UNH-IOL
NVMe Testing Service

Test Suite for NVMe Interoperability
Version 14.0
Target Specification: NVMe 1.4
Technical Document

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UNH-IOL NVMe Testing Service
21 Madbury Rd, Suite 100
Durham, NH 03824

Tel: +1 603-862-0090
Fax: +1 603-862-4181
Email: nvmelab@iol.unh.edu

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MODIFICATION RECORD

2012 May 7 (Version 0.1) Initial Release
David Woolf:

2012 June 21 (Version 0.2)
Raju Mishra:

2012 November 5 (Version 0.3)
David Woolf: Editorial Fixes

2013 April 30 (Version 0.4)
David Woolf: Preparation for plugfest, reorganization of interop tests to be more OS focused.

2013 May 21 (Version 1.0)
David Woolf: Clarification of test steps refined during May 2013 NVMe Plugfest.

2013 September 10 (Version 1.1)
David Woolf: Changes to test 1.3 to allow for use of stressing data patterns and varying transfer sizes. Addition of tests 1.4, 1.5, 1.6.

2013 December 16 (Version 1.1 DRAFT)
David Woolf: Modified Test 1.5 to clarify what OS media will be used, and that the OS install will occur using the UEFI NVMe driver. Modified Tests 1.1 and 1.2 to clarify procedure for identifying and formatting a drive in Windows and Linux operating systems. Updated Appendix A for latest version of vdbench. Added Appendix B. Added Appendix C.

2013 December 19 (Version 1.1 DRAFT)
David Woolf: Modified Appendix A

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David Woolf: Corrected link to vdbench parameter file in Appedix A. Modified the command to start vdbench to include the '-vr' modifier to cause all writes to be validated immediately.

2014 March 11 (Version 1.1)
David Woolf: Corrected link to vdbench parameter file in Appedix A to account for corner case discovered during February 2014 NVMe Plugfest.

2014 March 31 (Version 1.1)
David Woolf: Added notes to the Possible Problems section of Test 1.3, and Appendix A, to account for problems that may arise when testing devices that are less than 512 MB in storage capacity.

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David Woolf: Added information to Appendix C and Test 1.5.

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David Woolf: Added test 1.7

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David Woolf: Added Appendix D. Added note to all tests to refer to Appendix D if using a non-CEM form factor. Renamed document t o version 1.1b, to match latest NVMe specification and the IL policy to be used for the next plugfest.

2014 August 21 (Version 1.1b)
David Woolf: Edited Appendix A, and test 1.2 and 1.3 to clarify that an NVMe device should be unformatted when performing Test 1.3.

2014 August 25 (Version 1.1b)
David Woolf: Further clarifications to test 1.3 and 1.4 to clarify that an NVMe device should be unformatted when performing these tests.

2014 September 18 (Version 1.1b)
David Woolf: Clarifications to test 1.6 (hotplug) procedure and observable results.

2014 October 30 (Version 1.1b)
David Woolf: Clarifications to Appendix A and B on preparing drives for testing.

2014 December 9 (Version 1.1b)
David Woolf: Corrected URL for vdbench parameter file downloads

2015 April 7 (Version 1.2)
David Woolf: Added additional adapter types to Appendix D.

2015 May 7 (Version 1.2)
David Woolf: Updated links to VDBENCH Parameter files in Appendix A.

2015 August 31 (Version 1.2)
David Woolf: Clarified procedure in tests 1.3 and 1.5.

2015 September 28 (Version 1.2)
David Woolf: Clarified procedure in tests 1.6.

2015 November 5 (Version 1.2.1)
David Woolf: Test 1.5 now mandatory for hosts. References in *Introduction* and *References* sections now refer to NVMe 1.2 specification. Clarified step 6 in test procedure for test 1.3, to show that any partition information on the drive should survive the host restart.

2015 November 19 (Version 1.2.1)
Jeff Hensel: Updates to procedure for Test 1.5 reflect booting from an NVMe device using UEFI in a more modern motherboard than the previous procedure.

2015 December 11 (Version 1.2.1)
David Woolf: Updates to Test 1.5 to reflect that this test is not mandatory for NVMe IP Devices. Updated UNH-IOL address.

2016 January 19 (Version 1.2.1)
David Woolf: Updates to accommodate dual port testing in tests 1.1, 1.2, 1.6, 1.7.

2016 March 1 (Version 1.2.1)
Mike Bogochow: Fixed typos, clarified language, added links.

2016 May 19 (Version 6.0 r01)
David Woolf: Adopted new document numbering scheme. Removed test 1.4 'Multiple Devices on Bus'. Aligned procedures across all tests to use 2 devices at once and test them simultaneously in parallel.

2016 May 24 (Version 6.0 r02)
David Woolf: Added FYI tags to tests that are not mandatory. Added Appendix F with link to UNH-IOL Interop Test bed page, to help readers understand what hosts may be available for testing. Added Appendix G to outline NVMe Integrators List Requirements.

2016 June 7 (Version 6.0 r03)
David Woolf: Added test "Dual Port Device with Multiple Namespaces"

2016 June 13 (Version 6.0 r04)
David Woolf: Edited Test Procedure for test 1.7. Moved comments on Dual Port Device test setup from the Possible Problems section to the Test Setup section in tests 1.1, 1.2, 1.3, 1.4.

2016 June 16 (Version 6.0 r05)
David Woolf: Edited Test Procedure for Test 1.7 Procedure step 12a, to indicate that any values provided regarding sector size and namespace size are provided as examples only. These values can be adjusted according to device and driver support. Added complete version of Test 1.8.

2016 July 5 (Version 6.0 r06)
David Woolf: Edited Test Procedure for Test 1.2, and Appendix G, to allow, but not require, the use of multiple LBA formats which are supported by the DUT. Added FYI step to Test 1.4, to check that IO is functional after the hotplug event occurs.

2016 Jul y 5 (Version 6.0 r07)
David Woolf: Edited Test names to include Mandatory vs. FYI requirements. Updated Appendix G to be consistent with how Mandatory vs. FYI requirements are indicated in the Conformance Test Suite.

2016 August 30 (Version 6.0)
David Woolf: Final version published to UNH-IOL site ahead of October 2016 NVMe Plugfest #6.

2016 October 24 (Version 6.1 r01)
David Woolf: Clarified test procedure in Appendix A. Reordered some appendices.

2017 February 21 (Version 7.0 r01)
David Woolf: Clarified test procedure in Test 1.4 Hotplug.

2017 March 8 (Version 7.0 r02)
David Woolf: Clarified test procedure in Test 1.5 Boot, for hosts that are not intended to boot from of NVMe media.

2017 March 22 (Version 7.0)
David Woolf: Final version published to UNH-IOL site ahead of May 2017 NVMe Plugfest #7.

2017 August 28 (Version 8.0)
David Woolf:

- Clarified that test 1.4 is mandatory for U.2 devices.

- Added clarification to Possible Problems section of Test 1.3 to allow limited retesting in some circumstances.
- Removed Windows OFA driver from the list of drivers in Appendix F.

2017 December 7 (Version 9.0 draft)
David Woolf:

- Removed Appendix B about UEFI test requirements.
- Updated Appendix D on Interop Test Setups to include descriptions for testing NVMe Drives in both a common PCIe Server environment as well as an NVMe-oF Environment and a PCIe switch environment.
- Added requirements for testing NVMe Drives in an NVMe-oF environment in Appendix E (formerly Appendix F).

