Testing NVMe® Today and Tomorrow

Sponsored by NVM Express organization, the owner of NVMe specifications
Agenda

The UNH-IOL and the Beginning of IOL and ICC NVMe® Testing

Test Tool Information

Testing NVMe Technology

The Refactoring Effort

NVMe 2.0 Specifications and Beyond

Q&A
What the UNH-IOL Does

Tests a wide variety of technologies, student driven, staff managed

Neutral 3rd-party testing facility

Host Plugfests and Testing Events
Origin of NVMe® Specification and Importance of Testing

• Started with PCIe® as only transport
  • Admin and NVM I/O Command Sets
  • Testing for the last decade

• Conformance and Interoperability Testing
  • Why?
    • Making sure the product “just works!”
NVMe Technology Is Everywhere:

- Solid State Disks
- Disaggregated Storage Architectures
- Cell Phones
- Servers
- Mobile Computing
- Storage Arrays
- Data Centers
Test Plans Based on the Specifications

• Test published by the UNH-IOL, written in conjunction with the NVMe® Interop and Compliance Work Group

• Originally, 2-3 test plans were required for listing on Integrator’s List
  • UNH-IOL NVMe Conformance (NVMe-oF Conformance added later)
  • UNH-IOL NVMe Interoperability
  • UNH-IOL NVMe-MI™ Conformance (if supported)
Test Plan Development Process

1. Updates to test plans happen twice a year in order to keep pace with updates to the NVMe® specifications being developed at nvmexpress.org.

2. All test plan updates are created by NVMe Interop and Compliance Committee.

3. All updates are approved and voted on by the NVMe Technical Work Group and the NVMe Board of Directors.

4. All new tests added are made FYI, since in many cases there are no existing product in the market. This gives time for the test plan, DUT, and test scripts to be vetted.
NVMe Test Plans

The test plans on this page may be downloaded and used for internal purposes only. The test plans may not be commercialized in any way without express permission of the UNH-IOL.

The NVMe testing service currently offers the following test plans. These documents are constantly being updated to improve readability and to reflect the current specifications. Please contact us if you would like more information or have questions about the NVMe testing service.

When testing based on the following test plans is performed, all reports generated will be digitally signed using an Adobe digital certificate. Upon receipt of the report, the recipient can verify its authenticity using our document validation instructions.

### IOL

<table>
<thead>
<tr>
<th>Conformance</th>
</tr>
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<tbody>
<tr>
<td><img src="image" alt="Unh-Iol Nvme Conformance V16.0 (Pcie Based Nvme Ssd And Nvme-Of Nvm Subsystems)" /></td>
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https://www.iol.unh.edu/testing/storage/nvme/test-plans
## The NVMe® Integrator’s List

The NVMe® Integrator’s List is a website maintained by NVMe.org, an organization that promotes the adoption of the NVMe® protocol. It serves as a directory of NVMe® devices and systems that support the protocol. The list is updated regularly to reflect new integrations and changes insupported systems.

### NVMe® Integrator’s List

The NVMe® Integrator’s List is available at [https://www.iol.unh.edu/registry/nvme](https://www.iol.unh.edu/registry/nvme).

### NVMe® Integrators

The NVMe® Integrators are companies and organizations that have integrated the NVMe® protocol into their products or systems. The list includes both hardware and software integrations, and it is updated regularly to reflect new integrations.

### NVMe® Devices

The NVMe® Devices are the hardware devices that support the NVMe® protocol. The list includes both storage devices (such as SSDs and HHDs) and networking devices (such as switches and routers) that support the protocol.

The NVMe® Integrator’s List is a valuable resource for anyone looking to integrate the NVMe® protocol into their systems. It provides a comprehensive list of NVMe® integrators and devices, making it easy to find the right solution for your needs.

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Disclaimer: The information provided in the NVMe® Integrator’s List is intended for informational purposes only and should not be considered as endorsement or recommendation. Always consult with your provider before implementing any new technology.
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- Q&A
The Test Tools

- Conformance testing done with IOL INTERACT PC Edition and LeCroy Edition for automated testing
The Test Tools

- Interoperability testing completed with a variety of hosts, traffic generators, and hot plug testing capabilities from Quarch tools

<table>
<thead>
<tr>
<th>Make</th>
<th>Model</th>
<th>BIOS Version</th>
<th>Operating System</th>
<th>Driver Version</th>
<th>CPU Model</th>
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<tbody>
<tr>
<td>ASRock</td>
<td>ASRock Z270 Extreme4</td>
<td>P2.3</td>
<td>Ubuntu Linux</td>
<td>Intel®-NVMe Driver</td>
<td>Intel®-I5-6600 @ 3.30 GHz</td>
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<td>ASUSTeK Computer</td>
<td>ASUS ROG STRIX B350-F</td>
<td>0809</td>
<td>Windows 10</td>
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<td>AMD Ryzen 3 3300X @ 3.0 GHz</td>
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<td>ASUSTeK Computer</td>
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<td>Dell EMC</td>
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<td>Dell, Inc.</td>
<td>Dell PowerEdge R720</td>
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<td>GIGABYTE</td>
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<td>F30e</td>
<td>Ubuntu Linux</td>
<td>AMD Ryzen 5000G</td>
<td>Intel®-Kasco 3800 @ 3.7 GHz</td>
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<td>GIGABYTE</td>
<td>Gigabyte H170 Gaming G3 H170 Gaming G3</td>
<td>F22e</td>
<td>Ubuntu Linux</td>
<td>Linux Kernel 4.4 NVMe Driver 1.0</td>
<td>Intel®-Kasco 3800 @ 3.7 GHz</td>
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<td>Intel Corporation</td>
<td>Intel Server #1 S260SWT (Wildcat Pass)</td>
<td>T.T</td>
<td>Windows 10, Build 102490</td>
<td>Intel®-NVMe Driver</td>
<td>Intel®-Kasco CPU E5-2670W v4 @ 3.00 GHz</td>
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<td>Intel Corporation</td>
<td>Intel Server #2 S260SWT (Wildcat Pass)</td>
<td>T.T</td>
<td>CentOS 7, Kernel 2.6.32</td>
<td>Linux Kernel 2.6.32 NVMe Driver</td>
<td>Intel®-Kasco CPU E5-2670W v4 @ 3.00 GHz</td>
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Vdbench Users Guide

