Client NVMe™ SSD Objectives and Opportunities

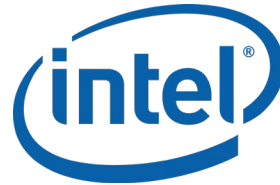**Sponsored by NVM Express™ organization, the owner of NVMe™, NVMe-oF™ and NVMe-MI™ standards**

Speakers

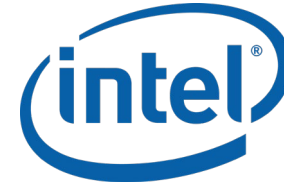Lee Zaretsky

Shivashekar Muralishankar

Romesh Trivedi

Client NVMe™ SSD Objectives and Opportunities

Lee Zaretsky, Distinguished Engineer, Dell

Agenda

Client storage strategic vision

Industry trends impacting client storage

Client classes of SSDs

Relevant form factors

Emergence of PCIe® 4.0

Dell view of different NVMe™ SSD classes

Summary

Epilogue: NVMe SSDs and hard drives

Client Storage Vision

Key Point: Client NVMe™-based SSD storage directly contributes to a positive end-user experience of responsiveness and mobility

Client NVMe solutions impact these areas:

- Performance → "System responds smoothly"

- Physical footprint → "System is smaller, thinner, lighter"

- Power → "System runs all day"

Trends Impacting Client Storage

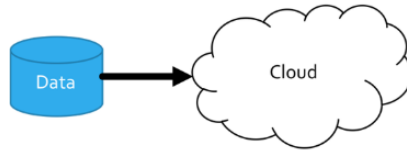| Ultra Mobility	Remote Storage	Massive Content	Professional & Pro-Consumer
Thinner, lighter, faster, with all day operation	End user data shift to remote location	Massive content creation that is used ubiquitously	Ultra performance devices utilized by high end consumer/ professional

Data Security

Cloud

Data

BIG
DATA

Intelligent Data Policies

Client SSD "Classes"

Performance Class
Best SUSTAINED performance

→ NVMe™ enables sustained performance at largest capacities

Best sustained performance within power constraints

Mainstream Class
Optimized for Client "bursty" workloads

→ NVMe enables peak performance at optimized capacities and form factors

Best burst performance within power/thermal constraints

Value Class
All about COST within constraints

→ NVMe enables performance while allowing for cost effective storage devices
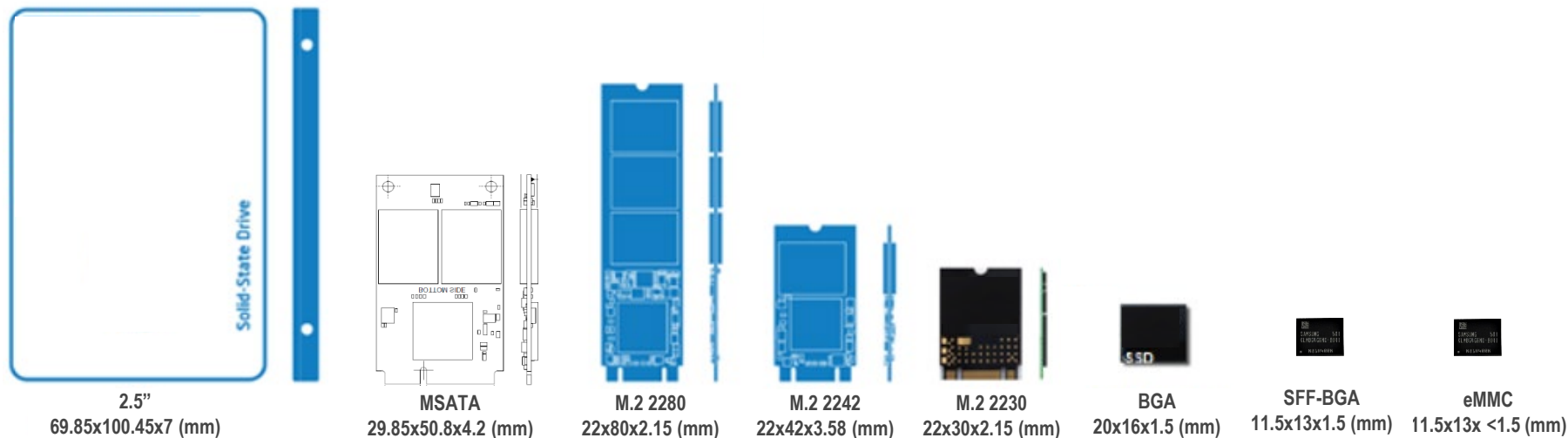
Optimizing cost with good performance

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It's all about form factors…

Diversity of customer workloads, usages and expectations drives the need for a diversity of SSD offerings

| 2.5"
69.85x100.45x7 (mm) | MSATA
29.85x50.8x4.2 (mm) | M.2 2280
22x80x2.15 (mm) | M.2 2242
22x42x3.58 (mm) | M.2 2230
22x30x2.15 (mm) | BGA
20x16x1.5 (mm) | SFF-BGA
11.5x13x1.5 (mm) | eMMC
11.5x13x <1.5 (mm) |

