What’s going on with NVMe?
An examination of new technology adoption

Mike Scriber
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What’s going on with NVMe?

- Our Industry Pace
- NVMe Growth
- More is Better
- Where is EDSFF going?
- What is QLC?
- Why NVMeoF?
- GPU Direct
We are driving fast and hard
Our customers are on their own pace
Is technology just science fiction?
Hype Cycle for Storage Technologies 2019

Source: https://www.gartner.com/doc/reprints?id=1-1YH750DY&ct=200225&st=sb
Will Flash Penetrate All Enterprise Storage?

- **IDC** reports by 2019, AFAs were generating almost **80%** of primary external storage revenues.

- Flash also brings benefits to the Secondary Storage
  - **Performance**
    - Higher throughput and bandwidth, the ability to move large data sets quickly
  - **Capacity**
    - Increased infrastructure density, reduce the floor space, energy and cooling capacity requirement and improve the overall TCO.
  - **Reliability**
    - No moving parts.

Enterprise SSD Form Factor and Unit Trend

https://pcisig.com/sites/default/files/files/PCI-SIG_Webinar_EDSFF_FINAL.pdf
NVMe Design Principle

- Optimized protocol for NAND flash.
- NVMe bypasses unneeded layers.
- Direct connection to CPU’s PCIe lanes.
- Dramatically reducing latency and increasing bandwidth.
- Scales with number of PCIe lanes.
- No HBA required.

Source: https://www.virtual.com/blog/i-o-i-o-its-nvme-i-go/
More is Better

New CPUs are helping NVME
- More PCIe Lanes
- PCIe Gen 4 and above
X11 1U32 NVMe Optimized Storage Family
Petascale NVMe Solution with Unprecedented Density and Performance

SSG-1029P-NES32R
32 x EDSFF Short (E1.S) NVMe SSD

SSG-1029P-NEL32
32 x EDSFF Long (E1.L) NVMe SSD

SYS-1029P-N32R
32 x U.2 NVMe SSD

SSG-136R-NE32JBF & SSG-136R-N32JBF
32 x E1.L & 32 x U.2 NVMe SSD JBOF

Super Storage
1U

Super JBOF
1U
1U NVMe Petascale Advantages

**Economic**
- More capacity and faster, less power and space
- Lower TCO with the best operation efficiency (Thermal and Performance per Watt)

**Architecture**
- Highest performance and lowest latency
- NVMe Over Fabric and Disaggregated/Hyperconverged building block

**Operation**
- Hot-swappable 32 front load NVMe SSD for easy access and service
- Optimized form-factor for heat dissipation and system thermal efficiency
Hot-Swap JBOF Design

- 8 Hot-Swap Fan Modules
- 32 Hot-Swap Drive Trays
- 2 Hot-Swap Redundant Power Supplies

Better Faster Greener™ © 2020 Supermicro
Application Scenarios

• High capacity storage requirements
  • High Throughput Ingest
  • High Density Hot Storage
  • HPC /Data Analytics
  • Media/Video Streaming
  • Content Delivery Network (CDN)
• Big Data Top of Rack Storage
NVMe Form Factor Comparison

- **U.2**
  - (7.5mm/15.0mm)
  - Dimensions: 100.45mm x 69.85mm

- **M.2**
  - (without carrier)
  - Dimensions: 110.0mm x 22.0mm

- **EDSFF**
  - **E1.S**
    - Short (without carrier)
    - Dimensions: 111.49mm x 31.5mm
  - **NF1**
    - Long (without carrier)
    - Dimensions: 110.0mm x 30.5mm

- **EDSFF**
  - **E1.L**
    - Long (includes carrier)
    - Dimensions: 318.75mm x 36.4mm

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What is EDSFF*?

