NVNe™ State of the Union

Peter Onufryk
NVM Express, Inc.
120+ Companies Defining NVMe Together

Board of Directors
13 elected companies, stewards of the technology & driving processes
Chair: Amber Huffman

Technical Workgroup
NVMe Base and NVMe Over Fabrics
Chair: Peter Onufryk

Management Intf. Workgroup
NVMe Management
Co-Chairs: Austin Bolen and John Goldman

Marketing Workgroup
NVMexpress.org, webcasts, tradeshows, social media, and press
Co-Chairs: Jonmichael Hands and Cameron Brett

Interop (ICC) Workgroup
Interop & Conformance Testing in collaboration with UNH-IOL
Chair: Ryan Holmqvist
Ten Years of NVMe

Enterprise NVMHCI Technical Work Begins

NVMe 1.0 Released

Name changed to NVM Express (NVMe)

NVMe Promoter Structure Created

NVMe Incorporated

NVMe Management Interface Workgroup Created

NVMe Over Fabrics Work Begins

Interoperability and Compliance Workgroup Created

NVMe-oF 1.0 Released

NVMe/RDMA & NVMe/FC

NVMe-MI 1.0 Released

NVMe/TCP TP Ratified
Strong Growth Across Segments

* Projections provided by Forward Insights Q2’19
With Millions of Units Shipping

<table>
<thead>
<tr>
<th>K Units</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019*</th>
<th>2020*</th>
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<td>82,613</td>
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* Projections provided by Forward Insights Q2’19
NVMe is The New Language of Storage

<table>
<thead>
<tr>
<th>NVMe Type</th>
<th>Companies Shipping Models</th>
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<tbody>
<tr>
<td>NVMe SSDs</td>
<td>23 Companies Shipping 96 Models</td>
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<tr>
<td>NVMe Servers</td>
<td>13 Companies Shipping 93 Models</td>
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<td>NVMe AFAs</td>
<td>11 Companies Shipping 21 Models</td>
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<td>NVMe Appliances</td>
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<td>NVMe-oF HBAs/NICs/RNICs</td>
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<td>NVMe-oF Accelerated Adapters</td>
<td>6 Companies Shipping</td>
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* Data provided by G2M Research
## 2019 NVMe Deliverables

<table>
<thead>
<tr>
<th>NVMe Base Specification</th>
<th>NVMe Over Fabrics Specification</th>
<th>NVMe Management Interface Specification</th>
<th>NVMe Plugfest</th>
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<tr>
<td><strong>NVMe 1.4</strong> 6/10/2019</td>
<td><strong>NVMe-oF 1.1</strong> 45-day Review</td>
<td><strong>NVMe-MI 1.1</strong> 4/29/2019</td>
<td>Plugfest #11 6/24/2019</td>
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<td><strong>NVMe 1.3</strong> 5/1/2017</td>
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<td><strong>NVMe-MI 1.0</strong> 11/17/2015</td>
<td>Plugfest #10 11/12/2018</td>
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<td><strong>NVMe 1.2</strong> 11/3/2014</td>
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<td><strong>NVMe 1.0</strong> 5/14/2008</td>
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# NVMe Specification Roadmap

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## NVMe

- **NVMe 1.2.1 May’16**
  - Transport and protocol
  - RDMA binding
- **NVMe 1.3 May’17**
  - Sanitize
  - Streams
  - Virtualization

## NVMe-oF

- **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 April’19**
  - Enclosure Management
  - In-band Mechanism
  - Storage Device Extension
- **NVMe-MI 1.1 April’19**
  - Enclosure Management
  - In-band Mechanism
  - Storage Device Extension

## In 45-day Review

- **NVMe Base Spec**
  - Merged w/Fabrics
  - Namespace Types
  - Alternate Cmd Sets
- **NVMe Transport Spec(s)**
- **NVMe Cmd Set Spec(s)**

## Released NVMe specification

- Released NVMe specification

## Planned release

- Planned release
Three New Specifications for 2019

**NVM Sets** and IO Determinism enable better performance, isolation, and QoS for hyperscale data centers. **Persistent event log** provides robust drive history for issue triage and debug. **Multipathing** provides optimal path for a namespace in multi-controller topologies.

**NVMe 1.4**

**Enhanced Discovery** for hosts to discover new NVMe devices. **TCP Transport Binding** NVMe/TCP enables efficient end-to-end NVMe operations with standard IP network with excellent performance and latency characteristics.