There are more form factors defined than those shown here, however these have proven to be the ideal balance between cost, capacity, and portfolio complexity for Client products

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PCIe® 4.0 is coming to Client

Emergence of PCIe® 4.0 for Client storage is a tradeoff between performance and power efficiency

Optimize for best bandwidth

Optimize for best lane usage

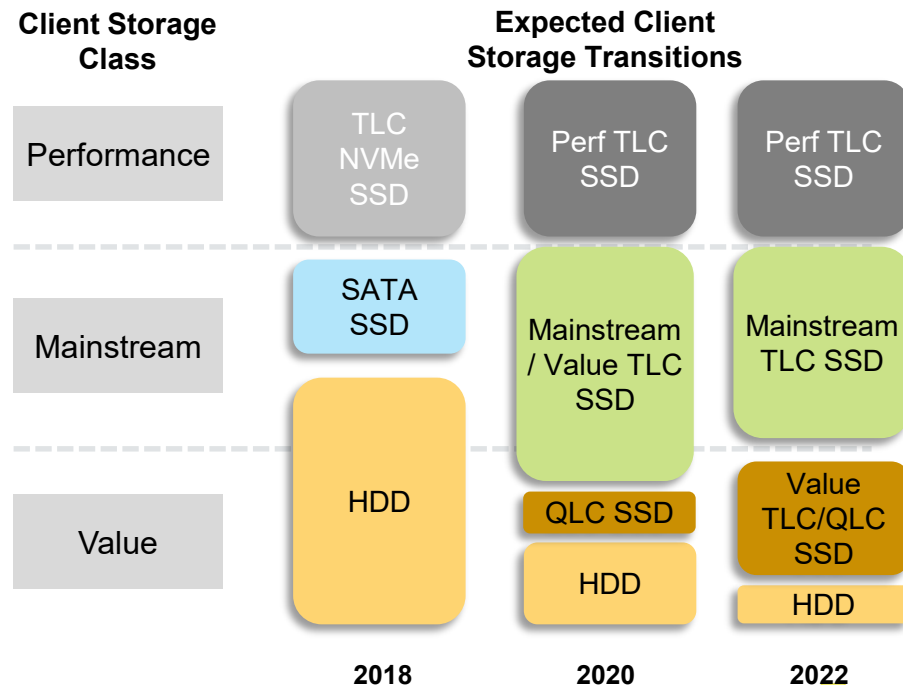Optimize for best power efficiency

By 2021, we expect all NVMe™ SSDs to be PCIe 4.0 capable

Dell view of different NVMe™ SSD classes

QLC vs TLC in Client NVMe™ storage:

- <u>QLC will not replace TLC NAND</u>, but will coexist in different product spaces

- TLC will continue to be the choice for performance and reliability

- QLC may displace HDDs in mainstream products, but HDDs will continue to offer the lowest cost opportunity for select entry products

- QLC supplier implementations are too scattered, reducing the opportunity for multi-sourcing

- As with TLC, QLC offers a much smaller physical footprint than a HDD, allowing for a good balance between cost and size

Client Storage Class

Expected Client Storage Transitions

Client Storage Class	2018	2020	2022
Performance	TLC NVMe SSD	Perf TLC SSD	Perf TLC SSD
Mainstream	SATA SSD	Mainstream / Value TLC SSD	Mainstream TLC SSD
Value	HDD	QLC SSD / HDD	Value TLC/QLC SSD / HDD

NVMe is now pervasive across <u>all</u> SSD storage classes, and continues to provide value independent of NAND technology

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Summary

- There is a wide diversity of Client NVMe^{TM} products based on varied customer needs

- Responsiveness matters to the end-user

- NVMe SSDs offer value in performance, physical size (mobility) and power efficiency (battery runtime)

- Smaller SSD form factors provide space for additional system features and capabilities

- Interface and media technologies continue to evolve, offering new benefits and challenges

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Epilogue: The value of NVMe™ SSDs and the need for hard drives

NVMe SSDs offer a balance between performance, capacity and footprint which is needed to meet a diverse range of Client workloads

And, we don't expect HDDs to disappear from the Client portfolio anytime soon

- They continue to offer the best cost/bit
- They offer large capacities that can address many customer usages
- They are a good fit for "cheap and deep" secondary data storage on the system

The direction of the Client products is toward NVMe SSDs across the portfolio, but we envision continuing to utilize HDD storage opportunistically

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SSDs in Client Platform: What should be the design focus?

Arijit Chattopadhyay, Client Storage Solution Architect, Intel

Shivashekar Muralishankar, Systems Engineer, Intel

Romesh Trivedi , Principal Engineer , Intel

Legal Disclaimer

Agenda

Overview

Workload Analysis

Summary & Conclusion

Overview

Overview

- Key Client Platform segment requirements:

  - Most laptops – Responsiveness (Performance) and Battery Life (Power) for common real-life client workloads

  - High-end Desktop (HEDT) & high-performance laptops (HENB: gaming, content creation) – Performance and higher capacity

- Storage subsystem in these platforms are expected to be tuned accordingly

- Most client SSDs in market today are tuned for performance, especially at high Queue Depth

  - With ever-increasing adoption of SSD in laptops, is this the right design choice?