1. A group of 15 companies working together\(^1\)
2. Industry standard connector and form factor optimized for NVMe* 
3. Built for increased operational efficiency and dense storage

Intel® SSDs with EDSFF* “ruler”

- E1.S
- E1.L 9.5mm
- E1.L 18mm

\(^1\) List of EDSFF members provided at https://edsffspec.org

*Other names and brands may be claimed as the property of others.
ALL EDSFF* SSDs support the same:

1. **Connector**
   - Drives high volumes

2. **Pinout**
   - Allows interoperability, simplifies backplane design

3. **Base Features**
   - But differentiated by segment and use case

**PCIe** 4.0 and 5.0 ready

*Other names and brands may be claimed as the property of others.*

EDSFF vs. 2.5” Storage Chassis Implementation

2.5” FORM FACTOR

- Backplane requires cut outs to optimize thermals
- Cables add cost and complicate installation, thermals
- LED controller adds failure point

- Drive cages add cost, failure points

RULER FORM FACTOR

- Eliminate the backplane
- Simplified thermal implementation
- No add in cards required
- No cables to SSDs
- Geographic drive mapping for simplified drive management

Less complicated chassis
Reduced component cost per SSD
Simple hot swap with high density capabilities
High Efficiency by Design

• Better Air-flow = Better Power Efficiency
  • Front Loading bays with increased Air-flow
  • High Performance - Up to 10 million IOPS in 1U
  • Hot Plug and Power Loss Protection
  • Capacity : 144 ~ 576TB
Advantage. Thermal efficiency.

Thermal efficiency
Up to 55% less airflow\(^4\) vs U.2 15mm
# EDSFF Long (E1.L) Form Factors

<table>
<thead>
<tr>
<th>Type</th>
<th>Width</th>
<th>Length</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1.L 9.5mm</td>
<td>up to 25W - 38.4mm</td>
<td>318.75mm</td>
<td>9.5mm</td>
</tr>
<tr>
<td>E1.L 18mm</td>
<td>up to 40W - 38.4mm</td>
<td>318.75mm</td>
<td>18mm</td>
</tr>
</tbody>
</table>

Illustrations left to right: E1.L 9.5mm (courtesy of Intel); E1.L 18mm (courtesy of Intel)
## EDSFF Short (E1.S) Form Factors

<table>
<thead>
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<th>Type</th>
<th>Width</th>
<th>Length</th>
<th>Thickness</th>
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</thead>
<tbody>
<tr>
<td>E1.S 5.9mm</td>
<td>31.5mm</td>
<td>111.49mm</td>
<td>5.9mm</td>
</tr>
<tr>
<td>E1.S 8mm heat spreader</td>
<td>31.5mm</td>
<td>111.49mm</td>
<td>8.01mm</td>
</tr>
<tr>
<td>E1.S Symmetric Enclosure</td>
<td>33.75mm</td>
<td>118.75mm</td>
<td>9.5mm</td>
</tr>
<tr>
<td>E1.S Asymmetric Enclosure</td>
<td>33.75mm</td>
<td>118.75mm</td>
<td>15mm</td>
</tr>
<tr>
<td>E1.S Asymmetric Enclosure</td>
<td>33.75mm</td>
<td>118.75mm</td>
<td>25mm</td>
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</table>
## EDSFF 3 (E3) Form Factors

![Illustrations left to right: various E.3 configurations (courtesy of Intel)](image)

<table>
<thead>
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<th>Type</th>
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</thead>
<tbody>
<tr>
<td>E3.S 7.5mm</td>
<td>76mm</td>
<td>104.9mm</td>
<td>7.5mm thickness</td>
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<tr>
<td>E3.S 16.8mm</td>
<td>76mm</td>
<td>104.9mm</td>
<td>16.8mm</td>
</tr>
<tr>
<td>E3.L 7.5mm</td>
<td>76mm</td>
<td>142.2mm</td>
<td>7.5mm</td>
</tr>
<tr>
<td>E3.L 18mm</td>
<td>76mm</td>
<td>142.2mm</td>
<td>16.8mm</td>
</tr>
</tbody>
</table>
QLC vs TLC

- QLC has 4-bits per cell, while TLC has 3-bits per cell.
  - 33% capacity improvement
- QLC costs less than TLC
  - Closing the price gap between SSDs and HDDs
- QLC EDSFF using 16K block writes
- QLC has slower write performance, but same read performance.
- QLC EDSFF endurance is <0.5 DWPD
  - 8TB drive * 1 DWPD = 8TB per day
  - 16TB drive * .5 DWPD = 8TB per day

QLC is best for read intensive applications
Why NVMe-oF?

