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NVM Express™ Technical Proposal (TP)

Technical Proposal ID	4077 – Performance Characteristics Reporting
Revision Date	2022.02.09
Builds on Specification(s)	NVM Express® NVM Command Set Specification 1.0a NVM Express® Base Specification 2.0a NVM Express® Management Interface Specification 1.2a
Ratified Technical Proposals Referenced	TP4074a Defining Scope for Features

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Technical Proposal Overview

This proposal allows an NVMe device to report performance characteristics to enable a host system to dynamically optimize its workload distribution to NVMe devices based on these reported characteristics.

Revision History

Revision Date	Change Description
2021.08.11	Initial draft.
2021.08.12	Incorporated feedback from sponsors alignment meeting.
2021.08.13	<ul style="list-style-type: none">• Moved the feature definition to the NVM Command Set Spec.• Base Spec Fig. 316: Added the (TBD) Feature ID.• State that feature scope is the NVM subsystem.• Added requirements for the UUID Selection Supported bit.• Added paragraph stating how to measure read latency, as an alternative to putting it in a figure note.• Added more code points for latencies less than 1 microsecond.• Reorganized the header for the VS performance attribute.• Added MPCID field to the I/O Command Set Specific Identify Controller data structure for the NVM Command Set.
2021.08.23	<ul style="list-style-type: none">• Removed use of UUID Index field in commands.• In CDW11, renamed the Page Identifier field to Page Index, to avoid confusion with the VS Page Identifier List, which contains UUIDs.

Revision Date	Change Description
	<ul style="list-style-type: none"> Added a heading for each page type. The wall of text needed to be broken up. Added VS Page Identifier List page. Renamed the MPCID field to PCVSPC. Required a saved value always to exist for VS Performance Attribute pages. See note in 4.1.3.TBD.2. Deleted the older material at the end of the document. This had been incorporated in an earlier revision.
2021.08.23a	<ul style="list-style-type: none"> Adjusted Page IDs to match TWG feedback Added additional latency buckets for the Standard Performance Attribute
2021.08.24	<ul style="list-style-type: none"> Removed statement about indicating support in the Feature Identifiers Supported and Effects log page. All features do that. Prohibit changing the Standard page. Made the picosecond ranges reserved, as they are probably not testable. Filled in the ambiguous 10% at the top of each range by using “greater than or equal to” and “less than”. Required VS page identifiers in the Page Identifier List to be cleared to 0h for unsupported pages.
2021-08-26	<p>Changes from 2021-08-26 meeting of TP sponsors:</p> <ul style="list-style-type: none"> Added specification of the relevant test loop. Added statement that PTS has reporting requirements for the test system, and that reporting that information is outside the scope of this spec. Made the VS page range C0H to FFh. Adjusted page identifier list accordingly. Removed requirement to set unwritten VS pages to 0h.
2021-08-31	<ul style="list-style-type: none"> Base Spec 2.0a: Added feature as Prohibited to Admin Controller and Discovery Controller figures. Figure FigCDW11: Reworded Page Index description. Changed two page names to use “attribute”. Changed PCVSPC to VSPAPC.
2021-09-01	<ul style="list-style-type: none"> Removed scope from the Feature description. Mandatory changeable/saveable if ONCS.b4==1 and VSPAPC>0. Added ref to PTS-C test parameters. Miscellaneous clarifications.
2021-09-08	<ul style="list-style-type: none"> Resolved some feedback
2021-09-10	<ul style="list-style-type: none"> Captured comment feedback from TWG. Change “pages” to “attributes”. Re-base all VS attributes to C0h. Moved VSPAPC field from Figure 102 to VS attribute C0h header as the VSPAC field. Added Attribute Type field to VS attribute C0h header to indicate Current, Default, or Saved.
2021-09-28	<ul style="list-style-type: none"> Added a reserved byte to the beginning of the standard attribute definition Split each of the standard attribute latency buckets in to two buckets
2021-09-29	<ul style="list-style-type: none"> Changed the reserved byte at the beginning of the standard attribute definition to be 4 bytes reserved
2021-10-06	<ul style="list-style-type: none"> Latency bucket 0h allocated as “Not Reported” Remaining latency buckets reversed order to allow for growth toward the end of the table for future lower latency definitions
2021-10-07	<ul style="list-style-type: none"> Renamed VSPAC field to Vendor Specific Performance Attributes Supported (VSPAS) to clarify that it is a static value. Added comment with suggested resolution of questions about the UUID field in the VSPA descriptor.
2021-10-12	<ul style="list-style-type: none"> Renamed Vendor Specific Performance Attribute Identifier (and List) to Performance Attribute Identifier.

