Scaling from Datacenter to Client

KeunSoo Jo

Sr. Manager Memory Product Planning
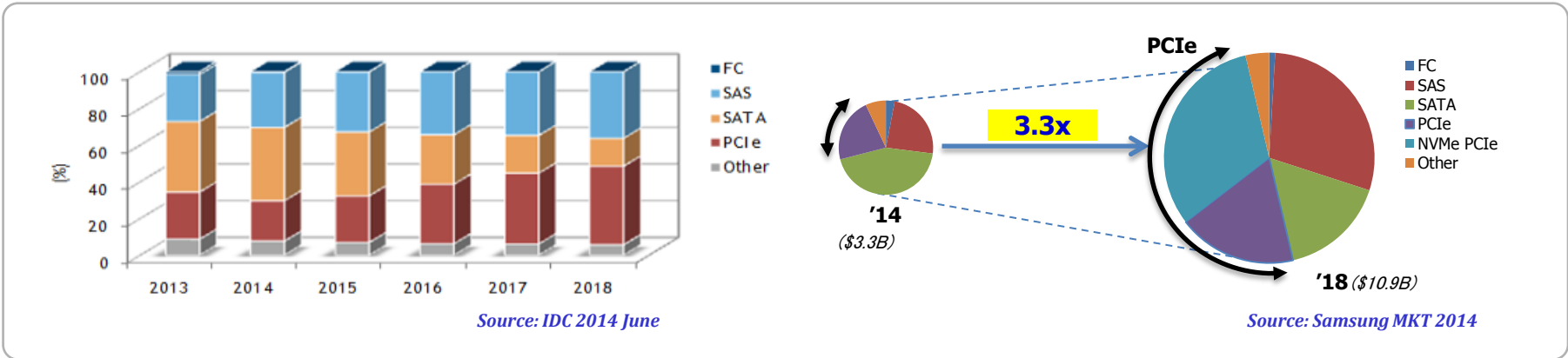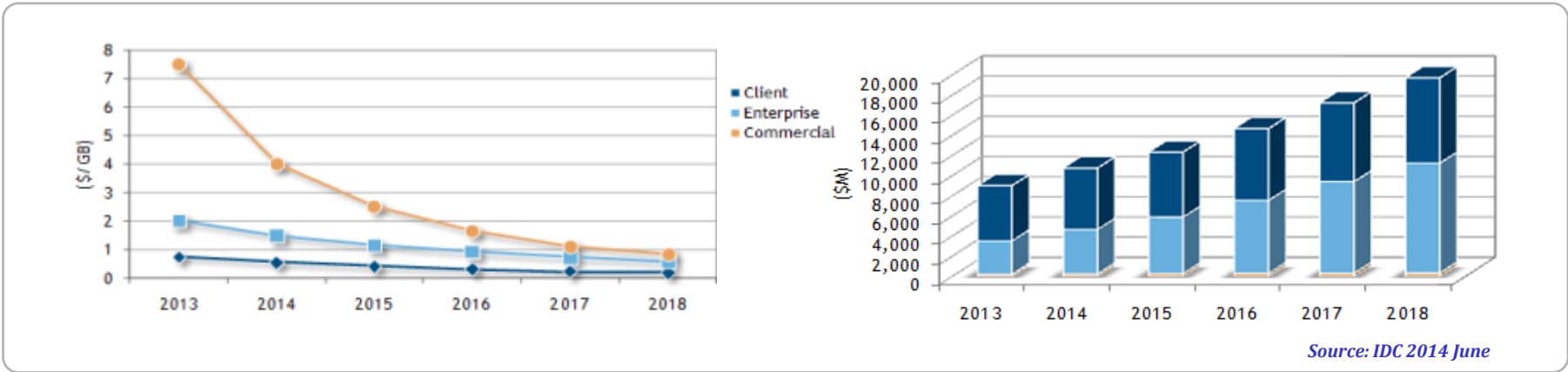
Samsung Semiconductor

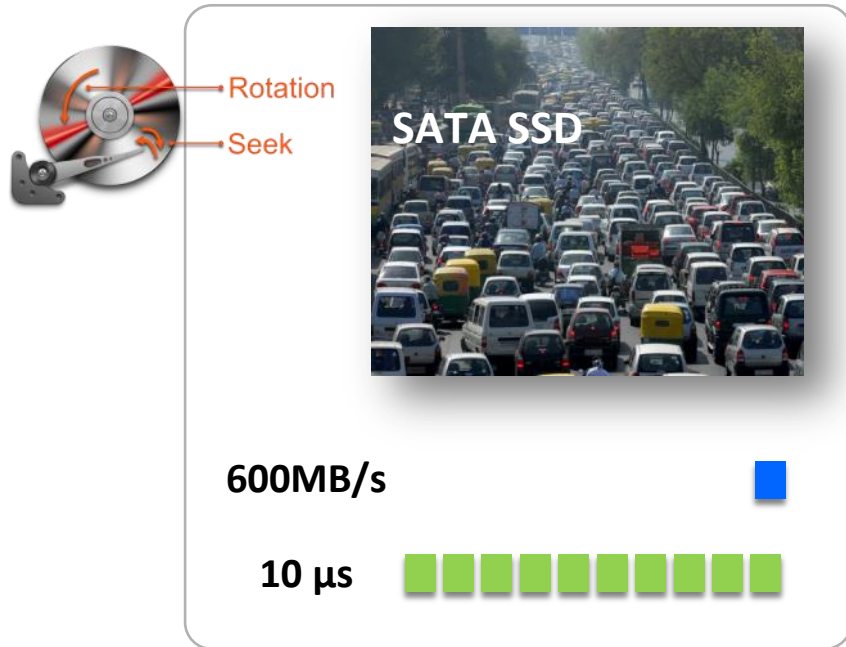Audio-Visual Sponsor

Shannon Systems

Outline

- **SSD Market Overview & Trends - Enterprise**

- **What brought us to NVMe Technology**

- **Samsung NVM Express SSDs**

- **NVMe in Read World**

- **Expanding to Energy Friendly Offerings**

- **SSD Market Overview & Trends - Client**

- **NVMe In Client Achieving Ultra Low Power**

SSD Market Overview & Trends - Enterprise

- **Enterprise SSD Connectivity**

Source: IDC 2014 June

Source: IDC 2014 June

Source: Samsung MKT 2014

3.3x

PCIe

'14 ($3.3B)

'18 ($10.9B)

What Triggered NVMe Development

- **NAND Flash Storage is a different breed than Disk Drives**

SATA SSD

600MB/s

10 µs

CH0

CH7

Way 0 ---------------- Way 7
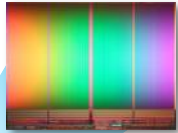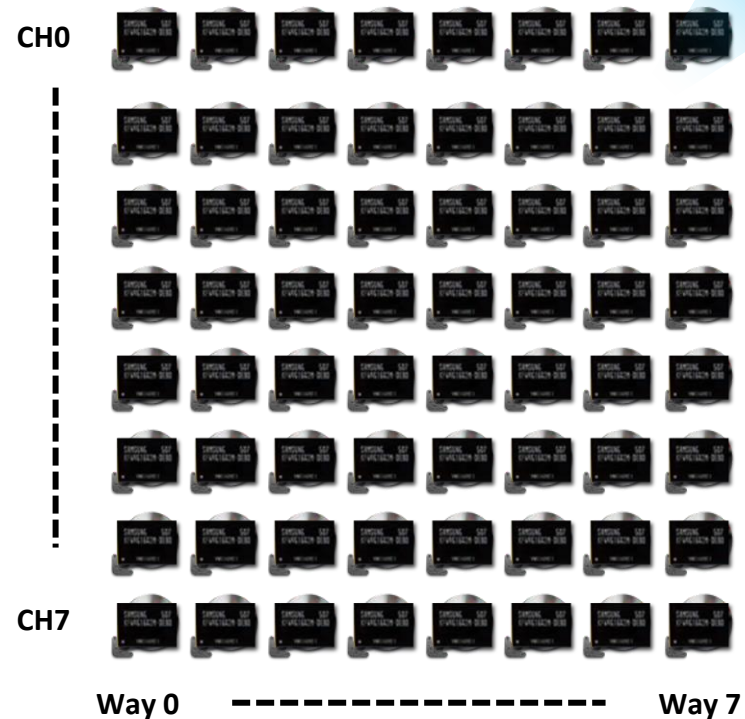
What Triggered NVMe Development

- **PCIe opens up the bottleneck**
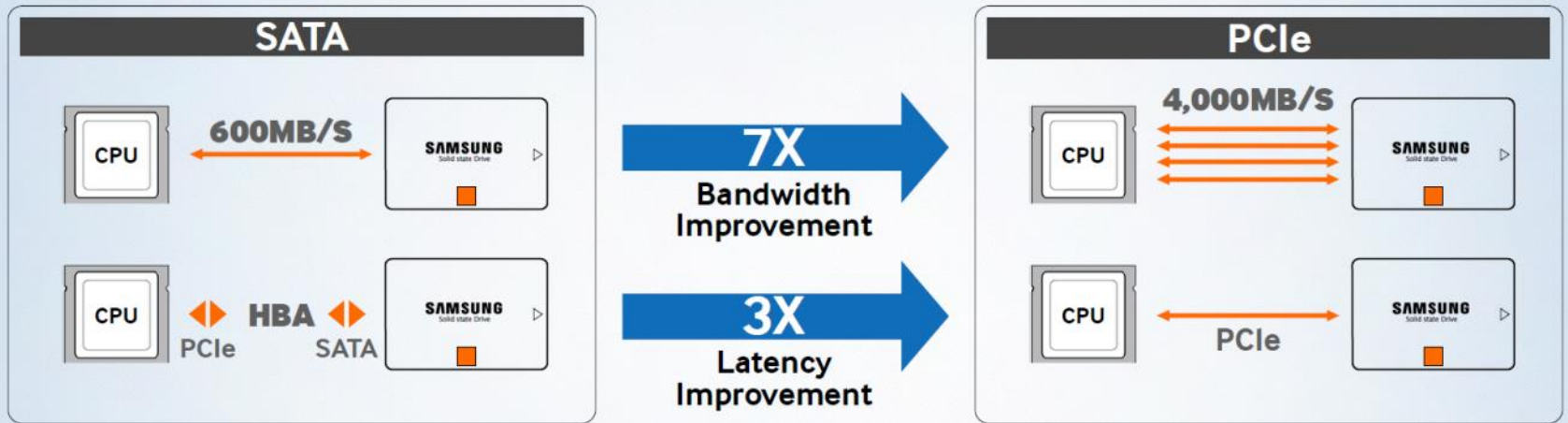
What Triggered NVMe Development

- **NVMe maximizes NAND Flash latency and parallelism**

NVMe PCIe SSD

SATA SSD

NVMe

* With 4 lanes (PCIe Gen 3)

7X   4GB/s   10µs   1/3X
600MB/s   3µs
SATA   NVMe   SATA   NVMe
Bandwidth   Latency
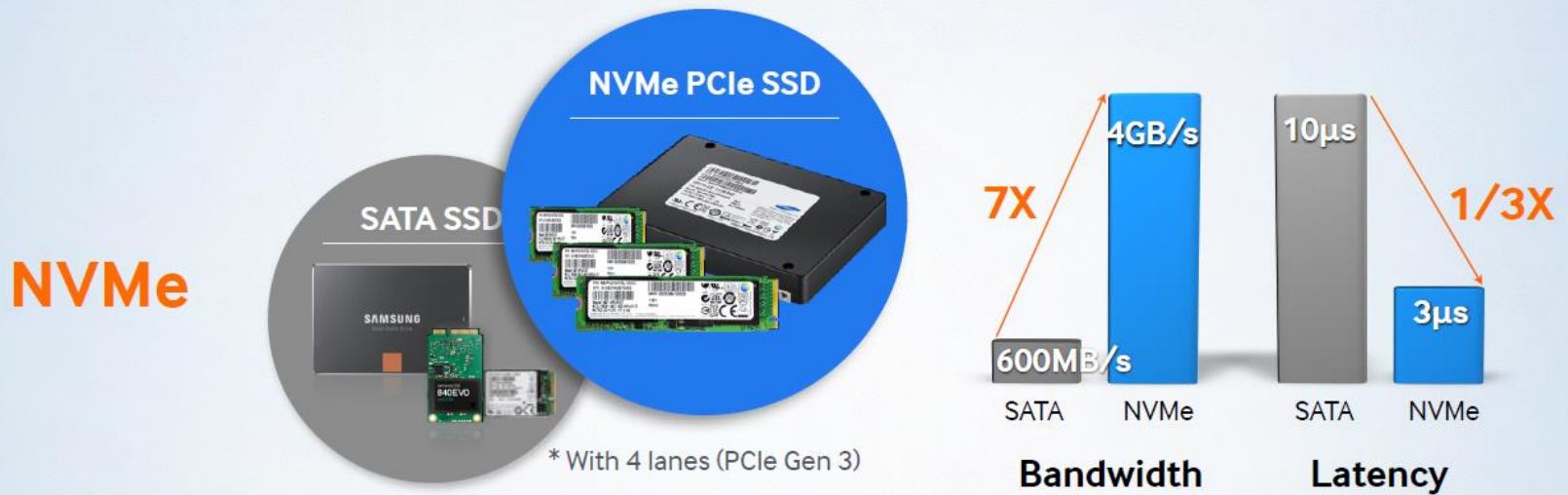
NVMe Unleashes the True Performance Capability of NAND

