystem 9100
  - 24 flash modules (19.2TB, 384TB net)
  - 16Gbps FC, NVMEoFC*
  - SVC based services
- NetApp A series AFF
  - A800 – 48 SSD slots
  - Sub 200µsec latency, 11 millionIOPS
  - Data OnTap services

Standards Progress



2014 | 2015 | 2016 | 2017 | 2018 | 2019

Q1 Q2 Q3 Q4 (each year)

NVMe™ Base

NVMe™ 1.2 – Nov '14
- Namespace Management
- Controller Memory Buffer
- Host Memory Buffer
- Live Firmware Update

NVMe™ 1.2.1 May'16

NVMe™ 1.3
- Sanitize
- Streams
- Virtualization

NVMe™ 1.4*
- IO Determinism
- Persistent memory Region
- Multipathing

NVMe™ oFabric

NVMe-oF™ 1.0 May'16
- Transport and protocol
- RDMA binding

NVMe-oF™-1.1*
- Enhanced Discovery
- TCP Transport Binding

NVMe™ MI

NVMe-MI™ 1.0 Nov'15
- Out-of-band management
- Device discovery
- Health & temp monitoring
- Firmware Update

NVMe-MI™ 1.1
- SES Based Enclosure Managment
- NVMe-MI™ In-band
- Storage Device Enhancements

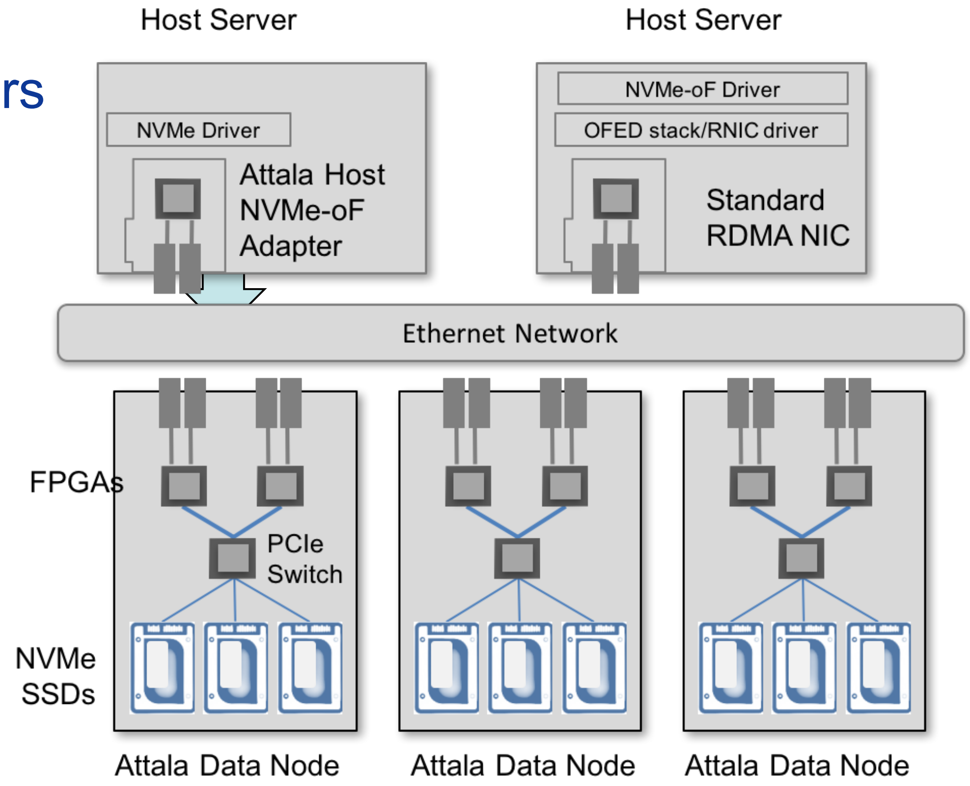
■ Released NVMe™ specification ⬚ Planned release