2018 January 23 (Version 9.0 Draft)
Colin Dorsey:

- Added Test 1.9.

2018 August 30 (Version 10.0 Release)
David Woolf:

- Release for 10.0.

2018 November 29 (Version 11.0 Release)
David Woolf:

1. New Test Case Test 1.5 Hot plug while I/O In Progress to include performing hotplug while the drive is performing IO. Expected Observable Results of the test will be that the system remains stable, and that the drive is recognized when reinserted into the system. This new test case would be FYI initially.
2. For Test 1.4 Hot Plug, increase the number of root complexes a drive must be tested with from 1 to 2 in the Integrators List requirements in Appendix E.
3. For Test 1.4 Hot Plug, clarify the amount and type of user action can be taken when a drive is reinserted to a system. The Possible Problems section will include information about specific expectations when using a MS Server system, that no user intervention is allowed during the test, such as a drive ‘rescan’ or ‘refresh’. A note that other operating systems and setups may have different requirements.
4. Remove Annex B and D on UEFI test tools.
5. Add EDSFF form factors as requiring hot plug testing.

2019 April 8, 2019 (Version 12.0 Release)
David Woolf:

1. Updated tests 1.4 and 1.5 to clarify expectations for multi-port devices.
2. Clarified procedure in Test 1.10.

2019 December 10, 2019 (Version 13.0 Release)
David Woolf:

1. Program Revision Update.

2021 July 21, 2019 (Version 14.0 Release)
David Woolf:

1. Updates to Appendix B, D, E.

Updates to tests 1.4 and 1.5 to accommodate E1.L and E1.S devices.

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David Woolf	UNH InterOperability Laboratory
Colin Dorsey	UNH InterOperability Laboratory

INTRODUCTION

The University of New Hampshire's InterOperability Laboratory (IOL) is an institution designed to improve the interoperability of standards-based products by providing a neutral environment where a product can be tested against other implementations of a common standard, both in terms of interoperability and conformance. This particular suite of tests has been developed to help implementers evaluate the NVMe functionality of their products. This test suite is aimed at validating products in support of the work being directed by the NVMe Promoters Group.

These tests are designed to determine if a product interoperates with other products designed to the NVM Express Revision 1.2 specification, hereafter referred to as the "NVMe Specification"). Successful completion of these tests provide a reasonable level of confidence that the Device Under Test (DUT) will function properly in many NVMe environments.

The tests contained in this document are organized in order to simplify the identification of information related to a test, and to facilitate in the actual testing process. Tests are separated into groups, primarily in order to reduce setup time in the lab environment, however the different groups typically also tend to focus on specific aspects of device functionality. A two-number, dot-notated naming system is used to catalog the tests. This format allows for the addition of future tests in the appropriate groups without requiring the renumbering of the subsequent tests.

The test definitions themselves are intended to provide a high-level description of the motivation, resources, procedures, and methodologies specific to each test. Formally, each test description contains the following sections:

Purpose

The purpose is a brief statement outlining what the test attempts to achieve. The test is written at the functional level.

References

This section specifies all reference material *external* to the test suite, including the specific references for the test in question, and any other references that might be helpful in understanding the test methodology and/or test results. External sources are always referenced by a bracketed number (e.g., [1]) when mentioned in the test description. Any other references in the test description that are not indicated in this manner refer to elements within the test suite document itself (e.g., "Appendix 5.A", or "Table 5.1.1-1")

Resource Requirements

The requirements section specifies the test hardware and/or software needed to perform the test. This is generally expressed in terms of minimum requirements, however in some cases specific equipment manufacturer/model information may be provided.

Last Modification

This specifies the date of the last modification to this test.

Discussion

The discussion covers the assumptions made in the design or implementation of the test, as well as known limitations. Other items specific to the test are covered here as well.

Test Setup

The setup section describes the initial configuration of the test environment. Small changes in the configuration should not be included here, and are generally covered in the test procedure section (next).

Procedure

The procedure section of the test description contains the systematic instructions for carrying out the test. It provides a cookbook approach to testing, and may be interspersed with observable results. These procedures should be the ideal test methodology, independent of specific tool limitations or restrictions.

Observable Results

This section lists the specific observable items that can be examined by the tester in order to verify that the DUT is operating properly. When multiple values for an observable are possible, this section provides a short discussion on how to interpret them. The determination of a pass or fail outcome for a particular test is generally based on the successful (or unsuccessful) detection of a specific observable.

Possible Problems

This section contains a description of known issues with the test procedure, which may affect test results in certain situations. It may also refer the reader to test suite appendices and/or other external sources that may provide more detail regarding these issues.

REFERENCES

The following documents are referenced in this text:

1. NVM Express Revision 1.3c Specification (May 24, 2018)
2.

Group 1: OS Based Interop Tests

Overview: This section describes a method for performing interoperability verification for NVMe products using features readily available in the most common operating systems.

Notes: The preliminary draft descriptions for the tests defined in this group are considered complete, and the tests are pending implementation (during which time additional revisions/modifications are likely to occur).

Test 1.1 – Storage Devices Identified (M)

Purpose: To verify that an NVMe Host can properly identify an attached NVMe Storage Device.

References:

[1] NVMe Specification

Resource Requirements:

NVMe Host Platform and Device.
If using a non-CEM form factor, see Appendix C

Last Modification: July 14, 2016

Discussion: NVMe Hosts should be able to identify all attached NVMe Devices and display these in the operating system.

Test Setup: All products are powered off. Two NVMe devices are physically attached to the NVMe Host Platform. If the NVMe devices are dual-port devices, the test should be performed using a port isolator to ensure that the Host communicates to Device 0 on Port 0 only, and that the Host communicates to Device 1 on Port 1 only.

Test Procedure:

1. Power on the NVMe Host and allow the OS to boot and all necessary drivers to be loaded.
    a. In Windows based systems the attached NVMe device should be visible under Control Panel > Administrative Tools > Computer Management > Disk Management.
    b. In Linux based systems the 'lspci' command can be used to list all attached PCI devices, followed by 'ls /dev/nvme*'.

Observable Results:

1. Verify that all NVMe devices are identified by the Host and can be displayed to the user through the operating system.

Possible Problems: Methods for performing this test may vary across different operating systems and drivers.

Test 1.2 – Format Storage Devices (M)

Purpose: To verify that an NVMe Host can properly format an attached NVMe Storage Device.

References:

[1] NVMe Specification

Resource Requirements:

NVMe Host Platform and Device.
If using a non-CEM form factor, see Appendix C

Last Modification: July 14, 2016

Discussion: NVMe Hosts should be able to format all attached NVMe Devices and display these in the operating system.

Test Setup: Two NVMe devices are physically attached to the NVMe Host Platform, have been identified by the Host Platform, and are visible to the user through the operating system. If the NVMe Device Under Test is a dual-port device, the test should be performed using a port isolator to ensure that the Host communicates to Device 0 on Port 0 only, and that the Host communicates to Device 1 on Port 1 only.

Test Procedure:

1. Use available operating system tools to format all attached NVMe Devices. See Appendix A for how to do this in Windows and Linux operating systems. If possible perform this test with all LBA formats supported by the DUT.
2. Delete the partition created when the NVMe Devices were formatted.