What Triggered NVMe Development

- **Unleashing the True Performance Capability of NAND Flash**

SATA SSD		NVMe SSD
600MB/s	X 7 Bandwidth	4GB/s
10 µs	X 0.3 Latency	3 µs
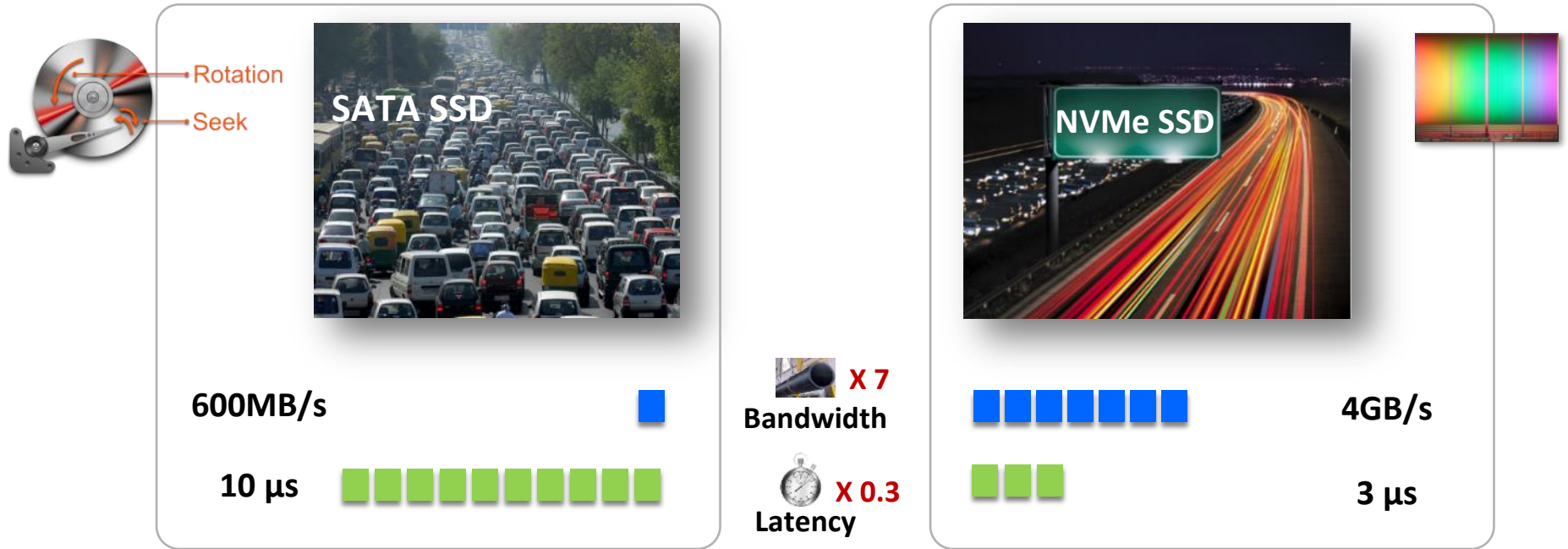
Samsung NVM Express SSDs

- **Samsung provides state-of-the-art NVMe SSD Solutions**
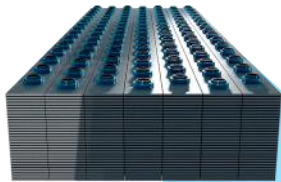
3D V-NAND

Power Loss Protection

SFF-8639
Hot-Pluggable 2.5inch

NVMe Standard
Dual-Port X4 PCIe Gen3

The 1st NVMe SSD

- **Successfully launched and now being <u>mass produced</u>**

XS1715 : 1st NVMe for Data Center

World's 1st NVMe Server
(Launched Mar '14)

Dell™ PowerEdge™ R920 server — up to **14.9X** the original performance*

Powered by the Intel® Xeon® processor E7 v2 family and upgraded with NVMe Express Flash PCIe® SSDs
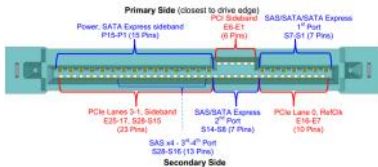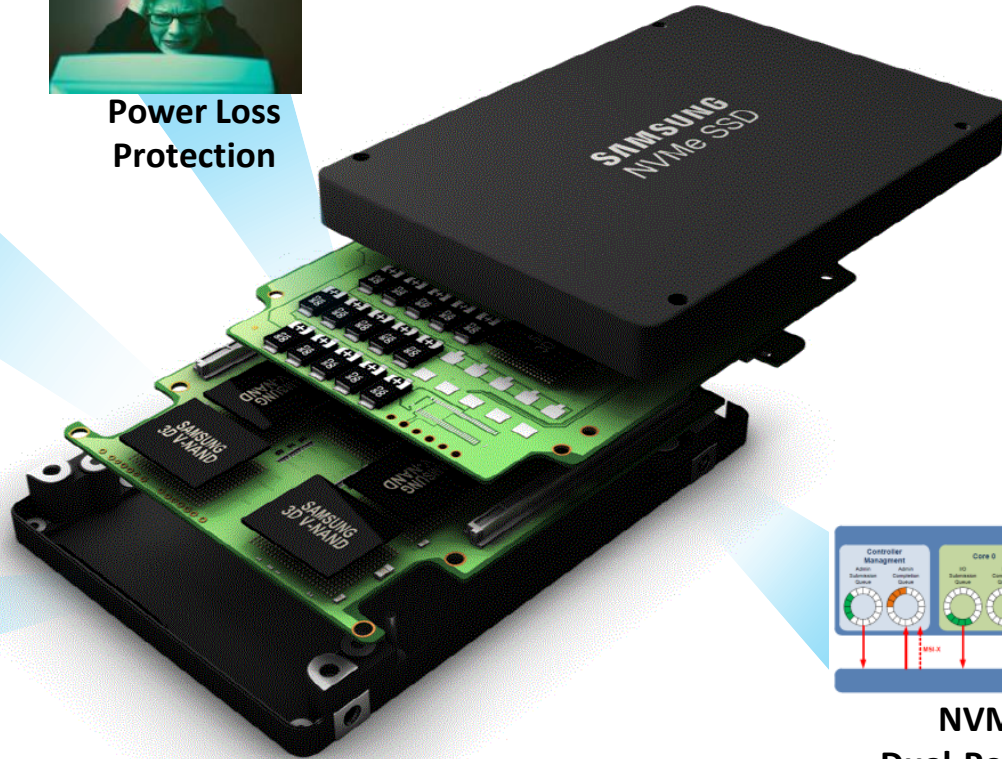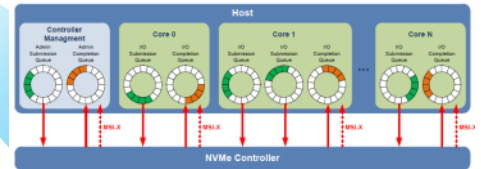
Samsung XS1715

*When running an Oracle® database workload, versus the same server with SAS hard drives

Performance Optimized NVMe SSD

	Samsung XS1715	Other NVMe
Sequential Speed (Read/Write MB/s)	3000/1400	2600/1700
Random Speed (Read/Write IOPS)	750K/115K	450K/70K

World's 1st NVMe Interoperability Certification

InterOperability Laboratory — University of New Hampshire

Product	firmware Version	Interop Program Revision	Date Listed	Test ID	Futher Info
IDT Princeton NVMe Controller	1611	v1.0	5/31/13		
Samsung XS1715	IPM04B20	v1.0	5/31/13		
Western Digital Technologies, Inc. PCIe NVMe SSD			5/31/13		

MAY '13

Up to 14.9X Faster With NVMe

Greater TCO saving opportunities ($, Watt)

Million IOPs
TB Capacity

TCO
$

Higher IOPs/Watt
Smaller Footprint

15/10K rpm SAS

SAS/SATA Gen3

NVMe

Aggregated SAS

Tired Storage

Tired Storage
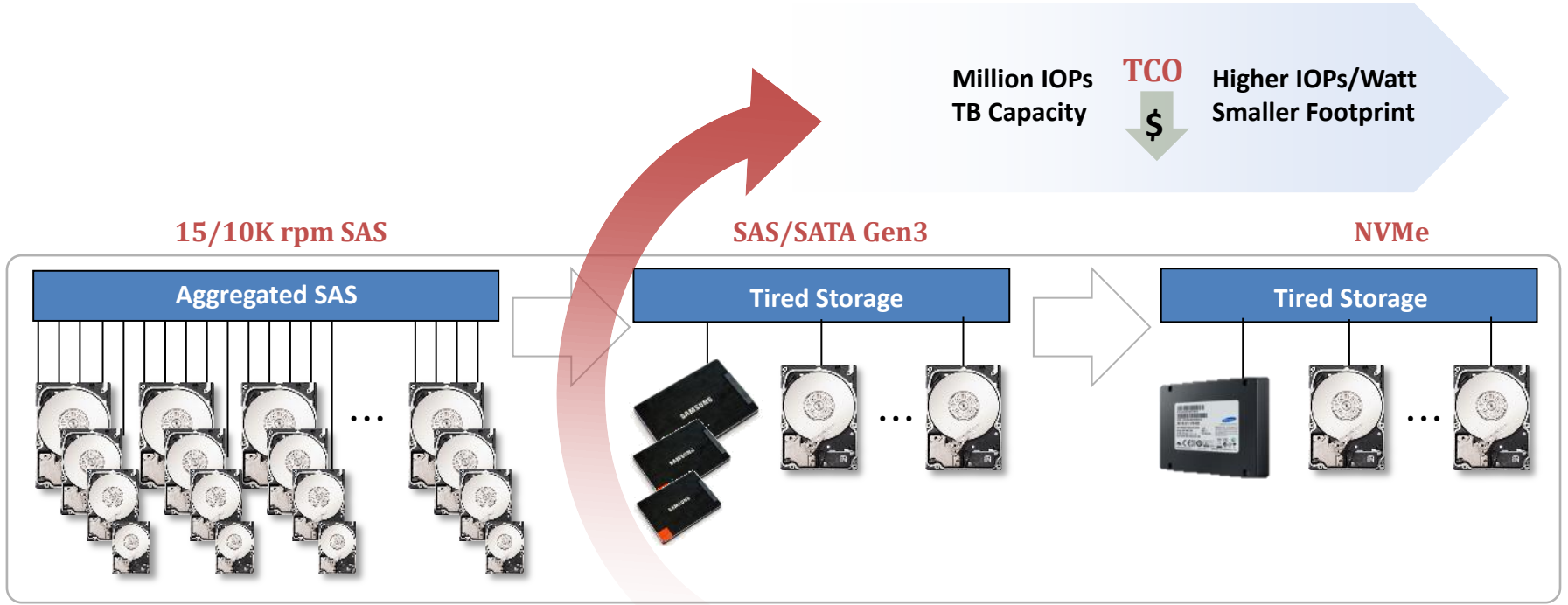
	SATA (480G)		XS1715 (1.6T)
Random Read	70,000IOPS	10.6x	750,000IOPS
Random Write	11,000IOPS	10.5x	115,000IOPS
Sequential Read	520MB/s	5.8 x	3,000MB/s
Sequential Write	420MB/s	3.3 x	1,400MB/s

NVMe "Real World" Performance

- **NVMe SSD is optimized for multi-treaded architecture.**
  - **Multiple workloads and CPU cores**