Revision Date	Change Description
	<ul style="list-style-type: none"> Deleted closed comments. Added the Revert Vendor Specific Performance Attribute (RVSPA) bit to the Set Features command. Added a requirement for the Set Features command to set the Save bit to '1'. Added the Maximum Saveable Vendor Specific Performance Attributes (MSVSPA) field and the Unsaved Vendor Specific Performance Attributes (UVSPA) field to the Performance Attribute Identifier List data structure. Added requirements for the new bit/fields to section 4.1.3.TBD.2. Rewrote reporting of the Performance Attribute Identifier List for different values of the Select field.
2021-10-15	<ul style="list-style-type: none"> Changed the name "Standard Performance Attribute" to "Standard Performance Attribute 00h". Removed VSPAS field. Renamed UVSPA field to "Unused Saved Vendor Specific Performance Attributes" (USVSPA).
2021-10-22	<ul style="list-style-type: none"> Made editorial changes based on TWG feedback Refactored saveable requirement to be grouped with ONCS.b4 text Moved RVSPA requirements into the general Set Features section Non-redline revision: Deleted all closed comments and accepted all changes.
Phase 3	
2021-11-11	<ul style="list-style-type: none"> Updated descriptions for changes documents. 4.1.3.TBD.2: Added clarifying words to the descriptions of behavior for each value of Select.
2021-11-16	<ul style="list-style-type: none"> All comments are resolved, so deleted them.
2021-12-02	<ul style="list-style-type: none"> Deleted notes to readers explaining why no change is needed to Figure 25 and Figure 194. Added TP4074 as a ratified TP that this TP builds on. Removed "New requirement / incompatible change" from descriptions for changes documents (because this feature is optional). Removed section references from descriptions for changes documents. Added specification version numbers. Changed "status of" to "status code of". For saved attribute values, changed the verb "removed" to "deleted". Added Scope column to the two Feature Identifiers figures. This column had been added to various specs by TP4074. Scope entry in Figure 79 is refers to the section describing this feature (4.1.3.TBD). Added feature scope statement to 4.1.3.TBD, which states that it depends on the NS Specific bit reported by Get Features command for 011b (Supported Capabilities).
2021-12-08	<ul style="list-style-type: none"> Deleted extraneous sentence concerning scope. Updated copyright notices from 2021 to 2022. Deleted all comments and accepted all changes.
Member Review	
2021-12-09	<ul style="list-style-type: none"> NVM Command Set Spec Figure 79: Split scope cell for this Feature, one part for NVM subsystem, one for Namespace.
2021-12-23	<ul style="list-style-type: none"> Initial resolution of Samsung comments.
2022-01-04	<ul style="list-style-type: none"> Added Solidigm to list of authors. Added Performance Characteristics feature to Figure 14, NVM Command Set spec.
2022-01-12	<ul style="list-style-type: none"> Complete resolution of Samsung comments.
Integration Ready	

Revision Date	Change Description
2022-01-12	<ul style="list-style-type: none"> • Comments deleted. • Changes accepted and tracking disabled.
2022-01-20	<ul style="list-style-type: none"> • Changed filename from "Integration Ready" to Integration", per process specification.
2022-02-06	<ul style="list-style-type: none"> • Integrated
2022-02-09	<ul style="list-style-type: none"> • Removed Base Spec changes to section 3 • Removed comments and integrated additional changes from review • Fixed footer name of company • Updated Feature list in NVM Express Base Specification to refer to the I/O Command Set