Observable Results:

1. Verify that each NVMe Device can be partitioned and formatted, and the partitions can be deleted.

Possible Problems: Methods for performing this test may vary across different operating systems and drivers. Be sure to delete the created partition when the test is complete. It is allowable to perform this test with multiple LBA formats supported by the DUT, however only 1 LBA format is required to meet the test requirements.

Test 1.3 – Write Read Compare (M)

Purpose: To verify that an NVMe Host can write and read to an attached NVMe Storage Device without error.

References:

[1] NVMe Specification

Resource Requirements:

NVMe Host Platform and Device.
If using a non-CEM form factor, see Appendix C

Last Modification: August 15, 2017

Discussion: NVMe Hosts should be able to write and read files to all attached NVMe Devices without error.

Test Setup: Two NVMe devices are physically attached to the NVMe Host Platform, have been identified by the Host Platform, and are visible to the user through the operating system. If the NVMe Device Under Test is a dual-port device, the test should be performed using a port isolator to ensure that the Host communicates to Device 0 on Port 0 only, and that the Host communicates to Device 1 on Port 1 only..

Test Procedure:

1. Remove or delete any formatting on the NVMe devices.
2. Use available tools to perform write/read/compare data operations containing a stressing data pattern to the attached NVMe Device under test. The data operations should be of varying transfer sizes. See Appendix A.
3. Shutdown the Host Platform. Power on the Host Platform.
4. Repeat steps 1, 2 and 3, 3 times. Ensure that any Partition Information on the NVMe DUT survives the shutdown.
5. Restart the Host Platform.
6. Repeat steps 1, 2 and 5, 3 times. Ensure that any Partition Information on the NVMe DUT survives the restart.

Observable Results:

1. Verify that for all cases:
   a. The write/read/compare operations complete without any data integrity errors being reported
   b. The NVMe DUT is visible to the Host Operating System after each shutdown/reboot cycle
   c. All Partition Information on the NVMe DUT survives each shutdown/reboot cycle.

Possible Problems: Methods for performing this test may vary across different operating systems and drivers. If the DUT has a storage capacity less than 512MB, it will be necessary to modify the threads parameter in the vdbench parameter file. Change the ‘threads=128’ to ‘threads=16’. See Appendix A for more detail on the use of vdbench.

Performing Test 1.3 as described above involves three ‘runs’ of IO to an NVMe DUT each separated by a reboot of the entire system, and three ‘runs’ of IO to an NVMe DUT each separated by a full shutdown of the entire system. In total, 6 ‘runs’ of IO are performed. If a at any point a failure occurs (data integrity error, NVMe DUT not visible from Host Operating System, or Partition Information is deleted), the test run can be performed again. Up to two such ‘reruns’ can be allowed out of the 6 ‘runs’, allowing for up to 8 total runs, with the NVMe DUT still meeting the passing test criteria. If more than 2 runs yield an error condition, the test is considered failed, and must be performed again from the beginning.

Test 1.4 – Hotplug NVMe Device No IO (M for NVMe Drives, FYI for NVMe Host Platfroms)

Purpose: To verify that an NVMe Host properly handles hotplugging of an NVMe Storage Device.

References:

[1] NVMe Specification

Resource Requirements:

NVMe Host Platform and Device supporting U.2 or EDSFF form factor.

Last Modification: April 8, 2019

Discussion: U.2 and EDSFF form factor NVMe Devices should be able to be hotplugged from/to an NVMe Host without error.

Test Setup: Two NVMe devices are physically attached to the NVMe Host Platform, have been identified by the Host Platform, and are visible to the user through the operating system. If the NVMe Device Under Test is a dual-port device, the test should be performed using a port isolator to ensure that the Host communicates to Device 0 on Port 0 only, and that the Host communicates to Device 1 on Port 1 only.

Test Procedure:

1. If the DUT does not have a U.2, E1.L, or E1.S interface, then this test is Not Applicable.
2. Power on the NVMe Host and allow the operating system (OS) to boot and all necessary drivers to be loaded.
3. Ensure that the OS has not loaded from the NVMe Device Under Test, but has loaded from another source.
4. Ensure that the NVMe Device can be accessed from the OS, and that IO can be performed.
5. Stop any IO to the DUT.
6. Physically remove the DUT from the NVMe Host. The DUT should remain physically disconnected from the Host for 5 or more seconds. Reinsert the DUT into the NVMe Host, as follows:
    a. 10 cycles of removal and reinsertion, with 25 ms removal/reinsertion time
    b. 10 cycles of removal and reinsertion, with 10 ms removal/reinsertion time
    c. 10 cycles of removal and reinsertion, with 100 ms removal/reinsertion time
    d. 10 cycles of removal and reinsertion, with 500 ms removal/reinsertion time

    Note that the prescribed removal/reinsertion time is that expected time that the plugging and unplugging action will take, not the time that the drive is not connected to the Host system.
7. Ensure that the NVMe Device can still be accessed from the OS, and that IO still can be performed.
8. If the DUT is a multi-port device, repeat the procedure described above for each port independently. The same observable results described below apply to each port.

Observable Results:

1. After each removal, verify that the removed device is no longer visible in the OS.
2. After each reinsertion, verify that the Host is able to access the NVMe device.
    a. If using a Microsoft Windows system, after reinsertion, the DUT is required to appear in the Disk Management utility without any additional user intervention, such as a user initiated ‘rescan’, or ‘refresh’.
    b. If using a Linux system, after reinsertion, a single ‘lspci’ or ‘nvme list’ command may be initiated by the user. After the command is performed, the DUT is required to be visible to the Host OS.
3. Ensure that after all steps, the Host still exhibits normal operation.
4. Ensure that after the hotplug event, IO operations are still functional. This observable result step can be considered FYI.

Possible Problems: Earlier versions of Linux Kernels have been observed to not enumerate NVMe devices properly after a hotplug event. If problems like this are observed, it is recommended to upgrade to the latest Linux Kernel.

Test 1.5 – Hotplug NVMe Device IO In Progress (FYI)

Purpose: To verify that an NVMe Host properly handles hotplugging of an NVMe Storage Device when IO is in progress.

References:

[1] NVMe Specification

Resource Requirements:

NVMe Host Platform and Device supporting U.2 or EDSFF form factor.

Last Modification: November 20, 2018

Discussion: U.2 and EDSFF form factor NVMe Devices should be able to be hotplugged from/to an NVMe Host without error.

Test Setup: Two NVMe devices are physically attached to the NVMe Host Platform, have been identified by the Host Platform, and are visible to the user through the operating system. If the NVMe Device Under Test is a dual-port device, the test should be performed using a port isolator to ensure that the Host communicates to Device 0 on Port 0 only, and that the Host communicates to Device 1 on Port 1 only.

Test Procedure:

1. If the DUT does not have a U.2, E1.L, or E1.S interface, then this test is Not Applicable.
2. Power on the NVMe Host and allow the operating system (OS) to boot and all necessary drivers to be loaded.
3. Ensure that the OS has not loaded from the NVMe Device Under Test, but has loaded from another source.
4. Ensure that the NVMe Device can be accessed from the OS, and that IO can be performed.
5. While IO is being performed, physically remove the DUT from the NVMe Host. The DUT should remain physically disconnected from the Host for 5 or more seconds. Reinsert the DUT into the NVMe Host, as follows, After each reinsertion, start IO to the drive again.:
    a. 10 cycles of removal and reinsertion, with 25 ms removal/reinsertion time
    b. 10 cycles of removal and reinsertion, with 10 ms removal/reinsertion time
    c. 10 cycles of removal and reinsertion, with 100 ms removal/reinsertion time
    d. 10 cycles of removal and reinsertion, with 500 ms removal/reinsertion time

    Note that the prescribed removal/reinsertion time is that expected time that the plugging and unplugging action will take, not the time that the drive is not connected to the Host system.
6. Ensure that the NVMe Device can still be accessed from the OS, and that IO can be started again successfully.
7. If the DUT is a multi-port device, repeat the procedure described above for each port independently. The same observable results described below apply to each port.