Max Performance Variation
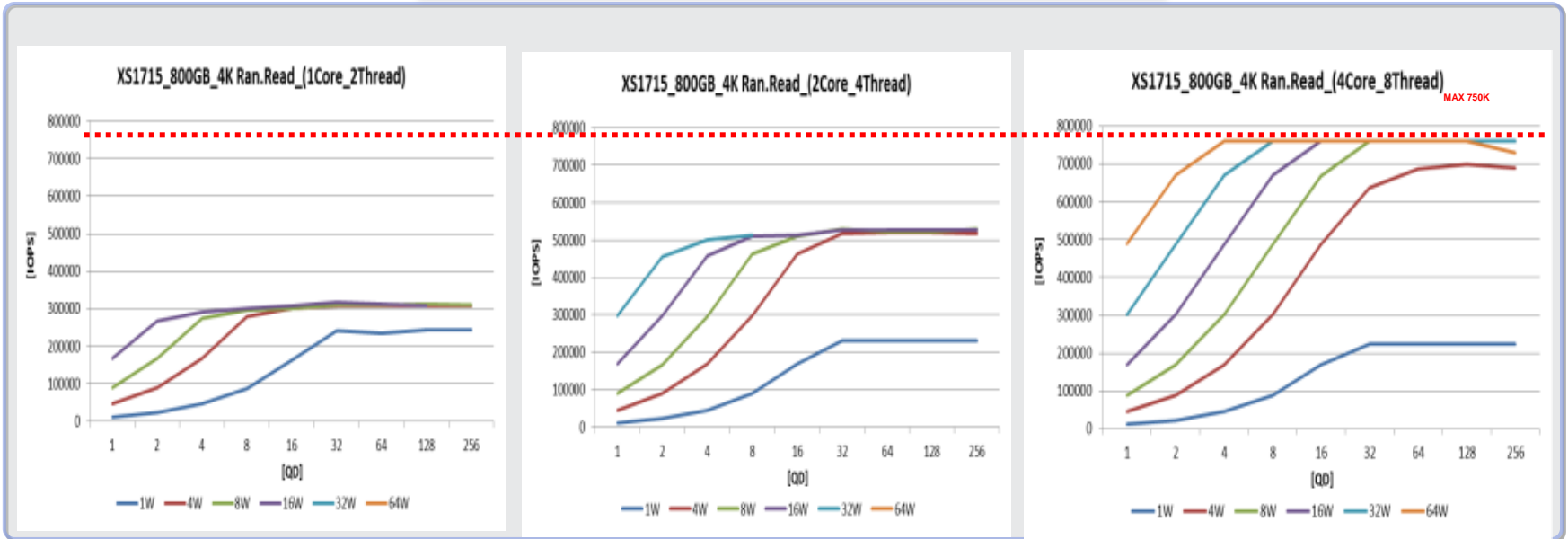
NVMe "Real World" Performance

- **Multi-thread performance is associated with CPU thread**

Mas Performance Variation
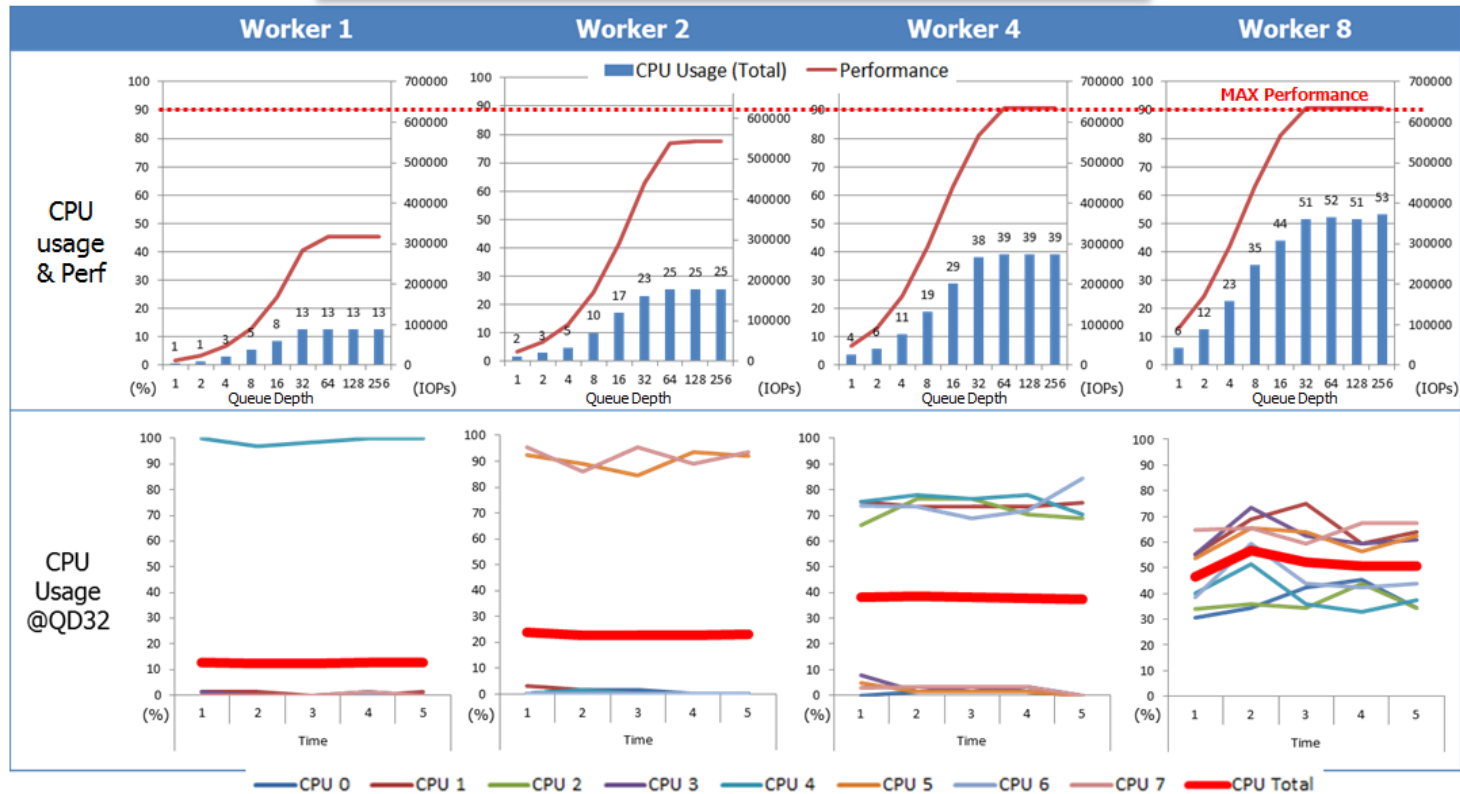
NVMe "Real World" Performance

- **Performance saturation point differs depending on OS**
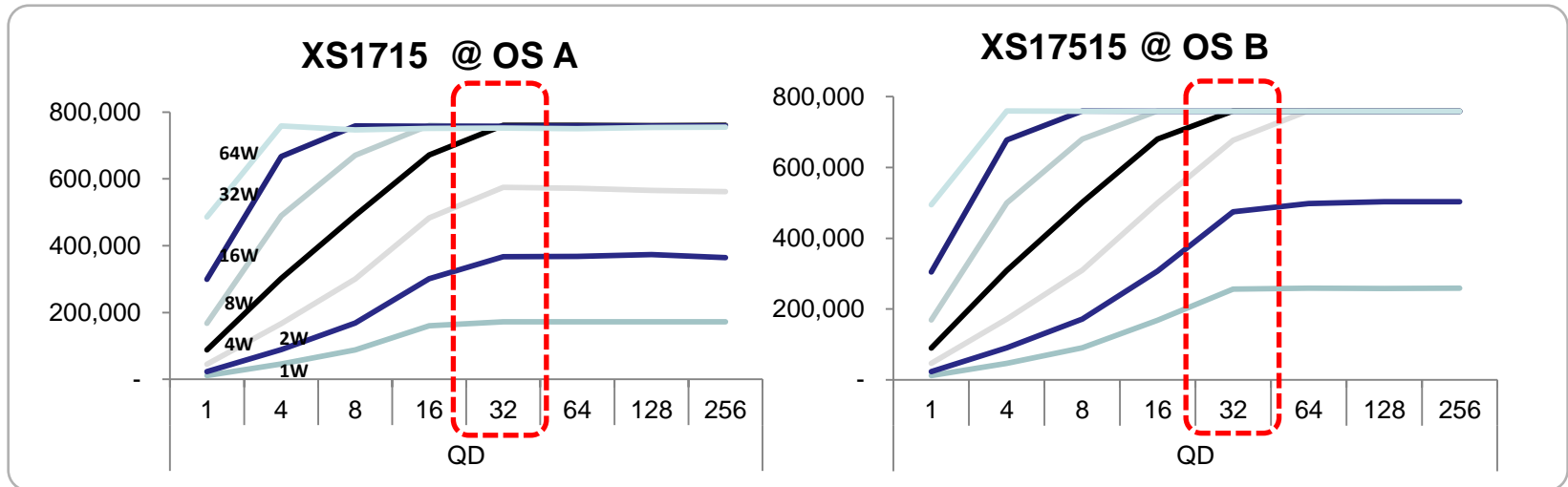
NVMe "Real World" Performance

- **NVMe shows much better performance with a multi-thread workload**

We need to develop multi-thread environment such as application which support multi-core processing.

Now, most applications use single core and low queue depth except for multi-tasking
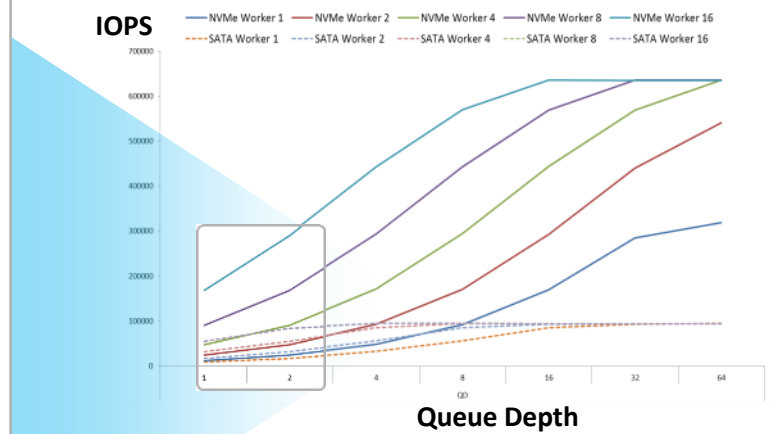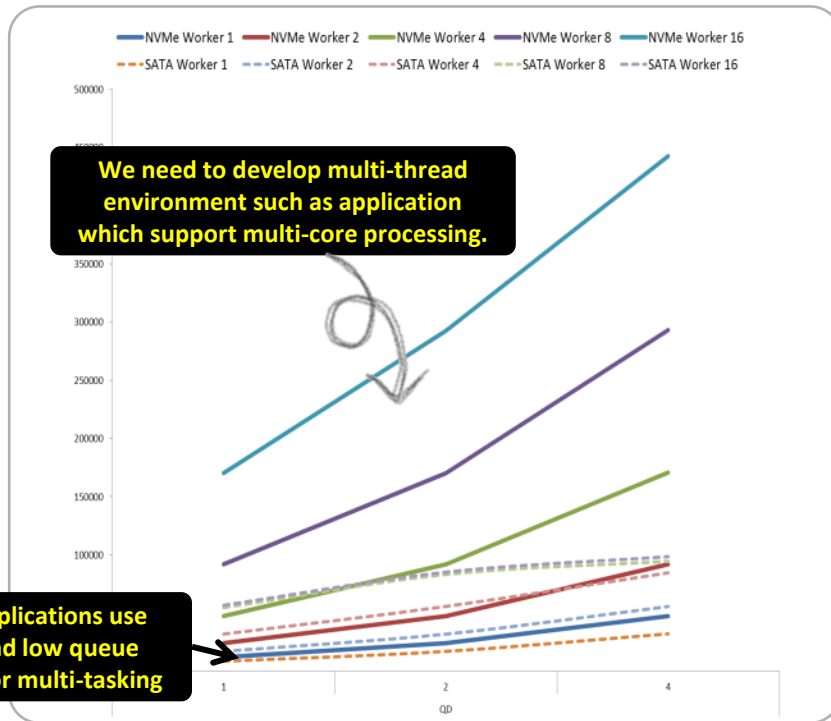
NVMe is Optimized Solution

- **NVMe is a best solution for Cloud services and virtualization**
  - Best suitable for multi-threads applications → Compute & Virtualization
  - However, there exists a big host delay in virtualization applications. (Hyper-V, VMWare …)
  - Need to co-work for performance optimization of NVMe SSD