* Subject to change

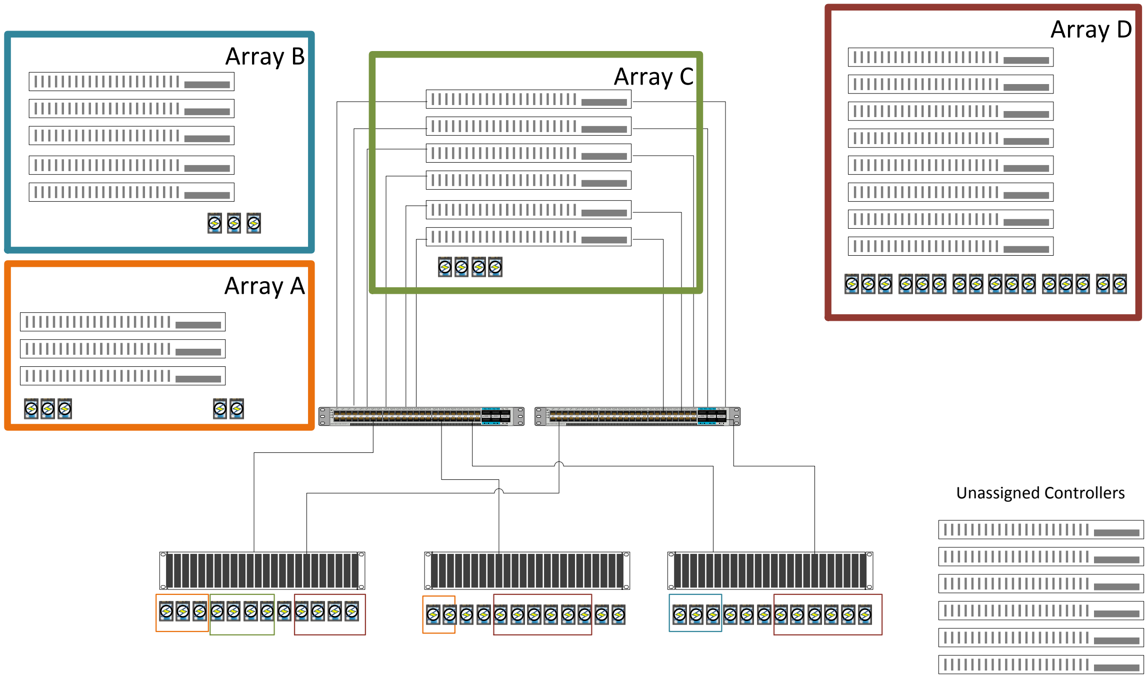
7

NVMe JBOFs Emerge

- Today's JBOFs are x86 servers
  - Eg: Toshiba KumoScale
  - High flexibility
  - High cost
- NVMEoF ASICs
  - Vastly reduce costs
  - Sampling from
    - SolarFlare Xilinx
    - Kazan Networks
    - Attala Systems



Kaminario K2 Composeable



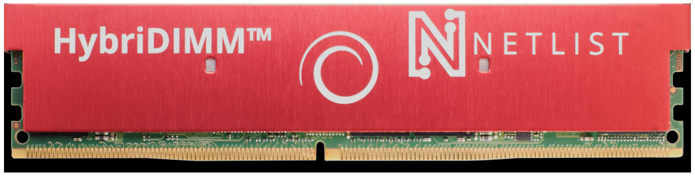
- NVMEoF
  - Controller to JBOF
  - Host to array (opt)
- Dynamically assign controllers and flash to virt array

Persistent Memory Now GA

- Scaleable Xeon servers support NVDIMM-N
- Good for software delivered storage
  - Small (8-16GB)
  - Expensive (2-3X DRAM)
- Full OS/Hypervisor Support
  - Windows
  - vSphere
  - Linux

NetList's HybriDIMM

- Combines DRAM-Flash
- Conceptually like Diablo/Sandisk UltraDimm)
  - Access:
    - DRAM as std memory
    - Flash w/DRAM buffer as Block storage
    - Flash as persistent memory via Linux Library
    - No special BIOS support needed
    - 128-512GB