Observable Results:

1. After each removal, verify that the removed device is no longer visible in the OS.
2. After each reinsertion, verify that the Host is able to access the NVMe device and perform IO successfully.
    a. If using a Microsoft Windows system, after reinsertion, the DUT is required to appear in the Disk Management utility without any additional user intervention, such as a user initiated ‘rescan’, or ‘refresh’

   b. If using a Linux system, after reinsertion, a single 'lspci' or 'nvme list' command may be initiated by the user. After the command is performed, the DUT is required to be visible to the Host OS.
3. Ensure that after all steps, the Host still exhibits normal operation.

Possible Problems: Earlier versions of Linux Kernels have been observed to not enumerate NVMe devices properly after a hotplug event. If problems like this are observed, it is recommended to upgrade to the latest Linux Kernel.

Test 1.6 – Boot from NVMe Device (M)

Purpose: To verify that an NVMe Host can boot from an attached NVMe Storage Device.

References:

[1] NVMe Specification

Resource Requirements:

NVMe Host Platform and Device.
If using a non-CEM form factor, see C

Last Modification: December 7, 2017

Discussion: NVMe Hosts should be able to boot from an attached NVMe Device without error. This test is only applicable to a single port NVMe Device.

Test Setup: A single port NVMe Device is physically attached to the NVMe Host Platform. The Host platform will use the UEFI NVMe Driver to boot from the NVMe Device.

Test Procedure: The procedure below describes installing Windows on an NVMe host platform with UEFI support. The procedure will vary for different operating systems and host platforms.

1. Choose the method of Install:
   a. Windows bootable USB
   b. Windows bootable installation disk
2. Install NVMe device
3. Install selected installation media
4. On boot, launch the Boot Menu. This can be done by pressing the "F11" key on boot in many systems.
5. Select the option that begins with "UEFI: "; if using a disk press any key after to boot
6. Once the Windows installer launches press "Next"
7. Select "Install Now"
8. Check the "I Accept…." box below the licensing scroll box
9. Select "Next"
10. Select "Custom: Install Windows Only (advanced)"
11. Select the NVMe Device and select "Next"
12. Ensure the device finishes installation without error
13. Remove the installation media and ensure the device is able to boot properly

Observable Results:

1. Verify that the operating system booted as expected, the NVMe device was identified properly by the operating system for each power down or reboot cycle.

Possible Problems: Methods for performing this test may vary across different operating systems and drivers. Not all operating systems may have boot support for NVMe. Additionally different hardware platforms may behave differently, with slightly different steps necessary. Methods that vary from the procedure outlined here on different host platforms are acceptable.

This test may not be applicable or possible to perform for certain types of NVMe IP Devices, such as those implemented on an FPGA platform. Therefore, for an NVMe IP Device, this test is not considered a required test for the NVMe Integrator's List.

This test may not be applicable or possible to perform for certain types of products acting as NVMe Hosts, such as certain test tool products that may mimic the behavior of an NVMe Host, but are not intended to boot from NVMe media. Therefore, for a test tool or IP Device mimicking an NVMe Host, this test is not considered a required test for the NVMe Integrator's List.

Test 1.7 – Dual Port Device (FYI)

Purpose: To verify that an NVMe Host properly handles a NVMe Storage Device with Dual Ports.

References:

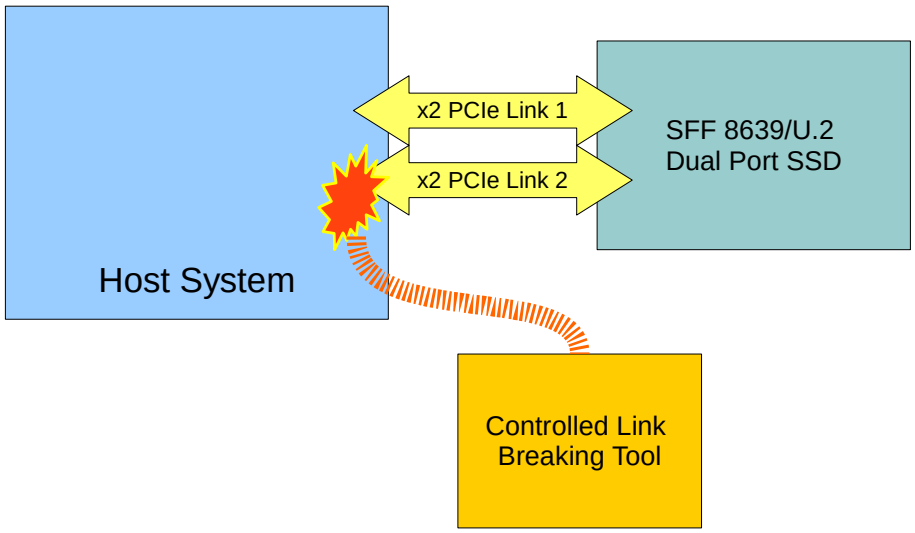
[1] NVMe Specification

Resource Requirements:

NVMe Host Platform and Device.

Last Modification: March 1, 2016

Discussion: Dual ported NVMe Devices provide redundancy in the face of link breakages or port failures. This test only applies to SFF-8639/U.2 devices that support dual ports. A controlled method must be used to break and repair links in this test, as shown in the diagram below.



Test Setup: A single NVMe dual ported device is physically attached to the NVMe Host Platform, has been formatted by the Host Platform, and is visible to the user through the operating system (OS).

Test Procedure:

1. Power on the NVMe Host and allow the OS to boot and all necessary drivers to be loaded.
2. Ensure that the OS has not loaded from the NVMe Device Under Test, but has loaded from another source.
3. Using the appropriate OS utilities, determine if the dual port NVMe Device appears twice in the OS, or, if some method of MPIO is enabled, the NVMe Device appears only once.
4. Using a controlled method, break one link to the NVMe Device while the other link remains connected and active.

5. Using a controlled method, reconnect the broken link to the NVMe Device while the other link remains connected and active.

Observable Results:

1. After step 4: Using the appropriate OS utilities, determine the following:
    a. If the dual port NVMe Device appeared twice in the OS in step 3, now only 1 instance of the NVMe Device is visible in the Host OS.
    b. If some method of MPIO is enabled, the NVMe device still appears in the Host OS.
2. After step 5: Using the appropriate OS utilities determine the following:
    a. If the dual port NVMe Device appeared twice in the OS in step 3, there are now again 2 instances of the NVMe Device visible in the Host OS.
    b. If some method of MPIO is enabled, the NVMe device still appears in the Host OS.

Possible Problems: Methods for disabling the NVMe Device may vary across different operating systems.

Test 1.8 – Dual Port Device with Multiple Namespaces (FYI)

Purpose: To verify that an NVMe Host properly handles a NVMe Storage Device with Dual Ports which also supports multiple namespaces

References:

[1] NVMe Specification

Resource Requirements:

NVMe Host Platform and Device.