Description for Changes Document for NVM Express® NVM Command Set Specification 1.0a

New Features/Feature Enhancements/Required Changes:

- Performance Characteristics Feature (optional)
 - Added the new Performance Characteristics feature
 - Defines three types of performance attributes:
 - Standard Performance Attribute indicates random 4KiB average read latency (not changeable and not saveable)
 - Performance Attribute Identifier List (not changeable and not saveable)
 - Vendor Specific Performance Attributes (changeable / saveable)
 - The Set Features command can revert a Vendor Specific Performance Attribute.
 - References
 - Technical Proposal 4077

Description for Changes Document for NVM Express® Base Specification 2.0a

New Features/Feature Enhancements/Required Changes:

- Performance Characteristics Feature (optional)
 - Description of change.
 - Added the Performance Characteristics feature identifier to the figure Set Features – Feature Identifiers.
 - References
 - Technical Proposal 4077

Description for Changes Document for NVM Express® Management Interface Specification 1.2a

New Features/Feature Enhancements/Required Changes:

- Performance Characteristics Feature (optional)
 - Description of change.
 - Added the Performance Characteristics feature to a figure listing feature support.
 - References
 - Technical Proposal 4077

Markup Conventions:

Black:	Unchanged (however, hot links are removed)
Red Strikethrough :	Deleted
Blue:	New
Blue Highlighted:	TBD values, anchors, and links to be inserted in new text.
<Green Bracketed>:	Notes to editor

Description of Specification Changes for NVM Express® Base Specification 2.0a

5 Admin Command Set

...

5.27 Set Features command

...

5.27.1 Feature Specific Information

...

Figure 316: Set Features – Feature Identifiers

Feature Identifier	Current Setting Persists Across Power Cycle and Reset ²	Uses Memory Buffer for Attributes	Feature Name	Scope ⁶
...				
1Ch	Refer to the NVM Command Set			
...				

...

Description of Specification Changes for NVM Express® NVM Command Set Specification 1.0a

Specification disclaimer page:

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...

1 Introduction

...

1.6 References

NVM Express Base Specification, Revision 2.0. Available from <http://www.nvmexpress.org>.

SNIA® Solid State Storage (SSS) Performance Test Specification (PTS), Version 2.0.2, October 1, 2020.
Available from <https://www.snia.org/>.

...

2 NVM Command Set Model

...

2.2 I/O Controller Requirements

...

2.2.3 Features Support

...

Figure 1: I/O Controller – Feature Support

Feature Name	Feature Support Requirements ¹	Logged in Persistent Event Log
...		
Performance Characteristics	O	O
...		

...

4 Admin Commands for the NVM Command Set

4.1 Admin Command behavior for the NVM Command Set

...

4.1.3 Get Features & Set Features commands

Figure 79 defines the Features support requirements for I/O Controllers supporting the NVM Command Set.

Figure 79: Feature Identifiers – NVM Command Set

Feature Identifier	Persistent Across Power Cycle and Reset ^{a)}	Uses Memory Buffer for Attributes	Description	Scope
...				
1Ch	Yes	Yes	Performance Characteristics	NVM subsystem Namespace
...				

...

4.1.3.TBD Performance Characteristics (Feature Identifier 1Ch)

This Feature is used by the host to set and get Performance Characteristics information.

If a Get Features command for this feature specifying the SEL field set to 011b (i.e., Supported Capabilities) reports the NS Specific bit:

- cleared to '0', then the NVM Subsystem Scope bit is set to '1' in the Feature Identifiers Supported and Effects log page (refer to NVM Express Base Specification); and
- set to '1', then the Namespace Scope bit is set to '1' in the Feature Identifiers Supported and Effects log page.

Figure FigCDW11: Performance Characteristics – Command Dword 11

Bits	Description
31:09	Reserved
08	Revert Vendor Specific Performance Attribute (RVSPA): If set to '1' in a Set Features command, then the saved attribute value of the Vendor Specific Performance Attribute specified by the Attribute Index field shall be deleted. If cleared to '0' in a Set Features command, then the saved attribute value of the Vendor Specific Performance Attribute specified by the Attribute Index field shall not be deleted.
07:00	Attribute Index: This field specifies the Performance Attribute to be transferred between the host and controller:

If a Set Features command is issued for this Feature and that command completes successfully, then the attribute specified by the Attribute Index field is transferred from the data buffer for that command.