SSDs move the Bottleneck from the Disk to the Network
How Does NVMe-oF Maintain NVMe Like Performance?

- By extending NVMe efficiency over a fabric
  - NVMe commands and data structures are transferred end to end
- Bypassing legacy stacks for performance
- First products all used RDMA
- Performance is impressive
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**What and Why is NVMe over Fabrics**

<table>
<thead>
<tr>
<th>Number of SSDs to Saturated Network BW</th>
<th>SATA HDD</th>
<th>SATA SSD</th>
<th>SAS SSD</th>
<th>NVME SSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>10GbE</td>
<td>24</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>40GbE</td>
<td>100</td>
<td>9</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>100GbE</td>
<td>250</td>
<td>24</td>
<td>10</td>
<td>4</td>
</tr>
</tbody>
</table>

**Latency (us)**

- iSCSI SAS: ~200us
- NVMe/TCP: ~100us
- NVMe-of/RDMA: ~80us

**File System/Application**

- Block Device: NVMe Transport Layer
  - NVMe Fabric Initiator
  - NVMe Fabric Target
  - Fibre Channel
  - RDMA
  - Ethernet/Infiniband

**Protocol Overhead**

- RoCE

What is NVMe over Fabrics (NVMe-oF)

- A protocol interface to NVMe that enable operation over other interconnects (e.g., Ethernet, InfiniBand, Fibre Channel).
- Shares the same base architecture and NVMe Host Software as PCIe.
- Enables NVMe Scale-Out and low latency (<10µS latency) operations on Data Center Fabrics.
- Avoids protocol translation overhead (avoid SCSI)

NVMe-oF Applications - Composable Infrastructure

- Also called Compute Storage Disaggregation and Rack Scale
- NVMe over Fabrics enables Composable Infrastructure
- Low latency
- High bandwidth
- Nearly local disk performance

- 8M IOPs, 512B block size
- 5M IOPs, 4K block size
- ~5 usec latency (not including SSD)

- Nearly local disk performance
NVMeoF JBOF (Rear View)

- Redundant 1000W Titanium Level Power Supplies
- Two PCIe FH x16 for BlueField 1500
- UID Button
- 2 IPMI LAN Ports
The Value of Shared Storage and The ‘Need for Speed’

- The cost of data-at-rest is no longer the right metric for storage TCO
  - The value of data is based on how fast it can be accessed and processed
- NVMe over Fabrics increases the velocity of data
  - Faster storage access enables cost reduction through consolidation
  - Faster storage access delivers more value from data
- SSDs are going to become much faster
  - 3D Xpoint Memory, 3D NAND, etc.
  - PMEM, Storage Class Memory, etc

Source: https://www.eetimes.com/nvme-tcp-improves-data-storage/
GPUDirect Storage

- Avoid copying through a CPU bounce buffer
- Performance
  - Raw IO bw difference varies by platform, e.g. 2-4X
  - Savings in memory management and utilization can be a force multiplier on top of the
  - Varies by platform
- Broad ecosystem interest, active enabling
- Enabling with broader Linux community
- Coming to a CUDA near you
GPUDirect Storage and Cluster

Diagram showing the flow of data from system memory through CPUs, NICs, and storage devices, with high-speed connections labeled at 50 GB/s and 100 GB/s.
GPUDirect with RDMA

Without GPUDirect Storage

With GPUDirect Storage
NVMe is on the Move with Innovation

- NVMe is growing and changing
- Processors are enabling better NVMe systems
- EDSFF will take over, if we can settle down the spec
- NVMeoF enables low latency transfer of data directly into the drives.
- GPU direct allows access to NVMe drives without the CPU.
- Customers need to know that this is not science fiction.
- Supermicro has products for everything that I have discussed.
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