Last Modification: June 16, 2016

Discussion: Dual ported NVMe Devices provide redundancy in the face of link breakages or port failures. This test only applies to SFF-8639/U.2 devices that support dual ports.

Test Setup: One NVMe dual ported device is physically attached to the NVMe Host Platform by both ports – NVMe controller IDs 0 and 1. This can be accomplished through the use of cables & retimers, passive PCIe splitter board, or PCIe switches as available/required.

Test Procedure:

1. Power on the NVMe Host and allow the OS to boot and all necessary drivers to be loaded.
2. Ensure that the OS has *not* loaded from the NVMe Device Under Test, but has loaded from another source.
3. Check for PCIe devices (PCIe Link) from both controller ID 0 and 1.
    a. Linux: lspci | grep Non
    b. Windows: Device Manager > Storage Controllers > Mass Storage Device
4. Check for NVMe devices (NVMe Driver Loaded) and namespaces within those devices
    a. Linux: ls –al /dev/nvm* or lsblk
    b. Windows: Device Manager > Disk Drives
5. Detach/Delete Namespaces. The following steps describe how to clear the SSD of all existing namespaces.
6. Identify existing Namespaces.
    a. In Linux using nvme-cli tools: nvme list-ns /dev/nvmeX - typically /dev/nvme0 and /dev/nvme1
    b. In Windows: issdcm or other tool > syntax TBD.
7. Detach Existing Namespaces
    a. In Linux, using nvme-cli tools:
        i. nvme detach-ns /dev/nvmeX -n X - repeat for additional namespaces
    b. In Windows: issdcm or other tool > syntax TB
8. Delete Existing Namespaces
    a. In Linux using nvme-cli tools:
        i. nvme delete-ns /dev/nvmeX -n X - repeat for additional namespaces
    b. In Windows: issdcm or other tool > syntax TB
9. Issue NVMe subsystem reset (NSSR) or Controller Reset, and Rescan or Reboot Host
    a. In Linux: Prior to 4.4 kernel, reboot Host Platform
    b. In Linux: 4.4+ kernel
        i. modprobe –r nvme, sudo sh –c “echo 1 > /sys/bus/pci/rescan”, modprobe nvme
    c. In Windows: Reboot or disable/enable devices in Device Manager
10. Verify Namespaces Deleted
    a. In Linux, using nvme-cli tools:
        i. nvme list-ns /dev/nvmeX (typically /dev/nvme0 and /dev/nvme1)
        ii. Can also be accomplished with: ls -1 /dev/nvm* or lsblk – look for absence of /dev/nvmeXnY, only controllers present
    b. In Windows: issdcm or other tool > syntax TBD
11. Create/Attach Namespaces
    a. For IOL multi-namespace testing the SSD should have a two namespaces, one attached to controller 0 and one attached to controller 1

12. Create Namespaces – Note: FLBA Size (logical block size) will vary from device to device, check available formats
    a. First Namespace: In Linux, using nvme-cli tools execute the following. Note that any values provided regarding sector size and namespace size are provided as examples only. These values can be adjusted according to device and driver support:
        i. nvme create-ns /dev/nvmeX -s <sizeInBlocks> -c <capInBlocks> -f <FLBA Size> -d <dataProtection> -m 1 <sharing on>
        ii. i.e. nvme create-ns /dev/nvme0 –s 52428800 –c 52428800 –f 2 –d 0 –m 1 creates a 200GB namespace on controller 0 based on 4k sectors -f 2 (4096b in this controller), no data protection information –d 0, and sharing enabled so that both controllers can attach to this namespace –m 1
        iii. Similarly nvme create-ns /dev/nvme0 –s 419430400 –c 419430400 –f 0 –d 0 –m 1 creates a similar 200GB namespace based on 512b sectors –f 0
    b. Second Namespace: In Linux using nvme-cli tools:
        i. nvme create-ns /dev/nvmeX -s <sizeInBlocks> -c <capInBlocks> -f <FLBA Size> -d <dataProtection> -m 1 <sharing on>
        ii. This creates a 2nd namespace, preferably of the same capacity as the 1st with the same –f <num> FLBA Size.
13. Attach Namespaces
    a. In Linux using nvme-cli tools: nvme attach-ns –n <namespace> /dev/nvmeX
        i. i.e. nvme attach-ns /dev/nvme0 –n1 –c0 attaches ns 1 to nvme controller /dev/nvme0
        ii. i.e. nvme attach-ns /dev/nvme1 –n2 –c1 attaches ns 2 to nvme controller /dev/nvme1
    b. In Windows: issdcm or other tool > syntax TB
14. Issue NVMe subsystem reset device and Rescan or Reboot
    a. In Linux: Prior to 4.4 kernel, reboot Host Platform
    b. In Linux: 4.4+ kernel
        i. modprobe –r nvme, sudo sh –c “echo 1 > /sys/bus/pci/rescan”, modprobe nvme
    c. In Windows: Reboot or disable/enable devices in Device Manager
15. Verify Namespaces Attached
    a. In Linux, using nvme-cli tools:
        i. nvme list-ns /dev/nvmeX (typically /dev/nvme0 and /dev/nvme1)
        ii. Can also be accomplished with: ls -1 /dev/nvm* or lsblk – look for presence of /dev/nvmeXnY, both controllers present and namespaces should be present
    b. In Windows: issdcm or other tool > syntax TBD
16. Using appropriate OS utilities, mount and format both instances of the NVMe device.
    a. In Linux: Format the drives with extX/xfs/other file system and assign a mount point.
    b. In Windows: Format the drives with NTFS and assign a drive letter.
17. Verify Namespaces are independent of each other
    a. Copy any unique file to the mount point of /dev/nvme0n1 (text file w/dev-nvme0n1)
    b. List the directory contents of the mount of /dev/nvme1n2 – verify the copied file is not there
    c. Copy any unique file to the mount point of /dev/nvme1n2 (text file w/dev-nvme0n2)
    d. List the directory contents of the mount of /dev/nvme0n1 – verify the copied file is not there
18. Using appropriate OS utilities, cease all IO to the drive, and unmount.
    a. In Linux: Unmount the devices from their mount points.
    b. In Windows: Remove the assigned drive letters.
19. Detach Existing Namespaces
    a. In Linux, using nvme-cli tools:
        i. nvme detach-ns /dev/nvmeX -n X - repeat for additional namespaces
    b. In Windows: issdcm or other tool > syntax TB
20. Attach Namespaces To Alternate Ports
    a. In Linux using nvme-cli tools: nvme attach-ns –n <namespace> /dev/nvmeX
        i. i.e. nvme attach-ns /dev/nvme0 –n2 –c0 attaches ns 2 to nvme controller /dev/nvme0
        ii. i.e. nvme attach-ns /dev/nvme1 –n1 –c1 attaches ns 1 to nvme controller /dev/nvme1
21. Issue NVMe subsystem reset device and Rescan or Reboot
    a. In Linux: Prior to 4.4 kernel, reboot Host Platform

   b. In Linux: 4.4+ kernel
      i. modprobe –r nvme, echo 1 > /sys/bus/pci/rescan, modprobe nvme
   c. In Windows: Reboot or disable/enable devices in Device Manager
22. Verify Namespaces Attached
   a. In Linux, using nvme-cli tools:
      i. nvme list-ns /dev/nvmeX (typically /dev/nvme0 and /dev/nvme1)
      ii. Can also be accomplished with: ls -1 /dev/nvm* or lsblk – look for presence of /dev/nvmeXnY, both controllers present and namespaces should be present
   b. In Windows: issdcm or other tool > syntax TBD
23. Using appropriate OS utilities, mount both instances of the NVMe device.
   a. In Linux: Assign a mount point.
   b. In Windows: Assign a drive letter.
24. Using the appropriate OS utility, check the filesystem for errors and verify file written in step 17 can be read
   a. In Linux: fsck both namespaces and cat the written files
   b. In Windows: chkdsk both the namespaces and open the written files
   c. File system check should return no errors and files should be readable
25. Unmount devices, shutdown hosts.

