NVM Express®
Awakening a New Storage and Networking Titan

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## Acronyms and Definition Check Point

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tr>
<td>NVMe™</td>
<td>Non-Volatile Memory Express®</td>
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<tr>
<td>NVMe-oF™</td>
<td>Non-Volatile Memory Express® over Fabrics (Ethernet, InfiniBand, Fiber Channel)</td>
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<td>NVMe Bay</td>
<td>NVMe connected 2.5” device slot typical installed into servers &amp; arrays</td>
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<td>NVMe I/O Block</td>
<td>NVMe based I/O card (Ethernet, InfiniBand, Fiber Channel)</td>
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<td>NVMe Accelerator Block</td>
<td>NVMe based CPU, GPU or FPGA based card for analytics or clustering</td>
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<tr>
<td>SSD</td>
<td>Solid State Drive</td>
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<tr>
<td>M.2</td>
<td>A small form factor “mezzanine” SSD for laptops and cloud servers</td>
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<td>U.2</td>
<td>The new name for an SFF-8639 connector (primary NVMe Bay connector)</td>
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<td>RDMA</td>
<td>Remote Direct Memory Access (Typically RoCE or iWARP )</td>
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<td>RoCE</td>
<td>Remote Direct Memory Access over Converged Ethernet</td>
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<tr>
<td>iWARP</td>
<td>internet Wide Area RDMA Protocol</td>
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<tr>
<td>AFA</td>
<td>All Flash Array</td>
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<tr>
<td>Hyperscale</td>
<td>Non-enterprise servers or data center such as OCP, Cloud, Google etc.</td>
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<tr>
<td>PCIe®</td>
<td>Peripheral Component Interconnect Express</td>
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<tr>
<td>SAS</td>
<td>Serial Attached SCSI (Small Computer System Interface)</td>
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<td>SATA</td>
<td>Serial AT (Advanced Technology) Attachment</td>
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<tr>
<td>SCM</td>
<td>Storage Class Memory (3D Xpoint, HybridIMM, ReRAM, and STT-MRAM)</td>
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<td>SDS</td>
<td>Software Defined Storage</td>
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NVMe – The Awakening a New Storage and Networking Titan
NVMe – Moving Data & CPUs Closer Together

Enterprises have a Role
Cost to Scale
Time to Deployment
Balance Business & Regulatory

Gen “C”loud is now Running IT
More Business Driven (AWS)
Attacking Latency (Google, Azure)
MSFT Sells More Office via Cloud

IoT drives “NanoData”
Driver of 5G, WIFI
Edge Networking
Fan-In Data and Networking
Market Drivers of the NVMe Market

1. NVMe is driven by the move to Flash & SCM
2. Intel is making NVMe pervasive and cost effective
3. Latency is the “value commodity” for applications
4. Faster apps need storage aligned with the CPU
5. Legacy connectivity always wins in the market

Over 80 Companies Are Delivering NVMe Enabled Solutions
NVMe - Ecosystem

- Over 80 NVMe Players
  - Servers
  - Storage server
  - Storage arrays
  - ASICs & controllers
  - SSD (U.2 and M.2)
  - NVMe-oF adapters
  - GPU & I/O adapters
  - Test equipment
  - NVMe software
NVMe Application Drivers

**Enterprise**
- DataBase & OTLP
  - Oracle, NoSQL, Mem SQL
- IMDB & Analytics
  - HANA and Hekaton
- Scale Out SD Storage & Fibre Channel Lives

**Cloud/xSP**
- Big Data & Advertising
- Content Distribution & Media Services
- Deep Learning & AI Systems

**Vertical**
- High Performance Computing
- Telco NFV
- IoT Fog Computing
NVMe – Intra-Chassis

NVMe Enabled Server or Storage Server

- NVMe Bay
- PCIe Bus
- PCIe Slot
- PCIe Bridge
- CPU/GPU
- Ethernet
- NVMe-oF
- SSD
- Accelerator
- PCIe M.2
- PCIe M.2
- SSD M.2

NVMe Enabled Server or Storage Server
# Top Predictions for the NVMe Market

<table>
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<th>NVMe Market Size</th>
<th>The NVMe market will be over $57 Billion by 2020 (servers, software defined storage servers, external arrays, connectivity and I/O)</th>
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<tbody>
<tr>
<td>NMVe SSD U.2 &amp; M.2 in Servers</td>
<td>Over 50% of servers will ship with NVMe drives by 2020 (The average server will have 5.5 NVMe devices)</td>
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<tr>
<td>SDS Storage Servers</td>
<td>Over 60% of storage servers drives are NVMe by 2020 (The average storage server will have 29 NVMe devices)</td>
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<tr>
<td>NVMe-oF Networking</td>
<td>NVMe-oF adapter shipments exceed 740K units by 2020 (Over 75% of these will be RDMA enabled Ethernet Adapters)</td>
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<td>AFA Moves to NVMe</td>
<td>Over 40% of AFAs arrays will NVMe based by 2020 (This will grow faster than the AFA transition vs HDD SAS arrays)</td>
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<td>NMVe SSD &amp; SATA Parity</td>
<td>NVMe SSD will reach price parity with SATA SSD by 2018 (The Intel push on NVMe integrated infrastructure and SCM will drive cost down)</td>
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Total NVMe Ecosystem $57B by 2020