■ Each VM Ran.R Performance in NVMe SSD [IOPS@QD4]
■ Each VM Ran.R Performance in SATA SSD [IOPS@QD4]

5.2X
Performance Gain
(@32VM)

	1 VM	2 VM	4 VM	8 VM	16 VM	32VM
NVMe	46K	37K	32K	23K	15K	9.4K
gain	2x	1.8x	2.3x	3.3x	4.1x	5.2x
SATA	23K	20K	14K	7K	3.6K	1.8K

<Test @IOMeter>
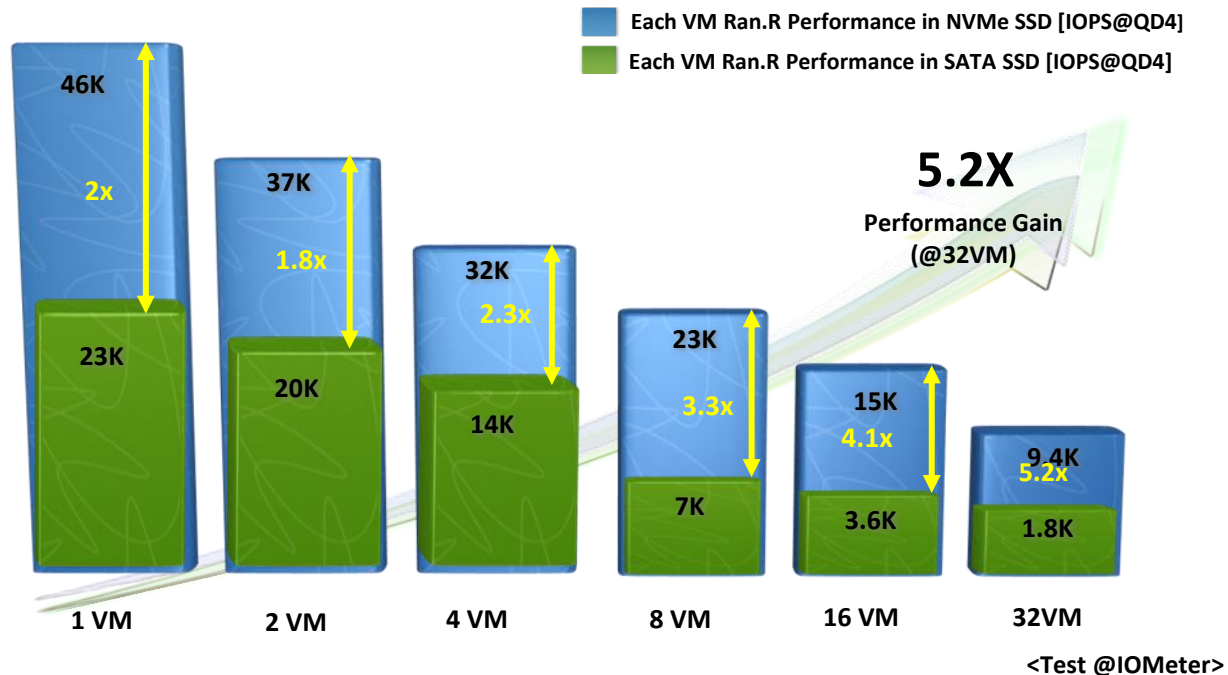
NVMe on Hyper-V

- **Performance on number of partitions with VM environment**

x 3.5

| 135K | 358K | 469K | 635K |

1 Partition + 32 VM   4 Partition + 32 VM   8 Partition + 32 VM   No Partition
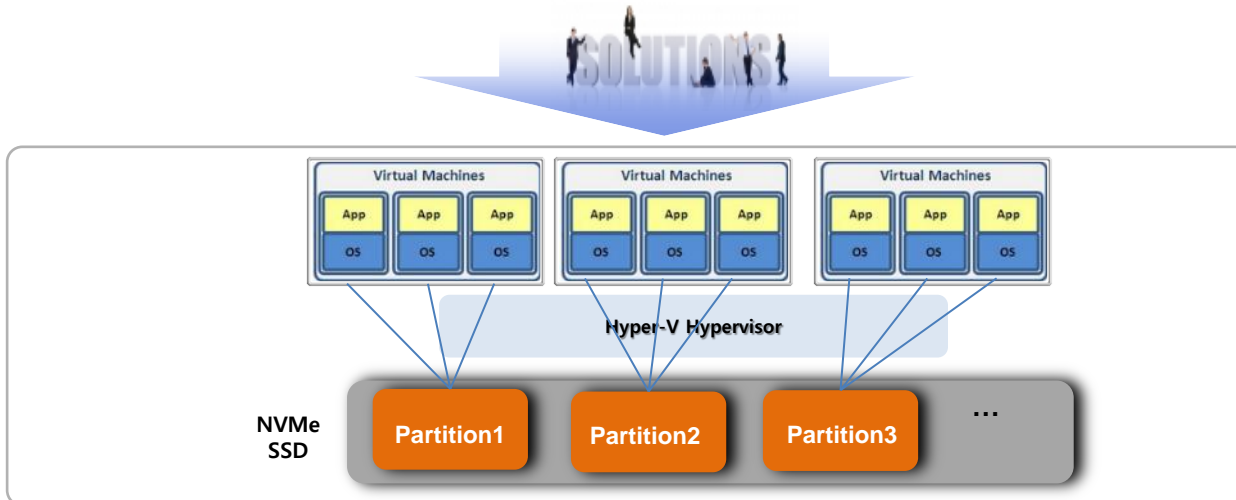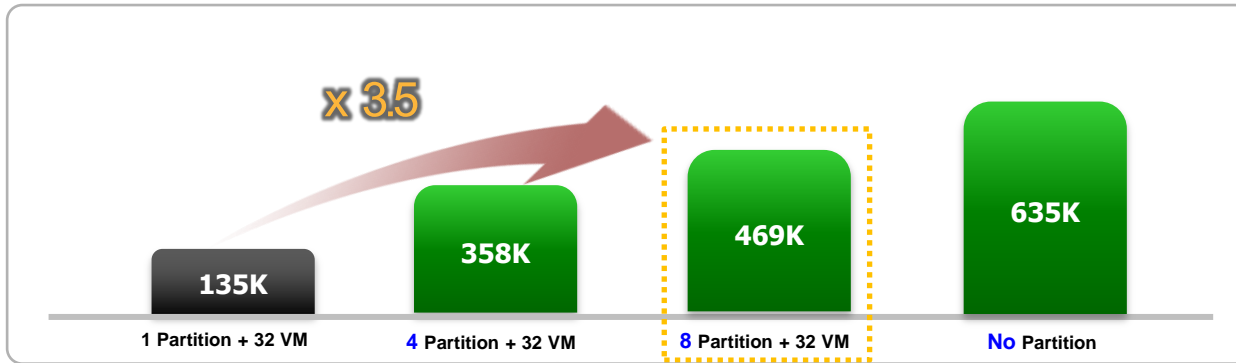
Expanding to More Energy Friendly Offerings

- **SM953: 1st Power Optimized NVMe SSD is <u>coming soon</u>**

World's 1st NVMe SSD for Cloud Service

SM953 (NVMe)

Power Optimized NVMe SSD

	Samsung SM953	Other NVMe
Active Power	6W	10W ~ 25W
Form Factor	2.5", M.2	2.5", HHHL

World's 1st NVMe Integrators 1.1 Interoperability Certification

iol University of New Hampshire InterOperability Laboratory

Product	Product Type	firmware Version	Interop Program Revision	Date Listed	Test ID
Huawei uniSSD	NVMe SSD	v1.0	v1.1	3/10/14	
Intel NVMe SSD Technology	NVMe SSD	8DV10036	v1.1	3/10/14	
Mobiveil UNEX 64 bit NVMe Controller IP	NVMe SSD IP	1	v1.1	3/10/14	
Mobiveil UNEX 128 bit NVMe Controller IP	NVMe SSD IP	1	v1.1	3/10/14	
PMC Sierra Princeton NVMe Controller	NVMe SSD Controller	1.9.0	v1.1	3/10/14	
Realtek NVMe RTS576x series Controller	NVMe SSD Controller	v1.0.0	v1.1	3/10/14	
Samsung NVMe 95X Series	NVMe SSD	BDU81S04	v1.1	3/10/14	

Mar '14

40-75% Power Reduction for Optimized TCO

SM953 NVMe Performance

- **Single-drive Server App. Performance (NVMe vs. SATA)**

Sever Application Performance

Performance [IOPS]

* High is better

- 3D V-NAND 2bit NVMe SSD (480GB)
- Planar 2bit SATA SSD (480GB)

1.8 x

3.2 x

2.8 x

2.4 x

File Servers

Seq. 25%	Ran. 75%
Read 90%	Write 10%

8KB

Decision Support

Ran. 100%
Read 100%

64KB

Media Streaming

Seq. 100%
Read 98%	Write 2%

64KB

OS Paging

Seq. 100%
Read 90%	Write 10%

64KB
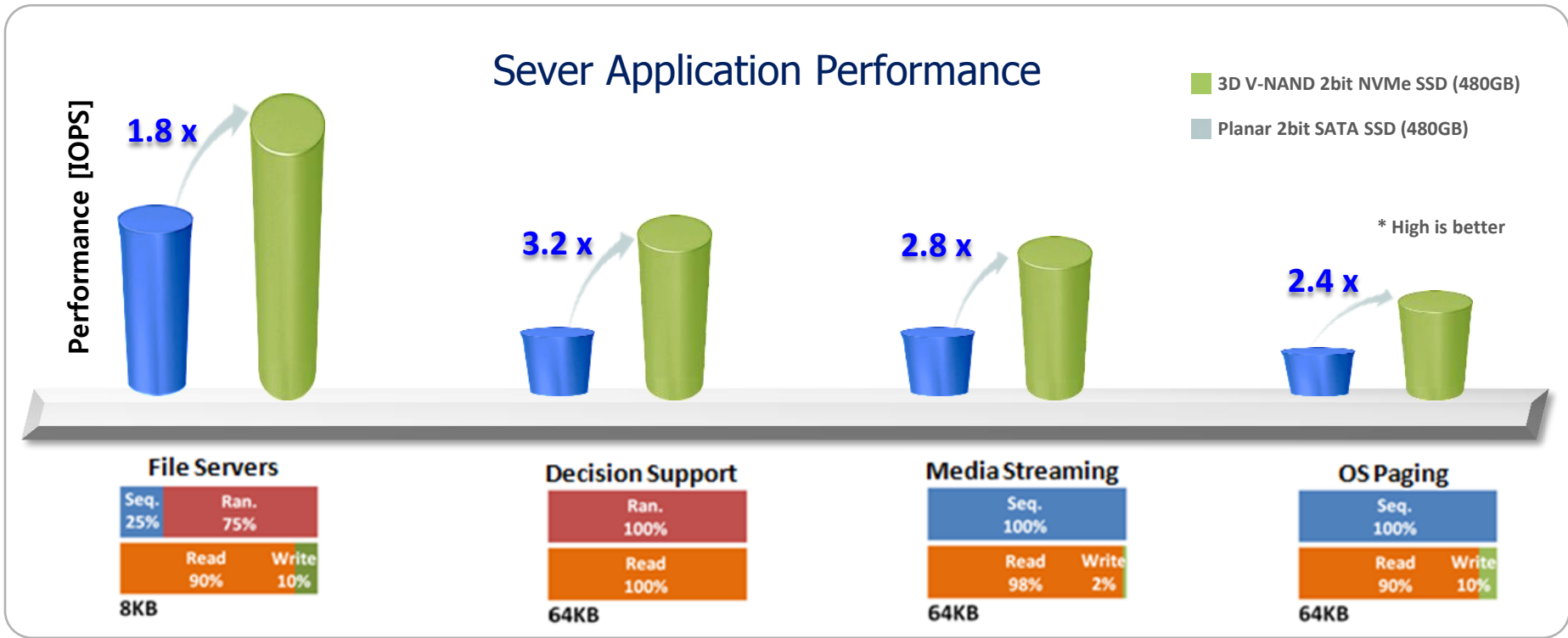
Single-drive Performance Comparison
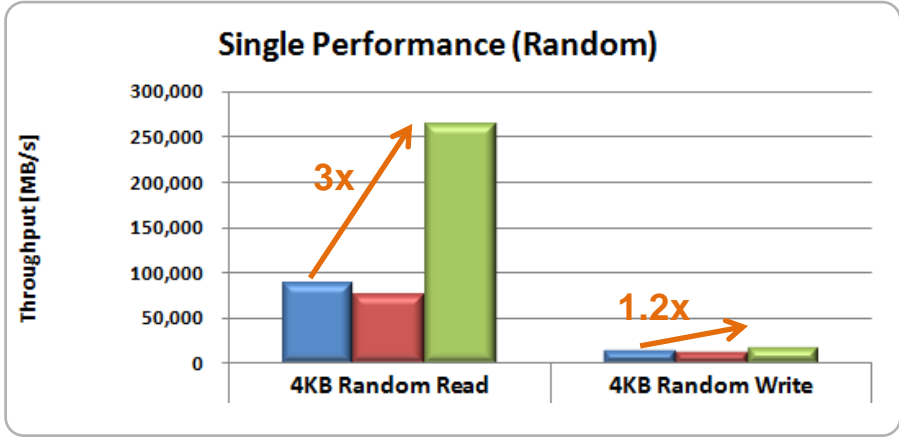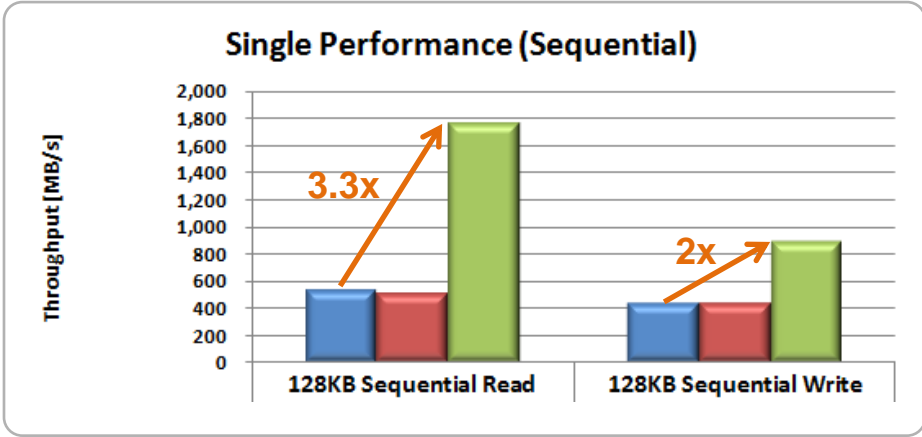
Single Performance (Sequential)