Note: 'Test 1.3 Write Read Compare' can be accomplished between step 15-16 and 24-25 in this procedure with ½ of the IO going to /dev/nvme0n1 and the other ½ going to /dev/nvme1n2. Performing the test in this fashion can save potentially save test time.

Observable Results:

1. After initial power on, verify the NVMe device appears as two distinct NVMe controllers in the appropriate OS utility.
2. Verify ability to detach & delete namespaces – Steps 7-10.
3. Verify ability to create & attach namespaces – Steps 11-15.
4. Verify namespaces can be formatted & mounted – Step 16.
5. Verify namespaces are independent of each other – Step 17.
6. Verify namespaces can be unmounted – Step 18.
7. Verify namespaces can be attached to alternate ports/controllers – Step 19-21.
8. Verify filesystem and files remain intact on controller change – Step 22-24.

Possible Problems: Methods for disabling the NVMe Device may vary across different OSs and Linux kernel versions. Open source tools for namespace manipulation may be unavailable in Windows OSs. NVMe subsystem-reset will be unavailable in Linux prior to 4.4 kernel and will be dependent on OEM Windows driver in Server 2012 r2 and Windows 8.1 OSs. In addition, the NVMe Linux driver writers made a change to the behavior of namespace enumeration between 4.4 and 4.5 kernels.

4.4 and previous kernels:
/dev/nvme0n1 - Controller 0 – Namespace 1
/devnvme1n2 – Controller 1 – Namespace 2

4.5 and after kernels:
/dev/nvme0n1 - Controller 0 – Namespace unknown (use nvme id-ns command to identify)
/devnvme1n1 – Controller 1 – Namespace unknown (use nvme id-ns command to identify)

Test 1.9 – Dual Port Device with Single Namespaces (FYI)

Purpose: To verify that an NVMe Host properly handles an NVMe Storage Device with Dual Ports which supports only a single namespace

References:

[1] NVMe Specification

Resource Requirements:

NVMe Host Platform and Device.

Last Modification: June 16, 2016

Discussion: Dual ported NVMe Devices provide redundancy in the face of link breakages or port failures. This test only applies to SFF-8639/U.2 devices that support dual ports.

Test Setup: One NVMe dual ported device is physically attached to the NVMe Host Platform by both ports – NVMe controller IDs 0 and 1. This can be accomplished through the use of cables & retimers, passive PCIe splitter board, or PCIe switches as available/required

Test Procedure:

1. Power on the NVMe Host and allow the OS to boot and all necessary drivers to be loaded.
2. Ensure that the OS has ***not*** loaded from the NVMe Device Under Test, but has loaded from another source.
3. Check for PCIe devices (PCIe Link) from both controller ID 0 and 1
    a. Linux: lspci | grep Non
    b. Windows: Device Manager > Storage Controllers > Mass Storage Device
4. Check for NVMe devices (NVMe Driver Loaded) and single namespace within those devices
    a. Linux: ls –al /dev/nvm* or lsblk
    b. Windows: Device Manager > Disk Drives
5. Identify Existing Namespace (Single Namespace Device should have only 1)
    a. In Linux, using nvme-cli tools*:*
        i. *nvme list-ns /dev/nvmeX* - typically /dev/nvme0 and /dev/nvme1
        ii. *nvme list*
    b. In Windows: issdcm or other tool > syntax TBD
6. Using appropriate OS utilities, Format and Mount ***ONE*** of the ***TWO*** NVMe devices.
    a. In Linux: Format the drive /dev/nvme0n1 with extX/xfs/other file system and assign a mount point.
    b. In Windows: Format the drives with NTFS and assign a drive letter.
7. Verify Namespaces are self-similar (same LBA range)
    a. Copy any unique file to the mount point of /dev/nvme0n1 (text file w/dev-nvme0n1)
    b. List the directory contents of the mount of /dev/nvme0n1 – verify the copied file is there and readable
    c. Unmount /dev/nvme0n1 and then Mount /dev/nvme1n1 to same mount point
    d. Using the appropriate OS utility, check the filesystem for errors and verify file written in step 7a can be read
        i. In Linux: *fsck* /dev/nvme1n1 and *cat* the written files
        ii. In Windows: *chkdsk* both the namespaces and open the *written* files
        iii. File system check should return no errors and files should be readable
    e. List the directory contents of the mount of /dev/nvme1n1 – verify the copied file is there and readable
    f. Modify the copied file in /dev/nvme1n1 – change text in file & save
    g. List the directory contents of the mount of /dev/nvme1n1 – verify the copied file is there and readable
    h. Unmount /dev/nvme1n1 and then Mount /dev/nvme0n1 to same mount point

   i. Using the appropriate OS utility, check the filesystem for errors and verify file written in step 7a can be read and change in file is present
      i. In Linux: *fsck* both namespaces and *cat* the written files
      ii. In Windows: *chkdsk* both the namespaces and open the *written* files
      iii. File system check should return no errors and files should be readable
   j. List the directory contents of the mount of /dev/nvme0n1 – verify the copied file is there & changes to file in step 7e are present
8. Unmount devices, shutdown hosts, end of test…

Note: 'Test 1.3 Write Read Compare' can be accomplished after step 8 in this procedure with ½ of the IO going to /dev/nvme0n1 and the other ½ going to /dev/nvme1n2. Performing the test in this fashion can save potentially save test time.

Observable Results:

1. After initial power on, verify the NVMe device appears as two distinct NVMe controllers in the appropriate OS utility.
2. Verify single namespace attached to both controllers
3. Verify ability to format & mount namespace from controller 0 – Step 6
4. Verify ability to write & read file – Step 6a-6b
5. Verify ability to unmount and remount namespace using alternate controller – Step 6C
6. Verify filesystem not corrupted and written file present & intact – Step 6d-6f
7. Verify ability to unmount and remount namespace using original controller – Step 6h
8. Verify filesystem not corrupted and written file present & intact – Step 6i-6j
9. End of Test

Possible Problems: Methods for disabling the NVMe Device may vary across different OSs and Linux kernel versions. The NVMe Linux driver writers made a change to the behavior of namespace enumeration between 4.4 and 4.5 kernels.

4.4 and previous kernels:
/dev/nvme0n1 - Controller 0 – Namespace 1
/devnvme1n2 – Controller 1 – Namespace 2

4.5 and after kernels:
/dev/nvme0n1 - Controller 0 – Namespace unknown (use nvme id-ns command to identify)
/dev/nvme1n1 – Controller 1 – Namespace unknown (use nvme id-ns command to identify)

Test 1.10 – Return from Hibernation (FYI)

Purpose: To verify that an NVMe Storage Device can enter and exit a hibernation state without error.