Crystal ball section

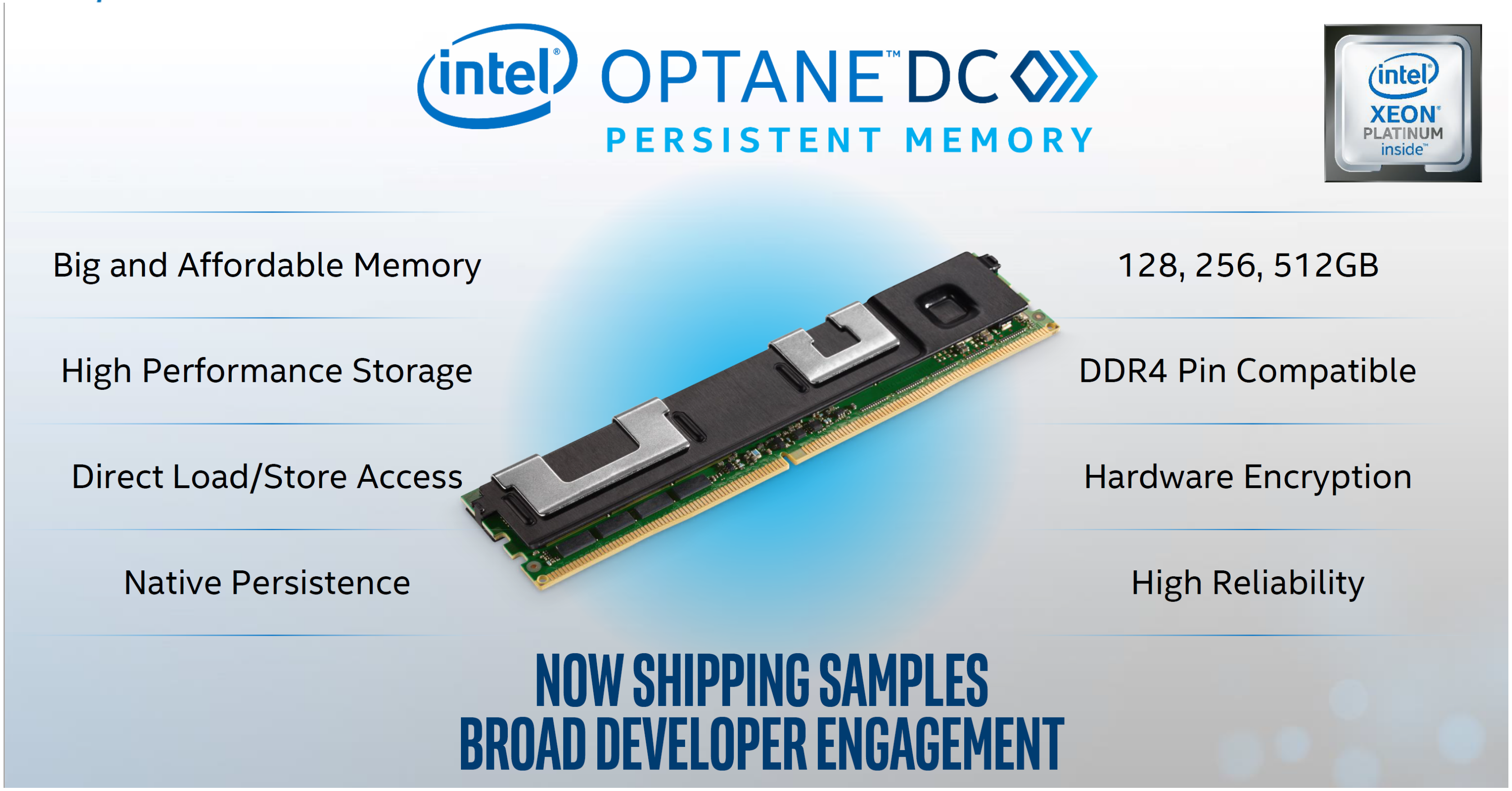
The Future

- All ~~PCIe~~ NVMe storage systems
  - As conventional storage
  - With memory interfaces
- Next-gen memory (PCM, 3d Xpoint, Etc)
  - First as write cache in SSD
  - Later as memory
  - Taking a bit longer than expected
- More persistent memory as memory
  - Needs application support ala SAP Hana

Storage Class Memory

- As well defined as Software Defined
- For me:
  - Inherently persistent
  - Latency between DRAM and NAND Flash
  - Addressable as memory
    - Not SSD, not NVMe
  - Capacity 4-∞X RDIMM
- Defines material AND implementation