3.3x

2x

128KB Sequential Read   128KB Sequential Write

Single Performance (Random)

3x

1.2x

4KB Random Read   4KB Random Write

Samsung Planar 3bit SATA SSD (480GB)   Planar 2bit SATA SSD (480GB)   Samsung 3D V-NAND 2bit NVMe SSD (480GB)

SATA vs. NVMe IOPS consistency

Single-drive IOPS Consistency Comparison

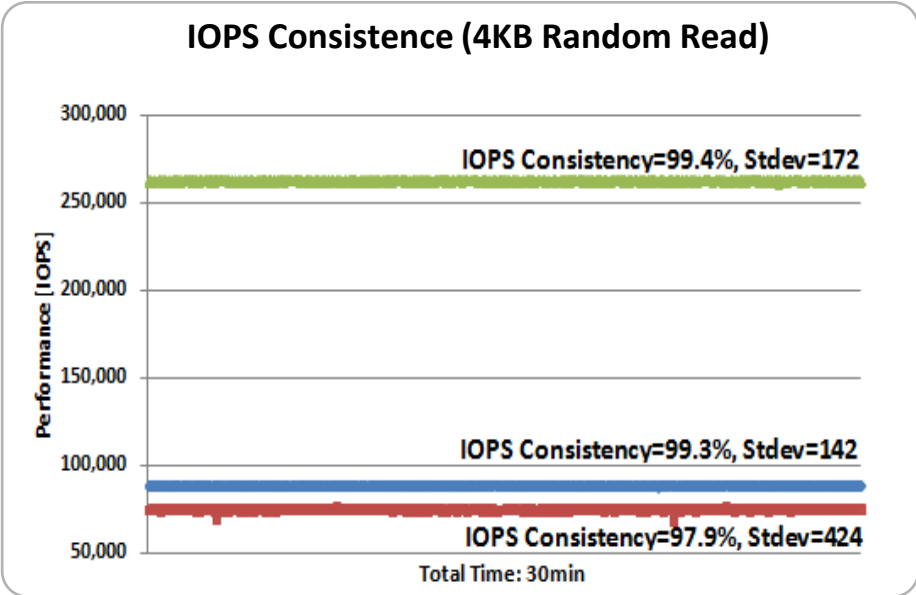IOPS Consistence (4KB Random Read)

IOPS Consistency=99.4%, Stdev=172
IOPS Consistency=99.3%, Stdev=142
IOPS Consistency=97.9%, Stdev=424
Total Time: 30min

IOPS Consistence (4KB Random Write)

IOPS Consistency=96.5%, Stdev=172
IOPS Consistency=92.1%, Stdev=342
IOPS Consistency=79.1%, Stdev=950
Total Time: 30min
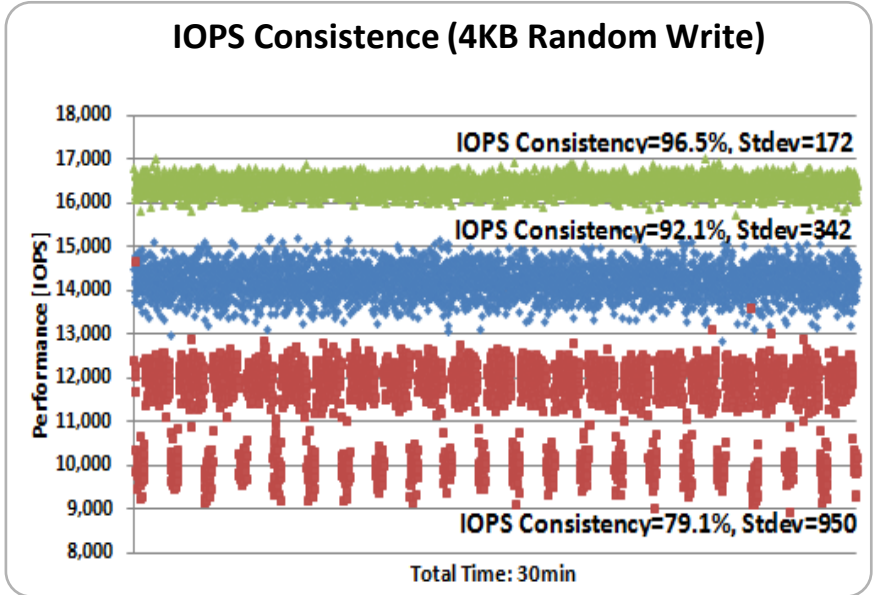
Samsung Planar 3bit SATA SSD (480GB) Planar 2bit SATA SSD (480GB) Samsung 3D V-NAND 2bit NVMe SSD (480GB)

4KB Random R/W(Worker 1)

SATA vs. NVMe S/W RAID Performance

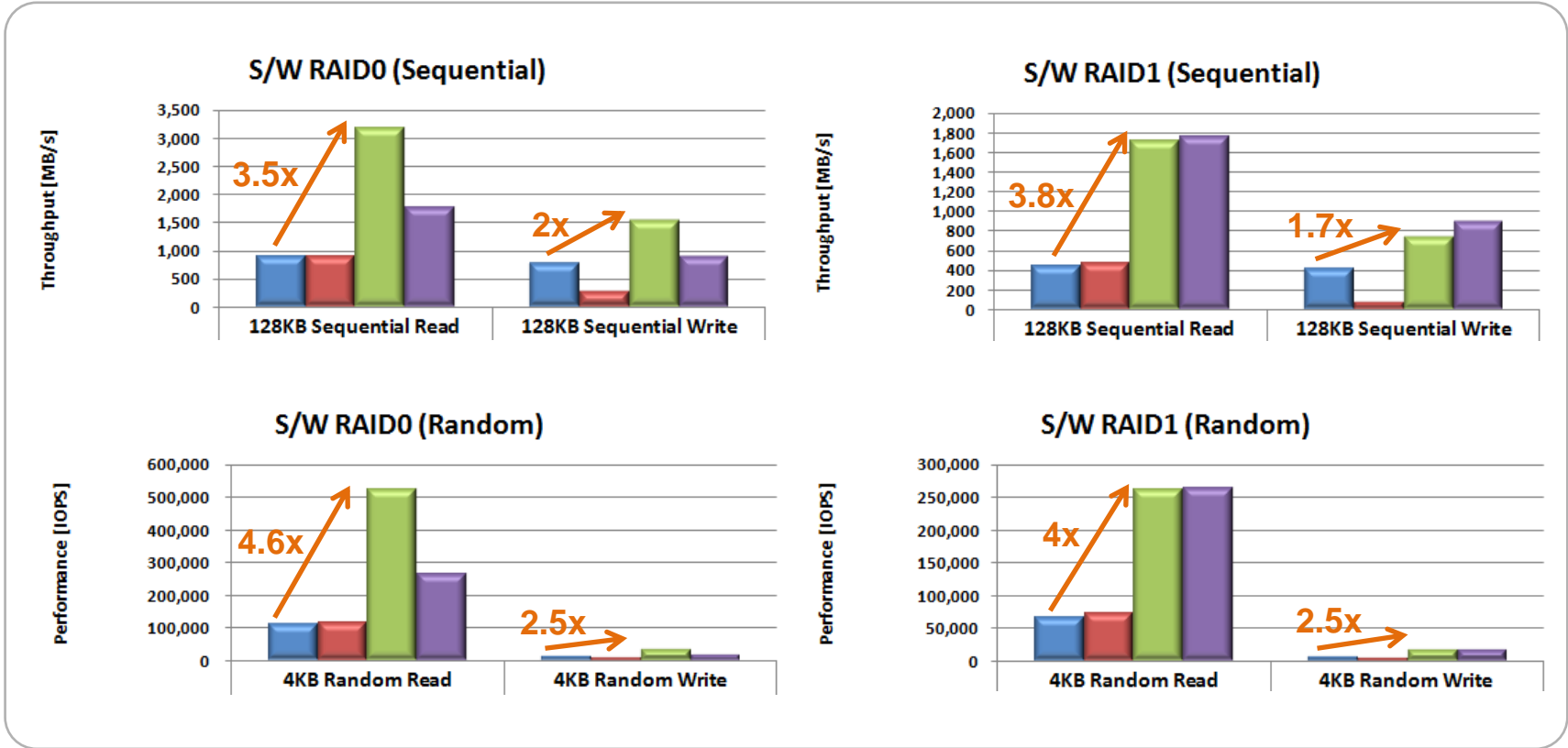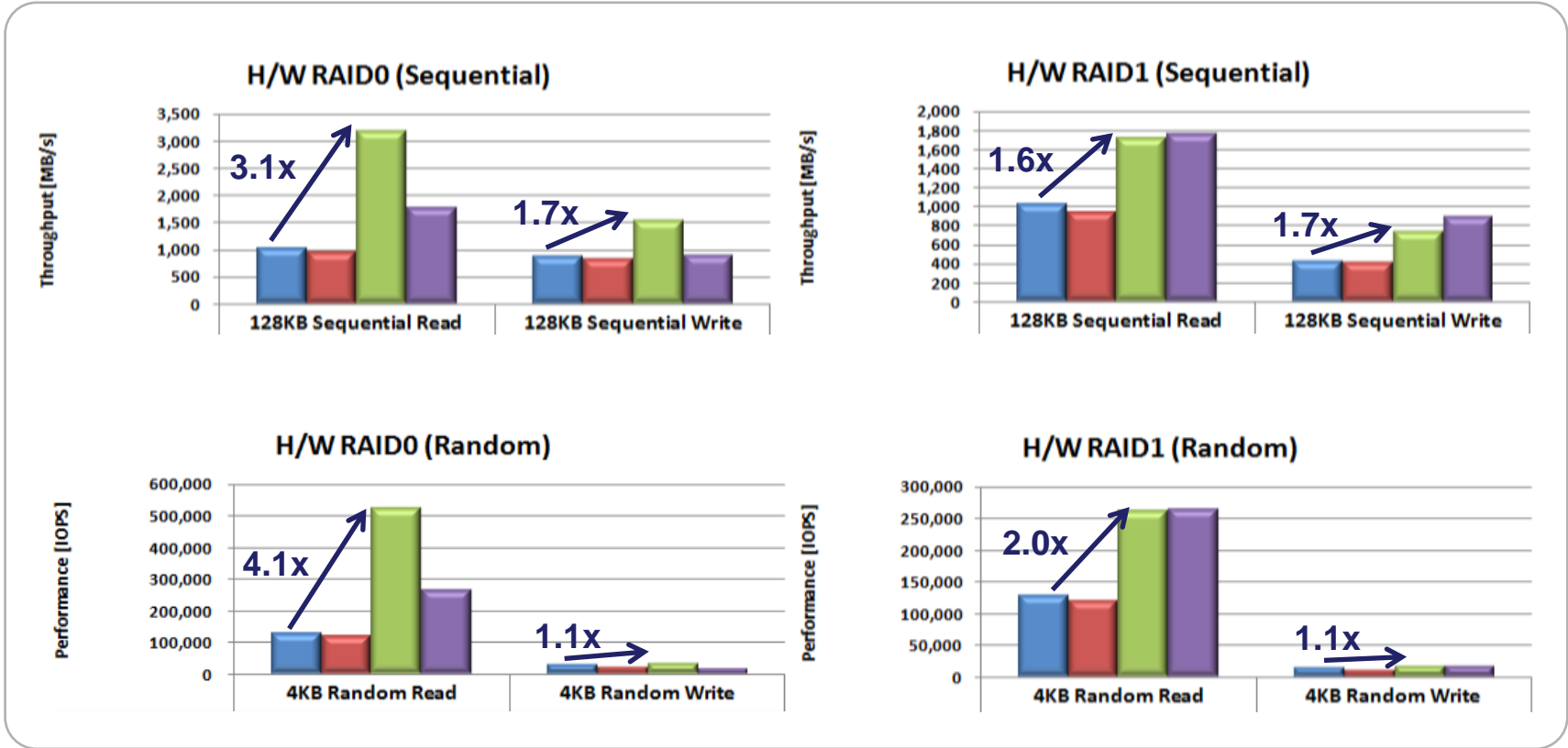Samsung Planar 3bit SATA SSD (480GB)   Planar 2bit SATA SSD (480GB)   Samsung 3D V-NAND 2bit NVMe SSD (480GB) + Single