References:

[1] NVMe Specification

Resource Requirements:

NVMe Host Platform and Device.
If using a non-CEM form factor, see Appendix C

Last Modification: January 23, 2018

Discussion: NVMe Devices should be able to enter and exit hibernation state without error.

Test Setup: Two NVMe devices are physically attached to the NVMe Host Platform, have been identified by the Host Platform, and are visible to the user through the operating system.

Test Procedure:

1. Remove or delete any formatting on the NVMe devices.
2. Hibernate the Host Platform, then return the Host Platform to an operational state. Ensure that any Partition Information on the NVMe DUT survives the transition.
3. Repeat step 2 6 times.
4. Use available tools to perform write/read/compare data operations containing a stressing data pattern to the attached NVMe Device under test. The data operations should be of varying transfer sizes. See Appendix A. The same IO utilities and parameter files used in Test 1.3 can be used in this test.

Observable Results:

1. Verify that for all cases:
   a. The write/read/compare operations complete without any data integrity errors being reported
   b. The NVMe DUT is visible to the Host Operating System after each hibernate cycle
   c. All Partition Information on the NVMe DUT survives each shutdown/reboot cycle.

Possible Problems: None known.

Appendix A - Write/Read/Compare Utility for Windows and Linux

Purpose: To define a means of connecting prototype NVMe products for performing the tests outlined in this document.

References:

[1]NVMe Specification

Resource Requirements:

NVMe Host and Device, PCIe conformance channel

Last Modification: March 1, 2016

Discussion: To perform interoperability testing between an NVMe Host Platform and an NVMe Device, a utility capable of writing, reading, and comparing data written to an NVMe Device is necessary. This Appendix will describe the use of the VDBENCH utility to perform this testing. Being a Java based tool, VDBENCH has the benefit of working across multiple operating systems (OS). Other utilities may be used instead of VDBENCH, but their behavior should be known to be similar to that implemented with VDBENCH.

Stressing patterns can be used in the test by using a configuration file with contents that will produce a pattern on the PCIe bus when the file transfer occurs.

Test Setup: The NVMe device is physically attached to the NVMe Host Platform. The NVMe device has not been formatted by the Host Platform, all partitions have been deleted, and is visible to the user.

Test Procedure:

Before performing tests, ensure the system under test is powered off completely, and that 2 samples of the NVMe drive are physically installed in the host system. . Ensure that the vdbench application and associated parameter files are available on the system under test. If not perform the following steps:

1. Install vdbench 504, following the instructions at http://www.oracle.com/technetwork/server-storage/vdbench-downloads-1901681.html
2. Download the VDBENCH parameter file for your OS:
    a. https://www.iol.unh.edu/sites/default/files/testsuites/nvme/unh_interop_6_0_linux.txt
    b. https://www.iol.unh.edu/sites/default/files/testsuites/nvme/unh_interop_6_0_windows.txt
3. Edit the provided VDBENCH parameter file so that the ‘lun’ parameter points to the SSD under test. If using a Windows operating system this should be “PhysicalDrive1” or similar. The number will change depending on how many drives are installed in the host platform. Use Disk Management found under Computer Management to get the Disk number for the drive intended for testing.

To perform the test:

1. Power on the system. Verify that both of the attached NVMe Devices are visible in the OS
    a. Use disk management in Windows
    b. Use “lspci | grep Non” in Linux)
2. If performing the first iteration of the testing with a new combination of host system and NVMe driver, perform the following steps, this step is only necessary when powering up the Host system for the first time with a given NVMe SSD.

For Linux based OS:

a. sudo fdisk /dev/nvme0n1, then press 'w'
b. sudo mkfs.ext4 /dev/nvme0n1 (the filename may vary depending on the device)
c. sudo mkdir /mnt/nvme ().
d. sudo mount /dev/nvme0n1 /mnt/nvme
e. sudo umount /mnt/nvme

For Windows based OS:

a. Search for “Create and Format Hard Disk Partitions” or ’Disk Manager’

   b. Ensure Disk Management identifies both NVMe devices, it should also see the current OS's hard drive.
   c. Right click the first NVMe SSD under test and select "New Sample Volume.."
   d. Format the disk.
   e. Right click the same drive and select "Delete Volume."
   f. Select "Yes" to unformat the drive
3. Navigate to the folder containing the vdbench application and parameter file.
4. Run the provided VDBENCH parameter file using the following command: `vdbench -f <parameter file filename> -vr`. The test will run for about 5 minutes. Test results will be displayed in the console while the test is running.
   a. If using a Windows operating system, be sure to run vdbench from an Administrator command prompt (Right click cmd icon, select 'Run as Administrator').
   b. If using a Linux operating system, be sure to give vdbench the correct permissions using 'chmod 777 vdbench'. This is only necessary when running vdbench for the first time on a new system.
5. Verify that the vdbench test run completed with no errors in the /vdbench504/output/summary.html file.
6. Save the entire output directory or just the summary.html output file with a filename following this convention: YYYYMMDD_ <NVMe SSD Name>_<Host System Hardware Name>_<OS Name and Version>_<Shutdown or Restart>_<1, 2, or 3>_<PASS/FAIL>.
7. Shutdown the Host system and repeat steps 1, 3-6 with a Shutdown 2 more times.
8. Reboot the Host system and repeat steps 1, 3-6 with a Reboot 2 more times.

Observable Results:

1. Verify that the write/read/compare operations complete without error to the NVMe Device.

Possible Problems:

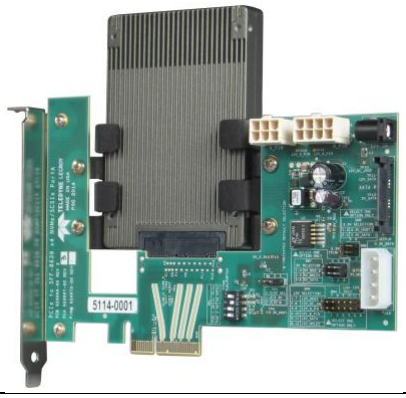
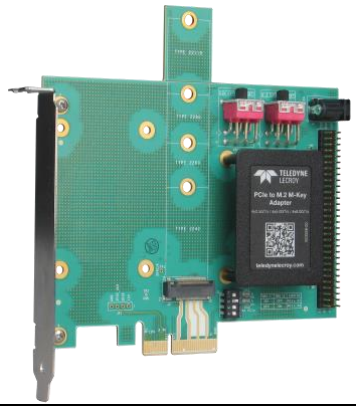
1. Methods for performing this test may vary across different operating systems and drivers.
2. On some Linux operating systems it may be necessary to install Java and csh. This can be the source of a 'bad interpreter' error message when attempting to run vdbench.
3. If VDBENCH indicates a Java error, it may be necessary to update the path to Java in the vdbench.bat file (Windows). To do this, use the following steps:
   a. Open vdbench.bat for editing.
   b. Find where the Java path is in the bat file; by default it says: set java=java.
   c. Find where Java is on the system. For example, in Windows 7 64 bit and Windows Server 2012 systems the default path is C:\Program Files (x86)\Java\jre7\bin\java.exe.
   d. Copy the new path into the vdbench.bat file: set java="C:\Program Files (x86)\Java\jre7\bin\java.exe". Be sure to use the double quotes.
4. If the DUT has a storage capacity less than 512MB, it will be necessary to modify the threads parameter in the vdbench parameter file. Change the 'threads=128' to 'threads=16'. If this adjustment is not made, the test may not complete, and vdbench may indicate a 'busy' or 'timeout' error.