Optane DIMMs Coming Soon



intel OPTANE™ DC

PERSISTENT MEMORY

Big and Affordable Memory

High Performance Storage

Direct Load/Store Access

Native Persistence

128, 256, 512GB

DDR4 Pin Compatible

Hardware Encryption

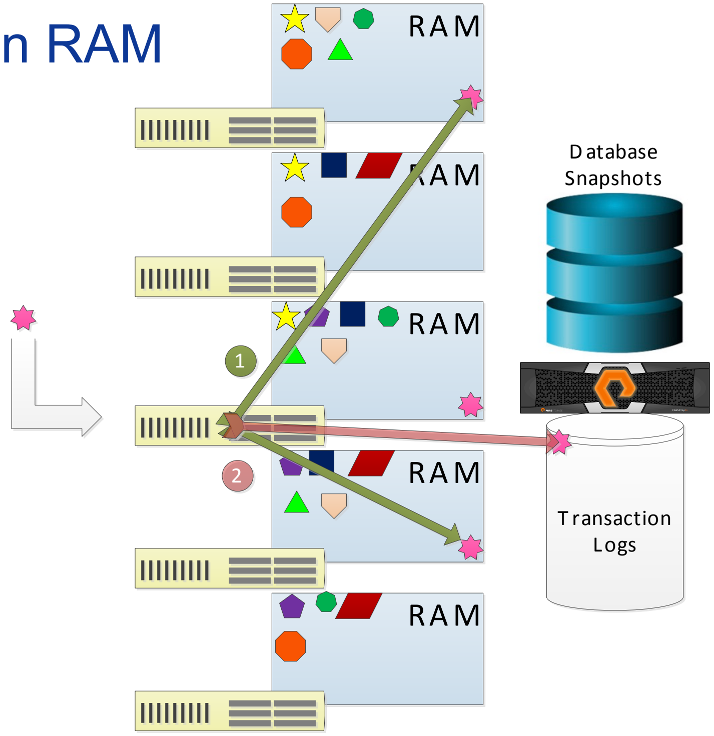
High Reliability

NOW SHIPPING SAMPLES

BROAD DEVELOPER ENGAGEMENT

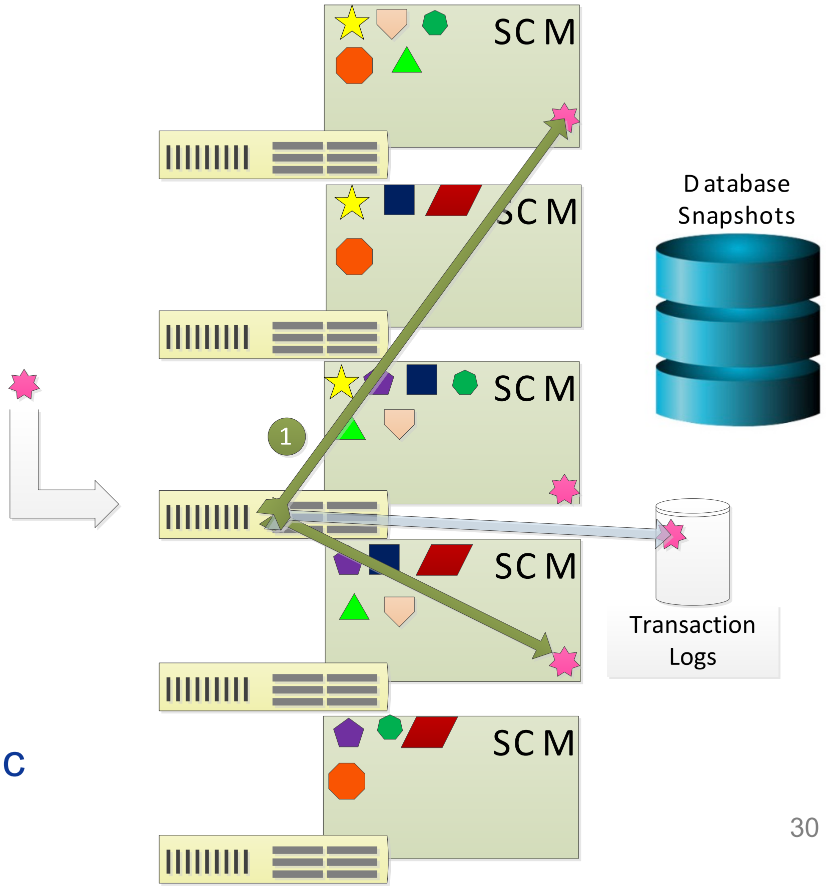
In Memory Databases Today

- All database operations performed in RAM
- Data replicated across nodes (x86)
- AFA/HCI back end for persistence
  - Snapshots
  - Transaction Logs
  - Playback in case
- On write:
  1. Replicate to 1-n nodes
  2. Write to persistent log (typically AFA)
  3. ACK