G2M NVMe Ecosystem Market Report 2016

95% CAGR (2015 – 2020)

- NVMe Servers
- NVMeoF Adapters
- NVMe M.2 SSDs
- NVMe Storage Arrays
- NVMe Storage Appliances
- NVMe Enterprise Native SSDs
- Enterprise NVMe PCIe SSDs
- NVMe I/O Blocks
- NVMe Accelerator Blocks
The Evolution of NVMe in Servers

Intel Driving NVMe

- 3D NAND SSD
- NVMe integrated into systems
- 2017 will be a pivotal year for NVMe

Top OEMs & ODMs Driving NVMe

- IBM
- Lenovo
- HP
- QCT
- Supermicro

NVMe to be 50% of Drive Bays

- Closer to the CPU reduces latency
- Applications demanding the performance
- Of Server & appliance drive bays will be NVMe by 2020

5.5 Bays/Server Chassis

- By 2020, servers and storage servers will have 5.5 drive bays per chassis
- Capacity growth will keep this number flat through 2020
NVMe Based Software Defined Storage

- 60% of Software Defined Storage servers will have NVMe bays by 2020
- RDMA support for OpenStack and other SDS platforms will push SDS server growth
- OS and Hypervisor vendors are leading the charge to native SDS solutions
- Hyper-Convergence and NVMe-oF will challenge the performance leadership of external arrays
The Evolution of NVMe Storage Arrays

40% of All-Flash Arrays will ship NVMe by 2020

30% of NVMe Array Vendors will deploy custom flash modules

M.2 Form Factor SSDs will also be used in NVMe based arrays

NVMe Flash Arrays will set the new standard for high performance and low latency

NVMe Arrays will leverage SDS to provide file system capacities

NVMe Arrays may or may not use NVMe-oF adapters if they export files systems via RNICs
NVMe – Accelerating SSD Apps & Adoption

30M NVMe SSD Devices will be shipped in 2020

- 25M NVMe U.2 based NVMe drives will ship in 2020 enterprise & HCI
- 5M NVMe M.2 based drives will ship in 2020 driven by cloud & embedded
- NVMe will be the same prices and SATA SSD by the end of 2017
- New SCM and Flash options promise to lower price and increase speeds
NVMe-oF – Ethernet, Fibre Channel & InfiniBand

Ethernet NVMe-oF
- Ethernet with RDMA will be over 70% of shipments
- Scale-out SDS will use NVMe to challenge arrays
- Mellanox is leading right now with RDMA/RoCE
- Broadcom, Chelsio have announced products

Fibre Channel NVMe-oF
- Life extension for Fibre Channel & legacy Storage
- Broadcom, Brocade and Cavium look to 2017 GA
- Target array changes will be 2018/19 time frame

InfiniBand NVMe-oF
- Mellanox has not announced a product
- Given their storage cluster inter-connect business this could be interesting
- Wait and see right now
NVMe – Life Finds A Way

- A New World of Options
  - Ethernet networking
  - Storage I/O port
  - NFV & SDx
  - Fan-In ports
  - Edge analytics (IoT)
  - Network monitoring
  - Security
  - GPU clusters
  - Console management
  - Embedded applications
  - Military

Don’t Bet Against Innovation

- Never underestimate creativity
- NVMe Bays moving to x8
- Aggregate Multiple NVMe Bays
- Legacy Lives On…
Final Thoughts

- NVMe adoption in servers, storage appliances, and storage devices will be rapid.
  - It is driven by the economics of the consumer and hyperscale markets; the enterprise will rapidly follow.
  - NVMe adoption in AFAs will also be rapid but will lag storage appliances, which will drive AFA adoption.

- NVMe will become the dominant interface for flash storage devices well before 2020.
  - Simpler and higher performance than SAS or SATA
  - Again, driven by the consumer and hyperscale markets.

- NVMe-oF will be dominated by Ethernet-based adapters.
  - Fibre Channel will pick up NVMe as a way to stay relevant (at least for a little while more).
  - InfiniBand NVMe-oF will be limited to the upper end of the HPC market.

- New devices will emerge that will plug into NVMe 2.5” drive bays (“NVMe bays”)
  - I/O “blocks” where front-panel, hot swappable I/O is critical.
  - Accelerator “blocks” to provide functions such as classification, filtering, and encryption.
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