If a Get Features command is issued for this Feature and that command completes successfully, then the attribute specified by the Attribute Index field and the Select field is returned in the data buffer for that command.

If a Get Features command or a Set Features command specifies an Attribute Index field with an unsupported value, then the controller shall abort that command with a status code of Invalid Field in Command.

If bit 4 is set to '1' in the Optional NVM Command Support (ONCS) field of the Identify Controller data structure and the value of the MSVSPA field is non-zero, then:

- a) the capabilities for the Performance Characteristics Feature shall report changeable and saveable; and
- b) a Set Features command specifying a Vendor Specific Performance shall specify a saved value. If a Set Features command is issued for this feature and specifies:
 - an Attribute Index field specifying a Vendor Specific Performance Attribute; and
 - a Saved bit cleared to '0',

then the controller shall abort that command with a status code of Invalid Field in Command.

If a Set Features command specifies the Attribute Index of a Vendor Specific Performance Attribute that has a saved value and specifies the RVSPA bit set to '1', then:

- the saved attribute value of that Vendor Specific Performance Attribute is deleted;
- the contents of the data buffer are not used;
- the Save bit is ignored by the controller; and
- if that Vendor Specific Performance Attribute has not been set by an intervening Set Features command, then a subsequent Get Features command specifying that Vendor Specific Performance Attribute will return the default value for that Vendor Specific Performance Attribute.

If a Set Features command specifies the Attribute Index of a Vendor Specific Performance Attribute that does not have a saved value, and specifies the RVSPA bit set to '1', then:

- the contents of the data buffer are not used;
- the Save bit is ignored by the controller; and
- that command returns a status code of Successful Completion.

4.1.3.TBD.1 Standard Performance Attribute

The Random 4 KiB Average Read Latency field of the Standard Performance Attribute (refer to **Figure FigStd**) indicates the range corresponding to the value of the measured average latency. Average latency shall be measured according to the Latency Test section in the Solid State Storage (SSS) Performance Test Specification (refer to section **1.6**). The Latency Test shall be performed using the PTS-C configuration parameters (WCE and AR=75). The measured latency is measured by the test loop for R/W% = 100/0 and Block Size = 4 KiB.

That specification describes reporting requirements for the test system used to perform the test. Reporting that information about the test system is outside the scope of this specification.

The Standard Performance Attribute is not able to be modified by a Set Features command. If a Set Features command is issued for the Feature and the Attribute Index field specifies the Standard Performance Attribute, then the controller shall abort that command with a status code of Invalid Field in Command.