Appendix B – Using Non-CEM Form Factors

Purpose: To define a means of connecting prototype NVMe products for performing the tests outlined in this document when using non-CEM Form Factors.

Last Modification: April 7, 2015

Discussion: An NVMe Drive may be implemented in a variety of form factors, including CEM, U.2, M.2, and a variety of EDSFF form factors (E1.L, E1.S). If a Host system supporting the needed drive form factor is not available, an adapter may be used to connect the drive and host for the purpose of protocol interoperability testing. Examples of such adapters are provided below for reference only. Adapters with similar functionality and specifications are acceptable.

<table>
<tr><td>Teledyne-LeCroy SFF-8639 Port A Adapter
  </td><td>Serial Cables PCI-AD-X439-01 Adapter
  </td></tr>
<tr><td>Teledyne-LeCroy M.2 M-Key Adapter
  </td><td></td></tr>
</table>

Appendix C – UNH-IOL Interop Test Bed

Purpose: To provide guidance on products that may be potential interop partners.

References:

[1] NVMe Specification

Resource Requirements:

NVMe Host Platform and Device.

Last Modification: May 24, 2016

Discussion: NVMe Interoperability should be performed across a variety of host system hardware and operating systems. UNH-IOL maintains a test bed of potential interop partners for use during private in-lab testing and plugfest events. Currently products available in the interop test bed can be seen here:

https://www.iol.unh.edu/testing/storage/nvme/equipment

Appendix D – Interop Test Setups

Purpose: To provide guidance on what test configurations can be used.

References:

[1] NVMe Integrators List Policy Document

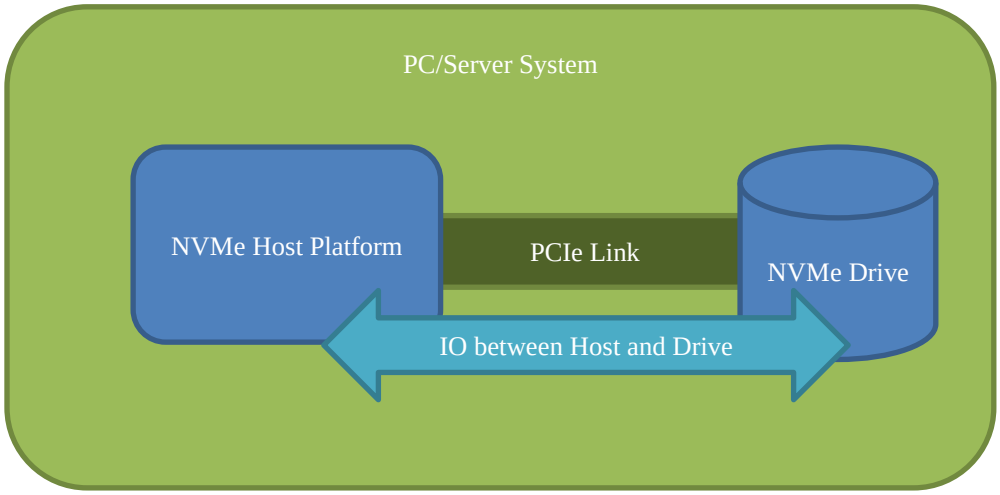
Resource Requirements:

NVMe PCIe Host Platform and NVMe Drive.
NVMe-oF Host, Target, and NVMe Drive

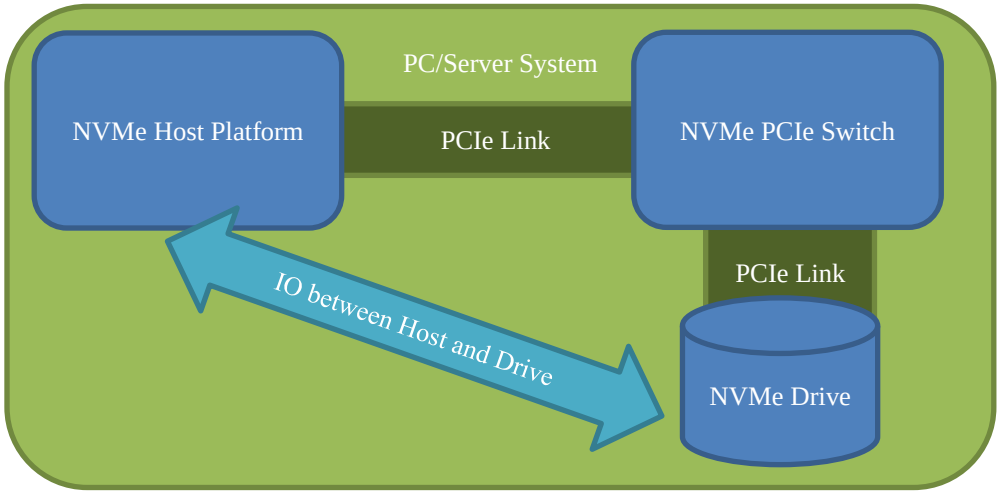
Last Modification: November 30, 2017

Discussion: NVMe Drives can be tested in a variety of configurations the diagrams below outline possible device configurations that can be used to perform the testing outlined in this document.

Interop Configuration 1: NVMe Drive in a Server with a PCIe Interface



Interop Configuration 2: NVMe Drive in a Server with a PCIe Interface and an NVMe PCIe Switch.



Appendix E – NVMe Integrators List Requirements

Purpose: To document what tests are required for Integrators List Qualification

References:

[1] NVMe Integrators List Policy Document

Resource Requirements:

Last Modification: December 7, 2017

Discussion: The Test name shows which items are Mandatory, FYI, or In Progress.

The table below shows how many interop configurations each Product Under Test must be tested with for each Integrators List. Interop Configurations are described in Appendix D.

If the product under test is NVMe Drive, then, among the passing NVMe Host Platforms, there must be at least one Linux-based OS and at least one Windows-based OS represented and both of the following drivers represented:

NVMe Linux Driver (Kernel Version 3.3.0 or later)
Microsoft StorNVMe.sys "In Box" Driver

If the product under test is an NVMe Host Platform or NVMe PCIe Switch, it is only necessary to use one operating system. The operating system used can be any OS chosen by the host.

Integrators List	Product Types	Number of Interop Configurations in Test Report
NVMe	NVMe/PCIe Host Platform	Pass Tests 1.1, 1.2, 1.3, 1.6 with at least 5 Interop Configurations using Interop Configuration 1 and/or 2 from Appendix D.
	NVMe/PCIe Drive	Pass Tests 1.1, 1.2, 1.3 with at least 5 Interop Configurations using Interop Configuration 1 and/or 2 from Appendix D. Pass Tests 1.4 with at least 2 Interop Configurations using Interop Configuration 1 and/or 2 from Appendix D. Pass Tests 1.6 with at least 2 Interop Configurations using Interop Configuration 1 and/or 2 from Appendix D.
	NVMe/PCIe Switch	Pass Tests 1.1, 1.2, 1.3 with at least 5 Interop Configurations using Interop Configuration 1 and/or 2 from Appendix D. Pass Tests 1.4 with at least 1 Interop Configurations using Interop Configuration 1 and/or 2 from Appendix D. Pass Tests 1.6 with at least 2 Interop Configurations using Interop Configuration 1 and/or 2 from Appendix D.