SATA vs. NVMe H/W RAID Performance

H/W RAID0 (Sequential)
H/W RAID1 (Sequential)
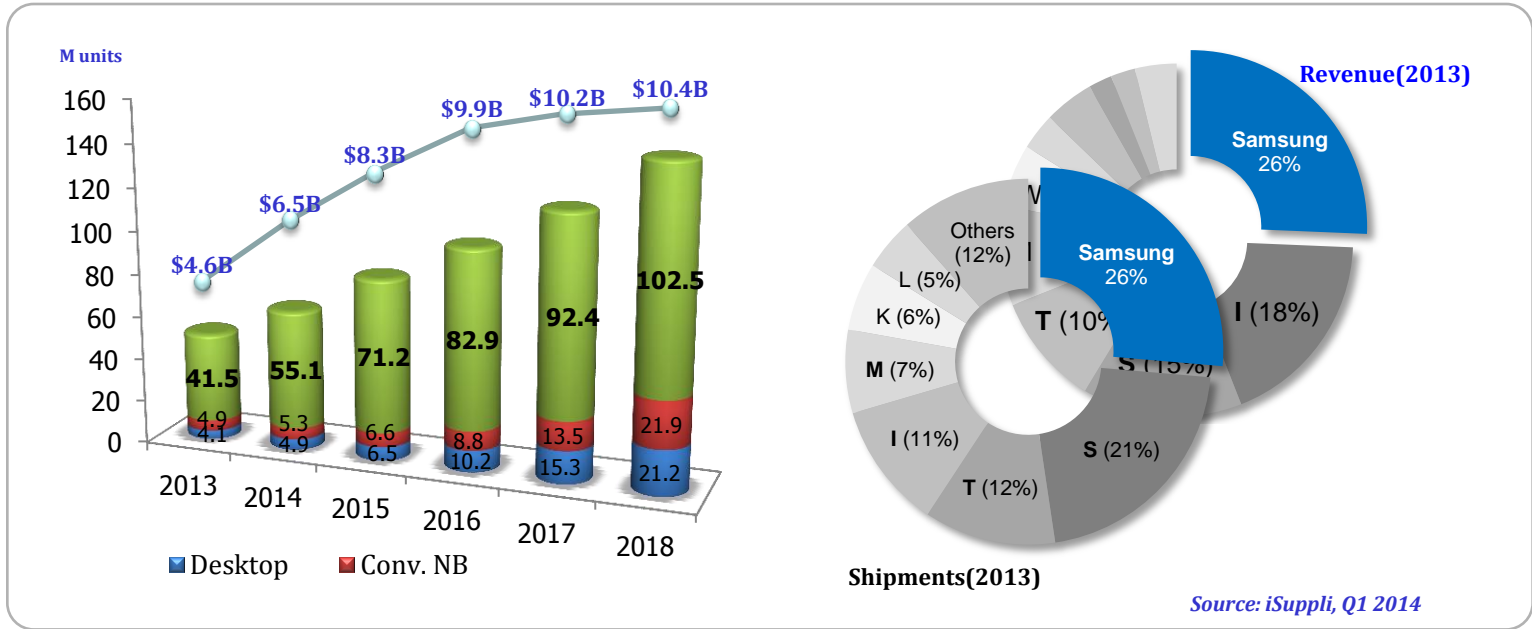H/W RAID0 (Random)
H/W RAID1 (Random)

Samsung Planar 3bit SATA SSD (480GB)   Planar 2bit SATA SSD (480GB)   Samsung 3D V-NAND 2bit NVMe SSD (480GB) + Single
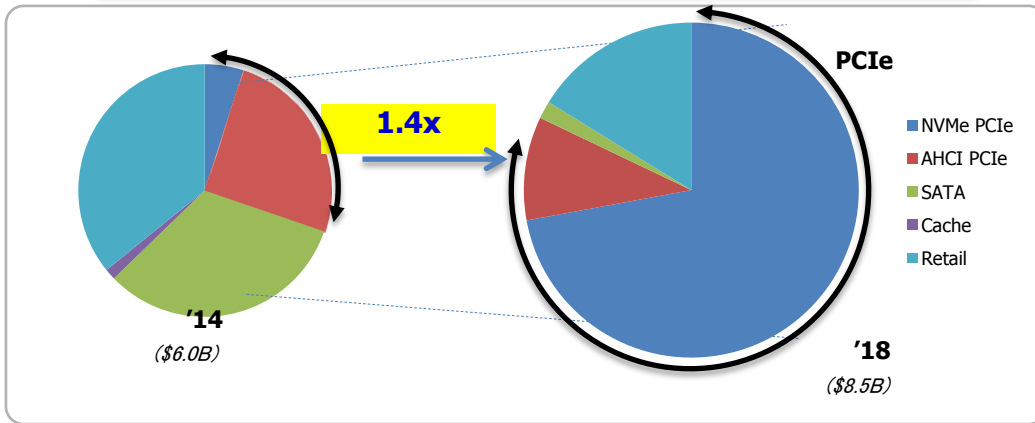
SSD Market Overview & Trends - Client

- **Client SSD Market will be growing fast due to ultramobile PC market growth**

- **Samsung has shown and will keep strong leadership in Client SSD Market (shipments & revenue)**

M units

Year	Desktop	Conv. NB	Green	Total
2013	4.1	4.9	41.5	$4.6B
2014	4.9	5.3	55.1	$6.5B
2015	6.5	6.6	71.2	$8.3B
2016	10.2	8.8	82.9	$9.9B
2017	15.3	13.5	92.4	$10.2B
2018	21.2	21.9	102.5	$10.4B

■ Desktop ■ Conv. NB

Revenue(2013)
- Samsung 26%
- I (18%)
- S (15%)
- T (10%)

Shipments(2013)
- Samsung 26%
- Others (12%)
- L (5%)
- K (6%)
- M (7%)
- I (11%)
- T (12%)
- S (21%)

Source: iSuppli, Q1 2014

SSD Market Overview & Trend - Client

- **Client SSD Connectivity**

Client Forecast by Interface

1.4x

'14 ($6.0B)

PCIe

'18 ($8.5B)

- NVMe PCIe
- AHCI PCIe
- SATA
- Cache
- Retail

Source: Samsung MKT

'13 Revenue Share by Vendor

SSD

Other (21.4%)
WD (5.5%)
Toshiba (6.9%)
Micron (7.7%)
SanDisk (13.1%)
Samsung (31.6%)
Intel (13.7%)

Total = $9.0B

SSD-Client

Other (15.7%)
Intel (8.9%)
Toshiba (10.6%)
SanDisk (16.7%)
Samsung (48.2%)

Total = $5.5B

Source: IDC 2014 June
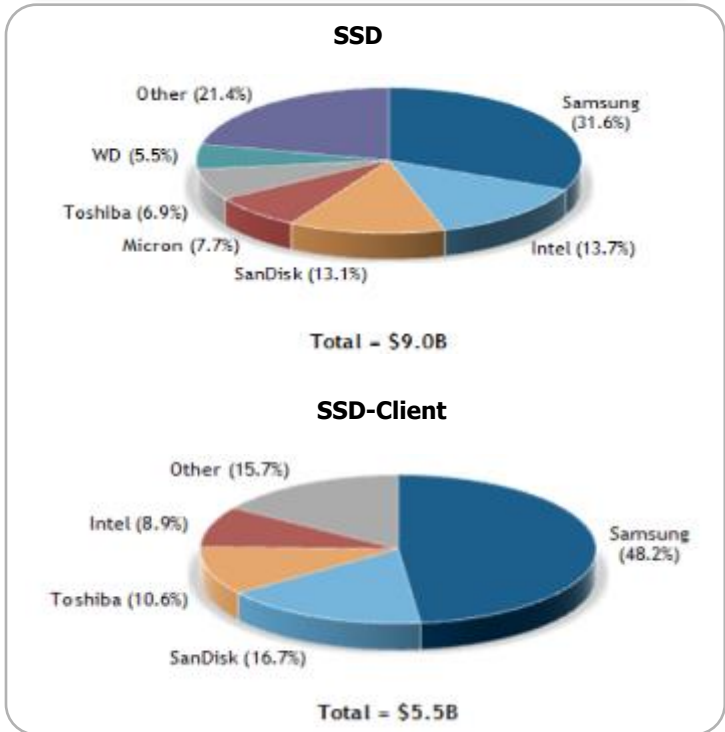
Expanding to Client Application

- **Low-power PCIe SSD for Client**

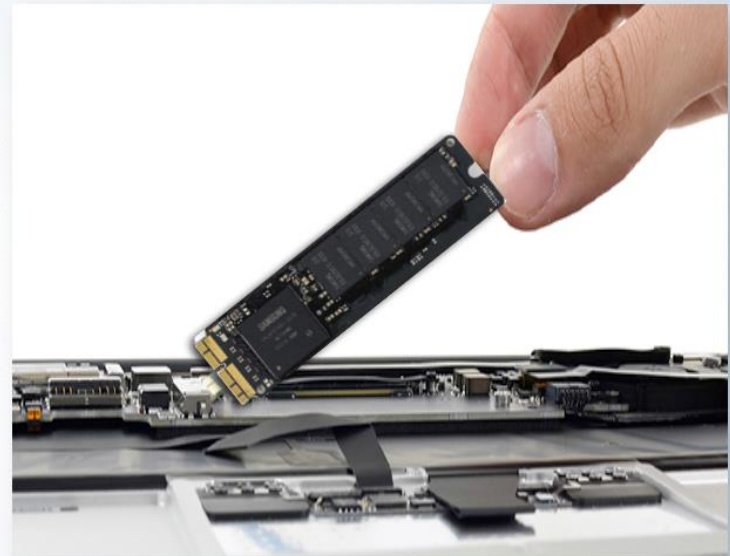## XP941 : 1st PCIe SSD for PC

1st Gen. Client PCIe SSD for '13

PCIe Gen2(5Gbps) x4 lane

Supporting AHCI Protocol

2nd Gen. Client PCIe SSD for '14

PCIe Gen3(**8Gbps**) x4 lane

Supporting AHCI/**NVMe** Protocol

ANANDTECH

"I can't wait for Samsung to release a retail version of the XP941"
"XP941 will be the king of the market"