Figure FigStd: Performance Characteristics – Standard Performance Attribute

Bytes	Description																																																			
03:00	Reserved																																																			
04	Random 4 KiB Average Read Latency: This field indicates the time to complete a 4 KiB random read. Each value indicates a range of latencies:																																																			
	Value	Description	00h	Not Reported	01h	Greater than or equal to 100 seconds	02h	Greater than or equal to 50 seconds and less than 100 seconds	03h	Greater than or equal to 10 seconds and less than 50 seconds	04h	Greater than or equal to 5 seconds and less than 10 seconds	05h	Greater than or equal to 1 second and less than 5 seconds	06h	Greater than or equal to 500 milliseconds and less than 1 second	07h	Greater than or equal to 100 milliseconds and less than 500 milliseconds	08h	Greater than or equal to 50 milliseconds and less than 100 milliseconds	09h	Greater than or equal to 10 milliseconds and less than 50 milliseconds	0Ah	Greater than or equal to 5 milliseconds and less than 10 milliseconds	0Bh	Greater than or equal to 1 millisecond and less than 5 milliseconds	0Ch	Greater than or equal to 500 microseconds and less than 1 millisecond	0Dh	Greater than or equal to 100 microseconds and less than 500 microseconds	0Eh	Greater than or equal to 50 microseconds and less than 100 microseconds	0Fh	Greater than or equal to 10 microseconds and less than 50 microseconds	10h	Greater than or equal to 5 microseconds and less than 10 microseconds	11h	Greater than or equal to 1 microsecond and less than 5 microseconds	12h	Greater than or equal to 500 nanoseconds and less than 1 microsecond	13h	Greater than or equal to 100 nanoseconds and less than 500 nanoseconds	14h	Greater than or equal to 50 nanoseconds and less than 100 nanoseconds	15h	Greater than or equal to 10 nanoseconds and less than 50 nanoseconds	16h	Greater than or equal to 5 nanoseconds and less than 10 nanoseconds	17h	Greater than or equal to 1 nanosecond and less than 5 nanoseconds	FFh to 18h	Reserved
	Value	Description																																																		
	00h	Not Reported																																																		
	01h	Greater than or equal to 100 seconds																																																		
	02h	Greater than or equal to 50 seconds and less than 100 seconds																																																		
	03h	Greater than or equal to 10 seconds and less than 50 seconds																																																		
	04h	Greater than or equal to 5 seconds and less than 10 seconds																																																		
	05h	Greater than or equal to 1 second and less than 5 seconds																																																		
	06h	Greater than or equal to 500 milliseconds and less than 1 second																																																		
	07h	Greater than or equal to 100 milliseconds and less than 500 milliseconds																																																		
	08h	Greater than or equal to 50 milliseconds and less than 100 milliseconds																																																		
	09h	Greater than or equal to 10 milliseconds and less than 50 milliseconds																																																		
	0Ah	Greater than or equal to 5 milliseconds and less than 10 milliseconds																																																		
	0Bh	Greater than or equal to 1 millisecond and less than 5 milliseconds																																																		
	0Ch	Greater than or equal to 500 microseconds and less than 1 millisecond																																																		
	0Dh	Greater than or equal to 100 microseconds and less than 500 microseconds																																																		
	0Eh	Greater than or equal to 50 microseconds and less than 100 microseconds																																																		
	0Fh	Greater than or equal to 10 microseconds and less than 50 microseconds																																																		
	10h	Greater than or equal to 5 microseconds and less than 10 microseconds																																																		
	11h	Greater than or equal to 1 microsecond and less than 5 microseconds																																																		
	12h	Greater than or equal to 500 nanoseconds and less than 1 microsecond																																																		
	13h	Greater than or equal to 100 nanoseconds and less than 500 nanoseconds																																																		
	14h	Greater than or equal to 50 nanoseconds and less than 100 nanoseconds																																																		
	15h	Greater than or equal to 10 nanoseconds and less than 50 nanoseconds																																																		
	16h	Greater than or equal to 5 nanoseconds and less than 10 nanoseconds																																																		
	17h	Greater than or equal to 1 nanosecond and less than 5 nanoseconds																																																		
FFh to 18h	Reserved																																																			
4095:05	Reserved																																																			

4.1.3.TBD.2 Performance Attribute Identifier List

The Performance Attribute Identifier List contains the Performance Attribute Identifiers of the Vendor Specific Performance Attributes, as described in [Figure FigList](#).

Figure FigList: Performance Characteristics – Performance Attribute Identifier List

Bytes	Description											
00	Bits	Description										
	7:3	Reserved										
	2:0	Attribute Type: Each Performance Attribute Identifier in this list is the value of the Performance Attribute Identifier field in the Vendor Specific Performance Attribute reported in response to a Get Features command specifying a Select field set to the value of this field. The value of this field shall be equal to the value of the Select field of the Get Features command which specified this attribute.										
		<table><tr><th>Value</th><th>Description</th></tr><tr><td>000b</td><td>Current attribute</td></tr><tr><td>001b</td><td>Default attribute</td></tr><tr><td>010b</td><td>Saved attribute</td></tr><tr><td>All other values</td><td>Reserved</td></tr></table>	Value	Description	000b	Current attribute	001b	Default attribute	010b	Saved attribute	All other values	Reserved
		Value	Description									
		000b	Current attribute									
001b	Default attribute											
010b	Saved attribute											
All other values	Reserved											