Version: 5.04.07
May 2018
Author: Henk Vandenbergh

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NVMe® and NVMe-oF™ Plugfests
Early NVMe® Specifications Testing

- NVMe PCIe® SSD testing requires
  - Conformance
  - Interoperability
- NVMe-oF™ Target testing requires
  - Conformance
  - Interoperability
- NVMe-oF™ Initiator and Switch testing is only interoperability

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Conformance</th>
<th>Interoperability</th>
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<tbody>
<tr>
<td>NVMe Storage Device</td>
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<td>√</td>
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<tr>
<td>NVMe Host Platform</td>
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<tr>
<td>NVMe-oF™ Target</td>
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<td>√</td>
</tr>
<tr>
<td>NVMe-oF™ Initiator</td>
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</tr>
<tr>
<td>NVMe-oF™ Switch</td>
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Conformance Testing

<table>
<thead>
<tr>
<th>Testing cutting edge features, new to the industry</th>
<th>Failing results are not always a bad thing</th>
<th>Trends of Features being Implemented</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both test tool and feature application being tested</td>
<td>Issues at this stage can be fixed</td>
<td>Never a shortage of TPs, but which ones are being implemented</td>
</tr>
</tbody>
</table>
Interoperability Testing

Will the product work in various environments?

Recent Issues of Unique Identifiers

PCle vs Other Transports complexity
Agenda

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The Refactoring Effort

• Why the Refactor?

• “A simplified format, easing the development of NVMe technology and allowing for rapid innovation.”

• Create scalable speciation intrastate to allow further growth of NVMe® technology as it becomes more common in storage applications

• Test plan changes required
Changes in the Conformance Test Plans

- NVMe® Conformance
- NVMe-oF™ Conformance
- NVMe Base and I/O Command Set Conformance
- NVMe over PCIe Transport Conformance
- NVMe over RDMA Transport Conformance
- NVMe over TCP Transport Conformance
- Admin and ZNS
- Admin and NVM
New Command Set Specifications

Command Sets Defined
- Zoned Namespace Command Set
- Key Value Command Set
- NVM Command Set

Upcoming Command Sets for Test
- Computational Programs

Transports Defined
- PCIe
- TCP
- RDMA/iWARP
NVMe® 2.0 Specification New Features: Currently Testing in Test Plan 17

- Group 2.14 in NVM
- Group 3.2 in ZNS

New Identify CNS values
- 5h
- 6h
- 7h
- 18h
- 19h
- 1A
- 1B
- 1C

Command Group Control, Command and Feature Lockdown
NVMe® 2.0 Specification New Features: To Be Tested in Test Plan 18

<table>
<thead>
<tr>
<th>Feature</th>
<th>Tests Added</th>
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<tbody>
<tr>
<td>Endurance Group Management</td>
<td>TP4052c: 48 New Tests</td>
</tr>
<tr>
<td>New Log Page Index Offsets</td>
<td>TP4075a: 9 New Tests</td>
</tr>
<tr>
<td>Namespace Capability Reporting</td>
<td>TP4095: 7 New Tests</td>
</tr>
<tr>
<td>Host Specifying Telemetry Host-Initiated Data Area</td>
<td>TP4109: 3 New Tests</td>
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NVMe® Testing Now

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of Tests</th>
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<tbody>
<tr>
<td>NVM Conformance Test Plan</td>
<td>389</td>
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<tr>
<td>ZNS Conformance Test Plan</td>
<td>265</td>
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<tr>
<td>MI Test Plan</td>
<td>107</td>
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<tr>
<td>RDMA Transport Conformance Test Plan</td>
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<tr>
<td>TCP Transport Conformance Test Plan</td>
<td>43</td>
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<tr>
<td>Interoperability Suites (PCIe and oF)</td>
<td>16</td>
</tr>
<tr>
<td><strong>Total Tests</strong></td>
<td><strong>849</strong></td>
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Future Testing Items

NVMe® 2.0 specifications and beyond

Based on the NVM Express® Road Map

- Computational Programs
- Key Per IO
- Cross Namespace Copy
- NVMe-oF™ Discovery Automation
The Overarching Goal is Confidence in the NVMe® Product

- When all devices are conformant, the storage industry performs better
- All caught issues are communicated such that they can be resolved prior to market release
- The UNH-IOL and ICC work directly with the TWG to test the most important and widely adopted features
- Your customers can see standardized reports showing which features are supported and conformant to the specification
- Certify with confidence that the product conforms to the applicable NVMe® specifications
Questions?