**NVMe-OF 1.1**

**Enclosure Management** enhances NVMe-MI for storage arrays for slot control, LED, and fans. **In-band Mechanism** opens up the NVMe-MI command set to standard NVMe driver (VPD, FRU). **Storage Device Extension** extends NVMe-MI to carrier cards and multiple controller devices.
I/O Determinism – NVM Sets

- NVM Sets are QoS Isolated
  - Write to namespace A1 does not impact QoS associated with namespace B2

- NVM Subsystem may support one or more NVM Sets

- One or more Namespaces may be allocated to an NVM Set
I/O Determinism – Predictable Latency Mode

- Deterministic Window
- Non-Deterministic Window

SSD #1

SSD #2
NVMe in High End Storage Systems

- **Back End (BE)**: BE Director, BE Director, BE Director
- **Fabric Interconnect**: Fabric Interconnect
- **Front End (FE)**: FE Director, FE Director, FE Director
- **NVMe SSDs**: NVMe SSDs
- **NVMe over Fabrics**: NVMe over Fabrics

Slide credit: Dell EMC
Asymmetric Namespace Access (ANA)
NVMe-oF TCP Transport Binding

**NVMe Transports**

- **Memory**
  - Commands/Responses & Data use Shared Memory
  - Example: PCI Express

- **Message**
  - Commands/Responses use Capsules
  - Data may use Capsules or Messages
  - Examples: Fibre Channel, TCP

- **Message / Memory**
  - Commands/Responses use Capsules
  - Data may use Capsules or Shared Memory
  - Examples: RDMA (InfiniBand, RoCE, iWARP)
NVMe/TCP - Open Source Performance

Upstream Linux kernel NVMe™/TCP vs. NVMe/RDMA (added latency over direct attached PCIe® SSD)
NVMe JBOFs

Facebook Lightning PCIe NVMe JBOF
NVMe Enclosure Management

- Native PCIe Enclosure Management (NPEM)
  - Submitted to the PCI-SIG Protocol Workgroup (PWG) on behalf of the NVMe™ Management Interface (NVMe-MI™) Workgroup
  - Approved by PCI-SIG on August 10th, 2017
  - Transport specific basic enclosure management

- SCSI Enclosure Services (SES) Based Enclosure Management
  - Technical proposal developed in the NVMe-MI workgroup
  - While the NVMe and SCSI architectures differ, the elements of an enclosure and capabilities to manage them are the same
    - Example enclosure elements: power supplies, fans, display or indicators, locks, temperature sensors, current sensors, voltage sensors, and ports
  - Comprehensive enclosure management for NVMe that leverages (SES), a standard developed by T10 for management of enclosures using the SCSI architecture
NVMe Storage Device – One NVM Subsystem with one or more ports, optional FRU Information Device, and an optional SMBus/I2C interface
NVMe Storage Devices in NVMe-MI 1.1

M.2 Carrier Board from Amfeltec

ANA Carrier Board from Facebook
The Evolution of NVMe

Phase 1
- Unify PCIe SSDs around a common interface
- Get an in-box driver in all major operating systems

Phase 2
- Scale NVMe over arbitrary fabrics

Phase 3
- Standardize NVM enabled storage innovations
- Expand NVMe into new use cases (e.g., Automotive and Storage Arrays)
NVMe Continues to Drive Simplicity in A World of Complexity

NVMe Base Specification (PCIe + Fabrics)

NVMe Architecture

IO Determinism • Multipath • Sets & Endurance Groups • Namespace Types • Domains & Partitions
Security • Sanitize • Persistent Event Log • Telemetry • Power Management • and many others ….

Admin Command Set

Admin Command Set

NVMe Features

IO Determinism • Multipath • Sets & Endurance Groups • Namespace Types • Domains & Partitions
Security • Sanitize • Persistent Event Log • Telemetry • Power Management • and many others ….

NVMe/PCIe

NVMe/RDMA

NVMe/FC

NVMe/TCP

NVMe/New Technology
Evolution of the NVM Express Organization

Board of Directors
Chair Amber Huffman (Intel)

Marketing Workgroup
Co-Chairs: Cameron Brett & Jonmichael Hands (Toshiba & Intel)

Technical Workgroup
Chair: Peter Onufryk (Intel)

Topic Task Groups
- Management Interface
  Co-Chairs: Austin Bolen & John Goldman (Dell & Toshiba)
- Interop (ICC)
  Chair: Ryan Holmquist (Microchip)
- Asymmetric Namespace Access (ANA)
  Chair: Fred Knight (NetApp)

Single Technical Proposal Task Groups
- Key Value
  Chair: Bill Martin (Samsung)
- Endurance Group Management
  Chair: Mark Carlson (Toshiba)
- Spec Refactoring
  Chair: Nick Adams (Intel)
- Zoned Namespaces
  Chair: Matias Bjorling (WD)
Increasing the Rate of Innovation Together with Greater Quality

- Formalized task groups with publicly published calendars and minutes
- Technical proposal phases with clear entries and exits
- Document repository with revision history
- Integrated draft specification always up to date
- Weekly electronic ballots
Summary

NVMe has unified client, cloud, and enterprise storage around a common command set and interface

The growth in NVMe adoption continues to accelerate

The NVMe organization has put in place processes and initiatives to support the increased rate of innovation enabled by NVM and new use cases

NVMe remains true to its core principles of simplicity and efficiency as it enters its second decade