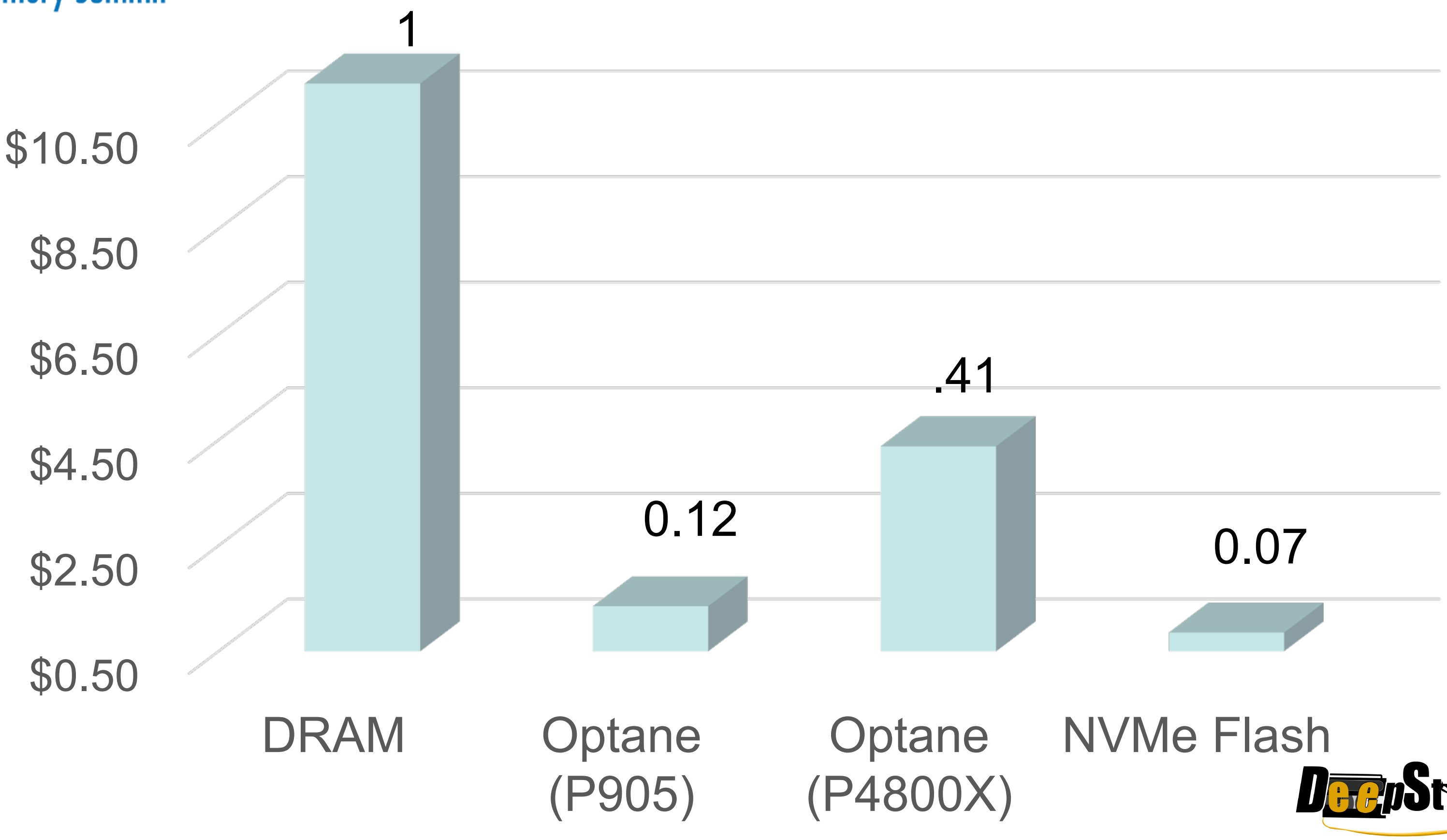


In Memory Database with SCM

- Much larger capacity/node
  - 512GB vs 64GB/DIMM
  - 10X latency (SWAG)
- Lower cost /GB
  - 2-10X we guess
  - More vs 128GB LRDIMMs
    - 3X cost of 64GB
- ACK after n-node write
  - Can be RDMA write
  - Data now persistent
  - Log writes can be aggregated, async



Relative Memory Costs



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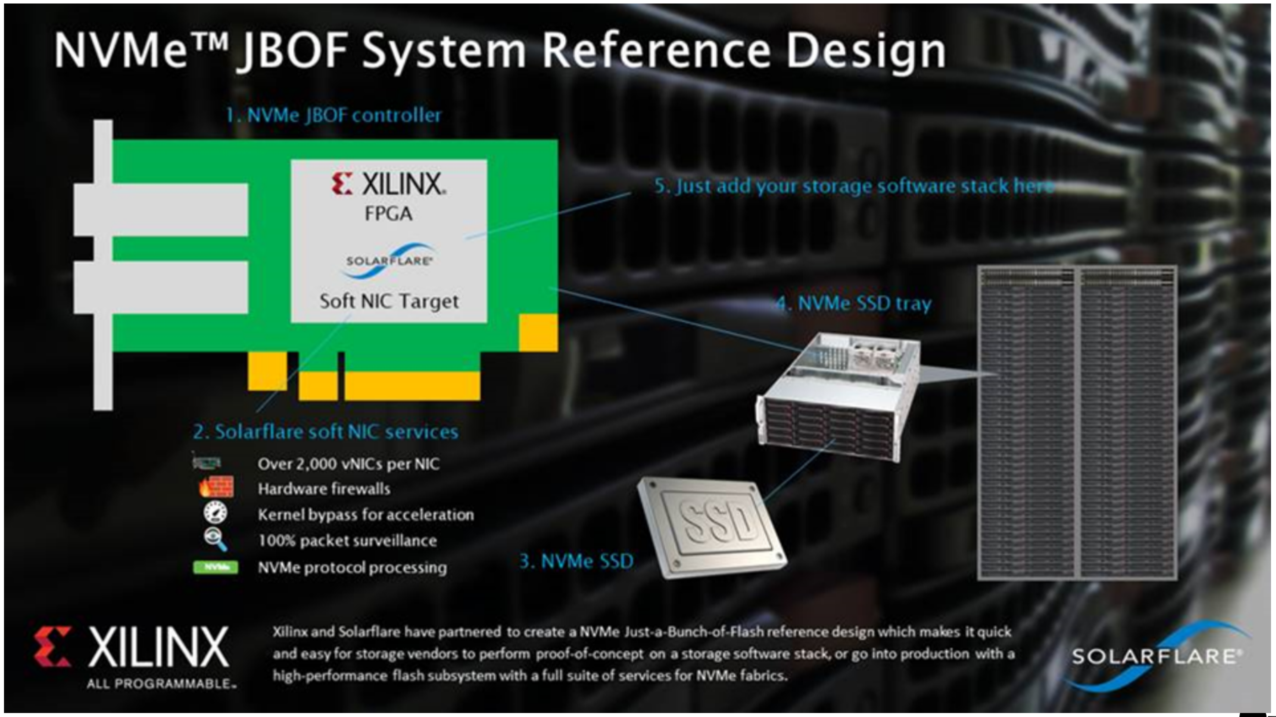
Flash Memory Summit



NVMe™ JBOF System Reference Design

- Over 2,000 vNICs per NIC
- Hardware firewalls
- Kernel bypass for acceleration
- 100% packet surveillance
- NVMe protocol processing

Xilinx and Solarflare have partnered to create a NVMe Just-a-Bunch-of-Flash reference design which makes it quick and easy for storage vendors to perform proof-of-concept on a storage software stack, or go into production with a high-performance flash subsystem with a full suite of services for NVMe fabrics.