Expanding to Client Application

- **Low power with unprecedented performance for PC**

SM951 : 1st NVMe SSD for PC
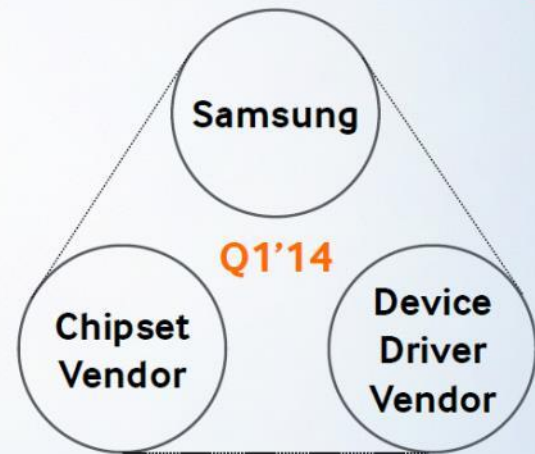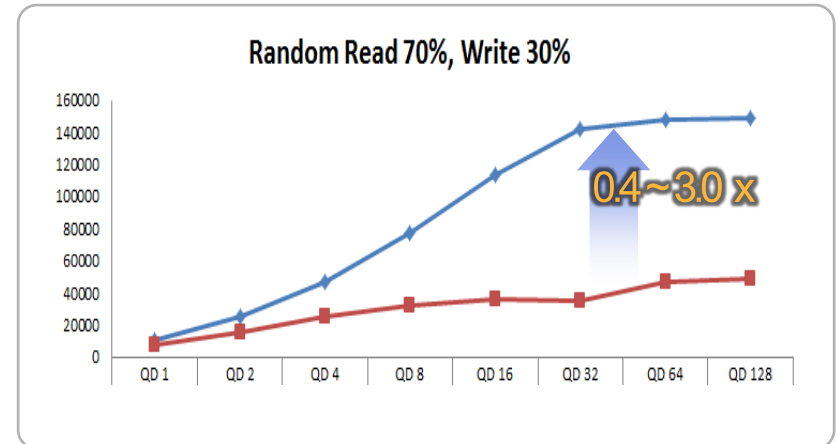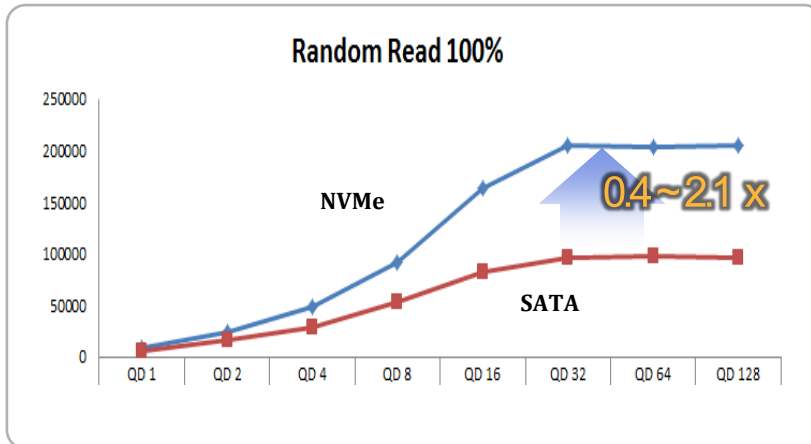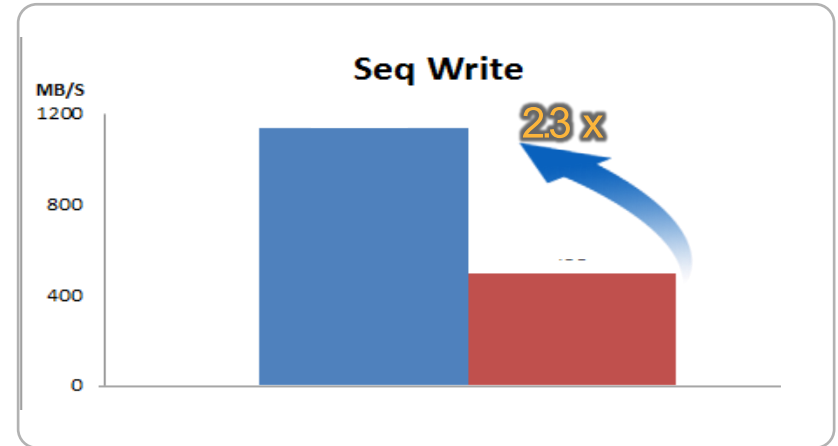
Coming Soon : World's 1st NVMe PC

SM951 (NVMe)

Ultrabook Optimized SSD

	Samsung SM951	SATA SSD (Ultrabook)	
Sequential Speed (Read/Write MB/s)	1600/1000	500/500	2-3X
Random Speed (Read/Write IOPS)	130K/100K	100K/90K	10-30%
Idle Power	2mW	<10mW	-80%
Capacity	1TB	1TB	
Form Factor	M.2, 2.5"	M.2, 2.5"	

World's 1st NVMe Low Power (L1.2) Certification

CERTIFIED

Samsung

Q1'14

Chipset Vendor

Device Driver Vendor

Client NVMe SSD Performance

Seq Read

MB/S
1600
1200
800
400
0

2.5 x

NVMe   SATA

Seq Write

MB/S
1200
800
400
0

2.3 x

Random Read 100%

250000
200000
150000
100000
50000
0

NVMe

0.4~21 x

SATA

QD 1 QD 2 QD 4 QD 8 QD 16 QD 32 QD 64 QD 128

Random Read 70%, Write 30%

160000
140000
120000
100000
80000
60000
40000
20000
0

0.4~3.0 x

QD 1 QD 2 QD 4 QD 8 QD 16 QD 32 QD 64 QD 128
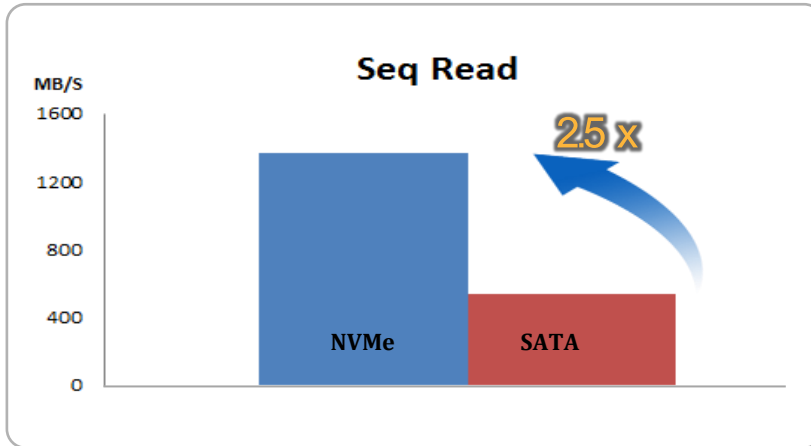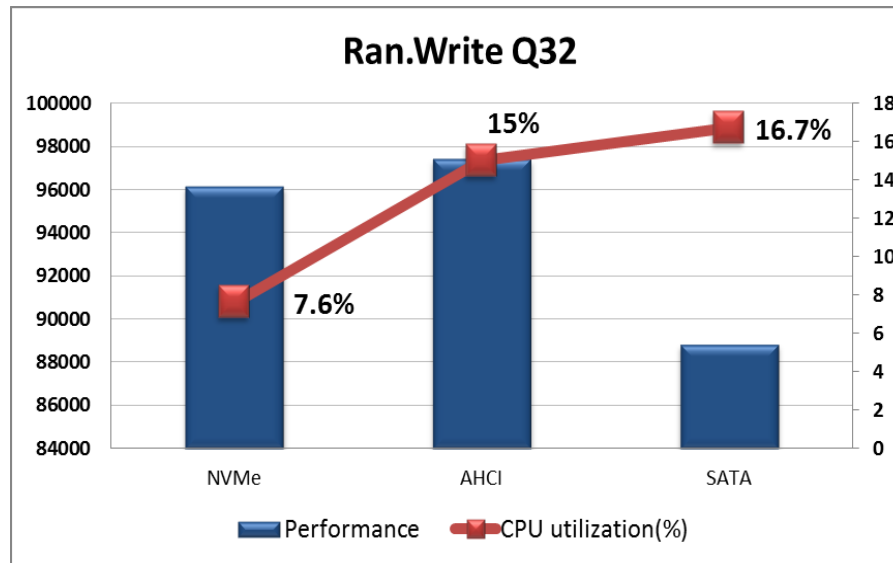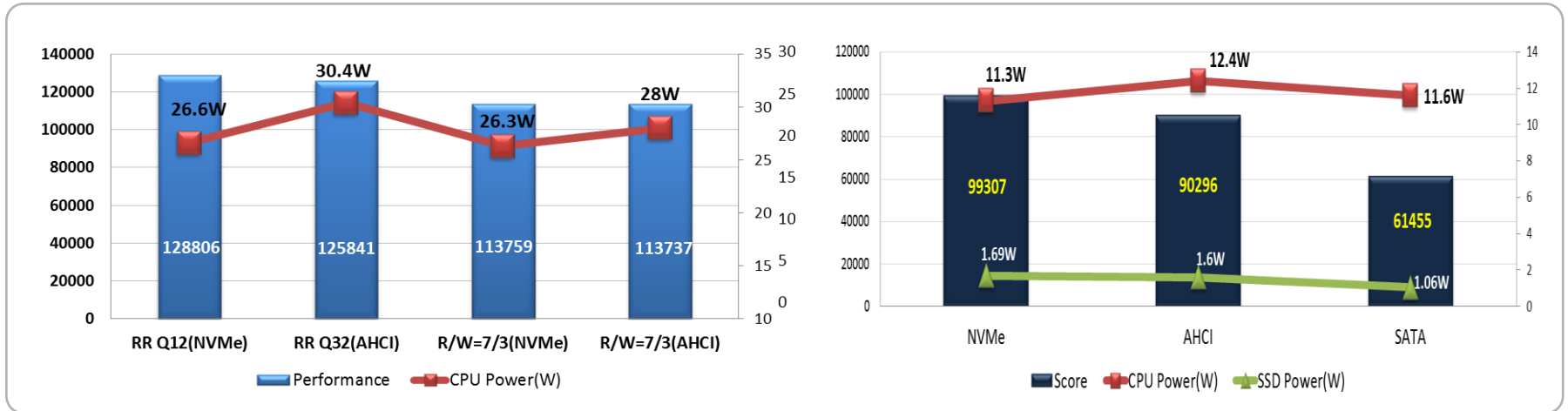
CPU Utilization

- **NVMe SSD has low CPU utilization benefits.**
- **Especially high QD condition**

CPU Power Comparison

- **High performance generates higher CPU power consumption**
- **NVMe SSD has a lower CPU power consumption per W/L**

- **Provide Opportunity for even lower power using PCIe SSD low power functionality (e.g., L1.2, LTR, and low power device states)**

World's First 3D Vertical NAND Flash Memory

Breaking Through the 10nm Process Barrier
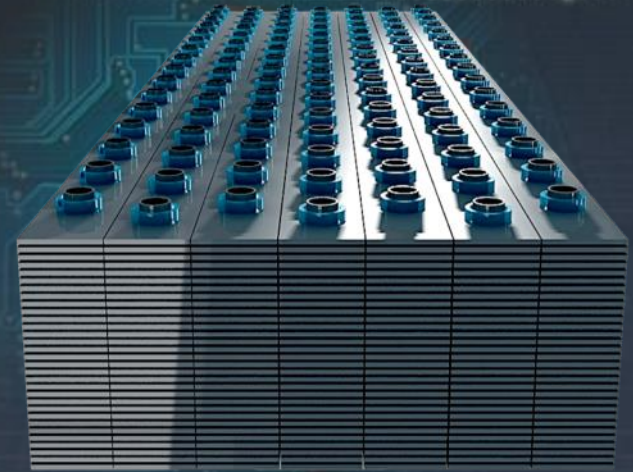with Innovative 3D V-NAND Technology

TWICE THE WRITE SPEED

TEN TIMES MORE ENDURANCE

HALF THE POWER CONSUMPTION

Continued Leadership with V-NAND

PC SSD — 3bit SSD — PCIe SSD — NVMe SSD

Data Center SSD — 3bit SSD — NVMe SSD

Samsung V-NAND Flash

Thank You!