Figure FigList: Performance Characteristics – Performance Attribute Identifier List

Bytes	Description
01	Maximum Saveable Vendor Specific Performance Attributes (MSVSPA): This field indicates the maximum number of Vendor Specific Performance Attributes which are able to be saved.
02	Unused Saveable Vendor Specific Performance Attributes (USVSPA): This field indicates the number of saveable Vendor Specific Performance Attributes which have not been saved. This field shall be set to a value less than or equal to MSVSPA.
15:03	Reserved
Performance Attribute Identifiers	
31:16	Performance Attribute C1h Identifier: Contains the Performance Attribute Identifier field of Vendor Specific Performance Attribute C1h.
47:32	Performance Attribute C2h Identifier: Contains the Performance Attribute Identifier field of Vendor Specific Performance Attribute C2h.
...	
1023:1008	Performance Attribute FFh Identifier: Contains the Performance Attribute Identifier field of Vendor Specific Performance Attribute FFh.
4095:1024	Reserved

The value of the MSVSPA field indicates the number of Vendor Specific Performance Attributes which may be saved. The Attribute Indexes of Vendor Specific Performance Attributes which have been saved may be discontinuous in the range C1h to FFh.

If a Set Features command specifies a Vendor Specific Performance Attribute (i.e., an Attribute Index field in the range of C1h to FFh and the value of the USVSPA field is cleared to 0h, then the controller shall abort that command with a status code of Invalid Field in Command.

The Performance Attribute Identifier List is reported separately for Current, Default, and Saved attributes. If bit 4 is set to '1' in the Optional NVM Command Support (ONCS) field of the Identify Controller data structure, a Get Features command specifies an Attribute Index field set to C0h, and the Select field is set to:

- Current (000b), then the controller reports a Performance Attribute Identifier List containing the Performance Attribute Identifier fields of the attributes reported in response to a Get Features command specifying a Select field set to Current and an Attribute Index set to a value in the range C1h to FFh;
- Default (001b), then the controller reports a Performance Attribute Identifier List containing the Performance Attribute Identifier fields of the attributes reported in response to a Get Features command specifying a Select field set to Default and an Attribute Index set to a value in the range C1h to FFh; or
- Saved (010b), then the controller reports a Performance Attribute Identifier List containing the Performance Attribute Identifier fields of the attributes reported in response to a Get Features command specifying a Select field set to Saved and an Attribute Index set to a value in the range C1h to FFh.

The Performance Attribute Identifier List is not able to be modified by a Set Features command specifying an Attribute Index field set to C0h. If a Set Features command is issued for this feature and specifies an Attribute Index field set to C0h, then the controller shall abort that command with a status code of Invalid Field in Command.

4.1.3.TBD.3 Vendor Specific Performance Attribute

The Vendor Specific Performance Attribute is described in **Figure FigVS:**

Figure FigVS: Performance Characteristics – Vendor Specific Performance Attribute

Bytes	Description
15:00	Performance Attribute Identifier: This field contains an identifier describing the contents of the Vendor Specific field. Unused Vendor Specific Performance Attributes shall clear this field to 0h. It may be desirable for this field to be universally unique. In that case this field should be compatible with the 128-bit Universally Unique Identifier (UUID) specified in RFC 4122. Refer to the NVMe Base Specification.
29:16	Reserved
31:30	Attribute Length: Indicates the number of valid bytes in the Vendor Specific field. The value shall be in the range 0h to FE0h.
4095:32	Vendor Specific

Description of Specification Changes for NVM Express® Management Interface Specification 1.2a

5 NVM Express Admin Command Set

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5.5 Set Features and Get Features

...

Figure 126: Management Endpoint - Feature Support

Feature Name ²	Feature Identifier	SMBus/I2C Feature Support Requirements ¹		PCIe VDM Feature Support Requirements ¹	
		NVMe Storage Device	NVMe Enclosure	NVMe Storage Device	NVMe Enclosure
...					
Performance Characteristics	1Ch	O	P	O	P
...					