NVM Express in the Real World

David Allen

Dir. Product Marketing

PMC

Audio-Visual Sponsor

Shannon Systems
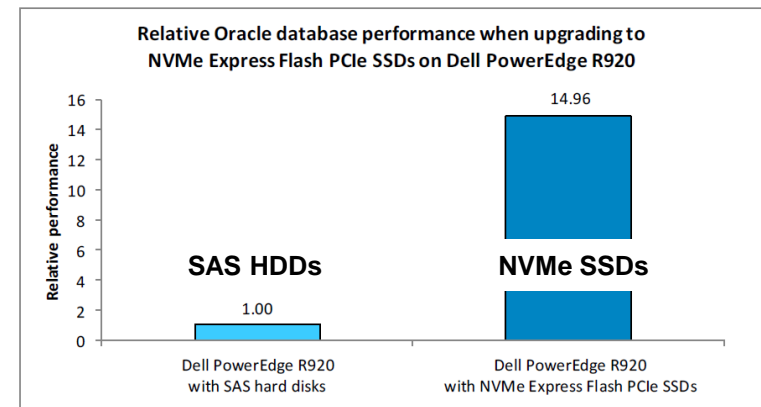
NVMe in the Real World

- New systems and components
- Robust ecosystem emerging
- Key Application acceleration
- Performance enhancements
- Futures

Targeting Application Acceleration

- ## Dell Power Edge R920

  - Accelerating Critical Business Applications
  - SAP HANA
    - A world record 4-socket Linux benchmark result of 25,451 benchmark users (on the SAP SD 2-Tier benchmark*)
    - Up to a **71% improved performance** over previous architectures
    - Nearly equivalent performance in an SAP environment compared with the previous generation 8-socket architectures
  - Oracle database performance
    - ROI improvement
      - o Power and cost
    - 15x improvement over SAS HDD implementations

Relative Oracle database performance

Relative Oracle database performance when upgrading to NVMe Express Flash PCIe SSDs on Dell PowerEdge R920

SAS HDDs — 1.00 (Dell PowerEdge R920 with SAS hard disks)

NVMe SSDs — 14.96 (Dell PowerEdge R920 with NVMe Express Flash PCIe SSDs)

Cohesive High Performance Systems

- ## Supermicro

  ## "NVMe Super Server Solutions"

  - New High density architectures supporting
    - NVMe and SAS direct attached storage
  - Targeting high performance applications
    - Hyperscale
    - Very Large Database (VLDB) applications
  - Up to 6x IOPs improvement over existing SATA solutions
  - Accelerates applications and overall ROI
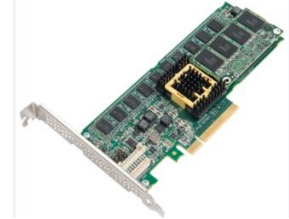
2U TwinPro™ SuperServer®

1U WIO SuperServer®

SYS-1027R-WC1NR/-WC1NRT

NVMe Non-Volatile Memory Tiers

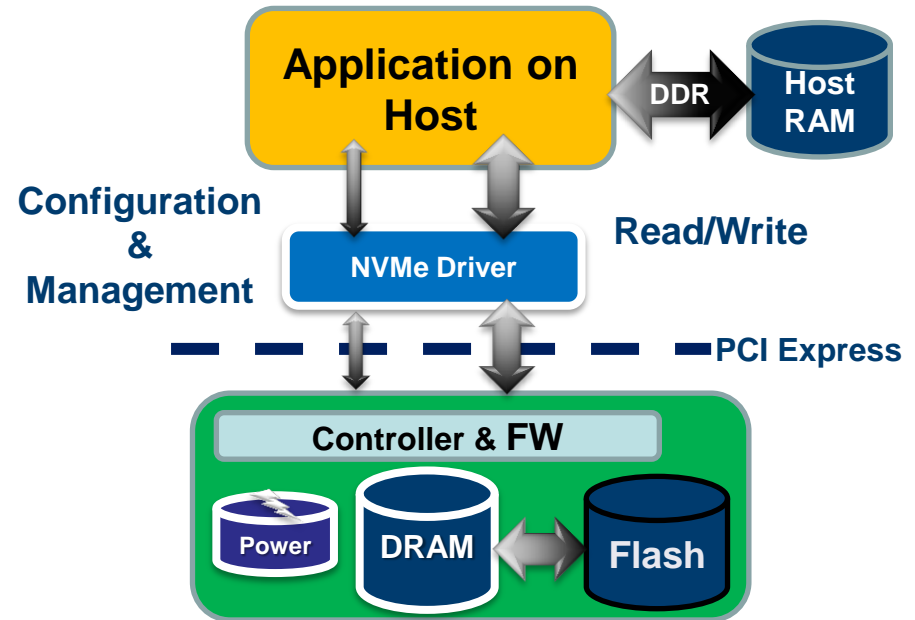- **Mission Critical applications**
  - High performance all flash arrays
  - Scale-Out Storage Systems
  - Database Systems
  - Distributed File System
  - Server-Side Caching

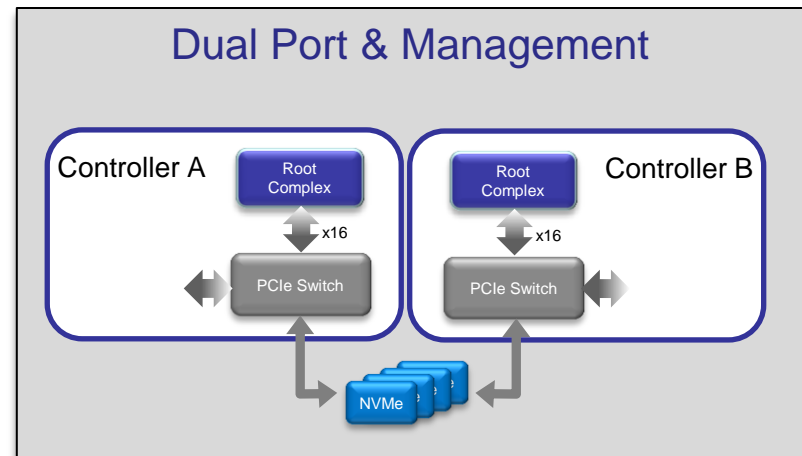- **DRAM endurance with flash persistency**

- **IO Storage Semantics**
  - Block level resolution

- **Management functions**

Application on Host ⟷ **DDR** ⟷ **Host RAM**

Configuration & Management | **Read/Write**

NVMe Driver

----- PCI Express

Controller & FW

Power | **DRAM** ⟷ **Flash**

Commercially Available Controllers

- Delivering performance
  - Up to 850K IOPs provided by single device
- Flexible programmable platform
- "Enterprise Class" features
  - Dual Port functionality
    - High Availability
  - Data Protection
  - Out-of-Band Management
    - Common feature set
    - Health Monitoring, Power Management, Firmware Update, Configuration
- Lowest overall latencies
  - Provides consistently low latencies

PMC
Flashtec™
NVMe Controller

Dual Port & Management

Controller A

Root Complex

x16

PCIe Switch

Controller B

Root Complex

x16

PCIe Switch

NVMe

Maximizing Flash Value

- **Recently announced SSDs**
  - Samsung 1715 series
  - Intel DC P3700/3600/3500 series

- **Reduces Architecture complexities**
  - CPU connected directly to storage
  - Lowers overall cost
  - Lowers overall latency
  - Direct scalability

- **Standardized drivers**

- **"NVMe Integrators List"**

NVMe Test and Emulation Equipment

- ## Agilent, JDSU, LeCroy, OakGate

  - Data analysis and decoding
  - Emulation
  - Traffic Analyzers
  - Traffic Generators
  - PCIe 3.0 support
  - 8639 Adapters
  - M.2 Interposers

http://www.nvmexpress.org/products/
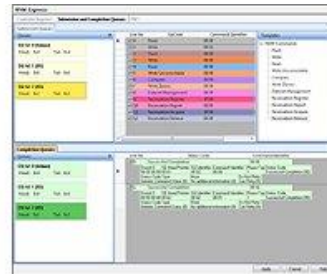
Addressing Today's Applications

Cloud & Big Data Computing
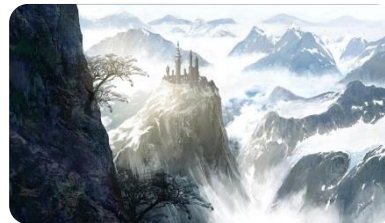
Financial Analysis

Datacenter Refresh

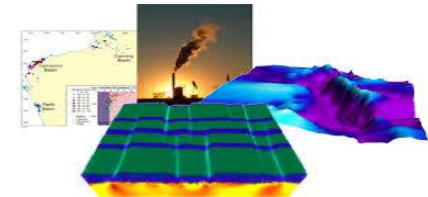Performance for Client, Enterprise and Data Center Applications
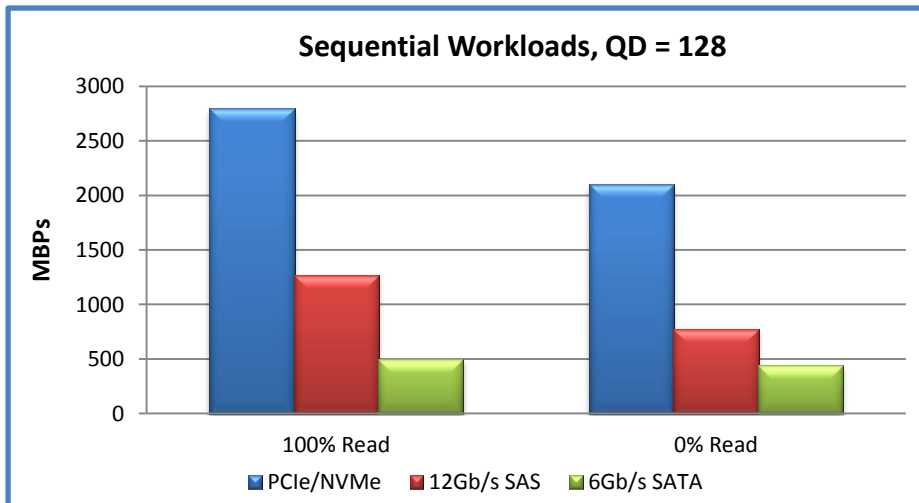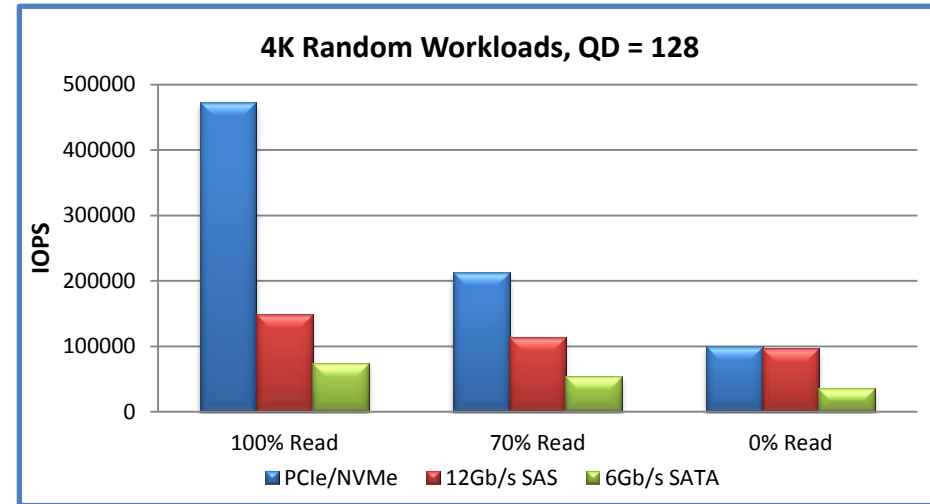
Digital Content

Web 2.0

Gaming

Energy Exploration

Industry Leading Performance

- **NVM Express delivers versus leading SAS/SATA products**
  - Random Workloads
    - > 2X performance of SAS 12Gbps
    - 4-6X performance of SATA 6Gbps

4K Random Workloads, QD = 128

Chart (IOPS vs. 100% Read, 70% Read, 0% Read) with series PCIe/NVMe, 12Gb/s SAS, 6Gb/s SATA.

Sequential Workloads, QD = 128

Chart (MBPs vs. 100% Read, 0% Read) with series PCIe/NVMe, 12Gb/s SAS, 6Gb/s SATA.

- **For sequential workloads, realize close to 3 GB/s reads**
  - Sequential Workloads
    - 2X performance of SAS 12Gbps
    - > 4X performance of SATA 6Gbps

Unlocking PCIe & NVMe Performance

NVMe Solutions Summary

- Driving new levels of application performance

- Accelerating development with expanding ecosystem
  - Standards based building blocks

- Pioneering new storage tiers

- "Enterprise Class"
  - Features, Management, RAS

- More coming soon
  - Systems & Test
  - SSD's & Memory tiers

Thank You!