  - How important is high Queue Depth for real-life client workloads?

Workload Analysis

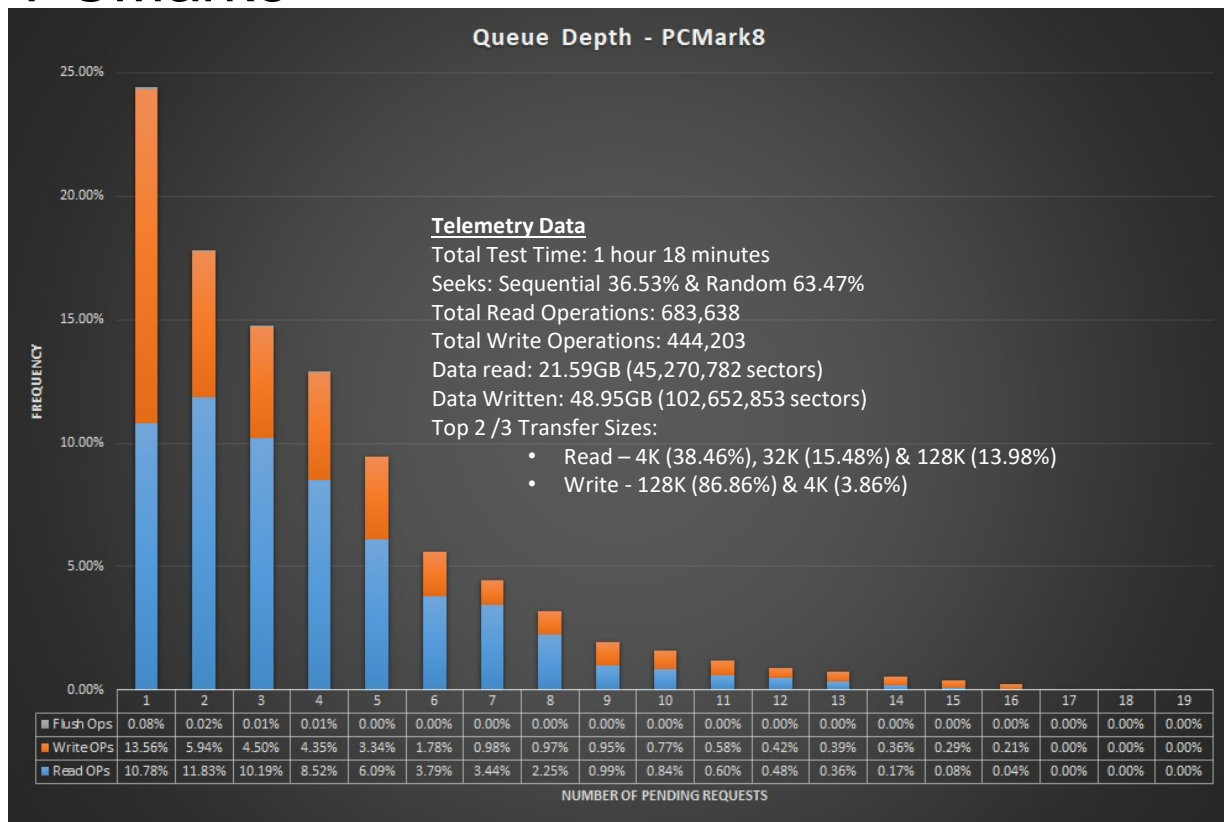**PCMark8* benchmark and other real-life client workloads**

PCMark8*

Queue Depth - PCMark8

Telemetry Data
Total Test Time: 1 hour 18 minutes
Seeks: Sequential 36.53% & Random 63.47%
Total Read Operations: 683,638
Total Write Operations: 444,203
Data read: 21.59GB (45,270,782 sectors)
Data Written: 48.95GB (102,652,853 sectors)
Top 2 /3 Transfer Sizes:
- Read – 4K (38.46%), 32K (15.48%) & 128K (13.98%)
- Write - 128K (86.86%) & 4K (3.86%)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Flush Ops	0.08%	0.02%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Write OPs	13.56%	5.94%	4.50%	4.35%	3.34%	1.78%	0.98%	0.97%	0.95%	0.77%	0.58%	0.42%	0.39%	0.36%	0.29%	0.21%	0.00%	0.00%	0.00%
Read OPs	10.78%	11.83%	10.19%	8.52%	6.09%	3.79%	3.44%	2.25%	0.99%	0.84%	0.60%	0.48%	0.36%	0.17%	0.08%	0.04%	0.00%	0.00%	0.00%

NUMBER OF PENDING REQUESTS

FREQUENCY

Key Learnings:

- PCMark8 is dominated by QD=1-6, more than 80%

- Performance of the SSD at lower QD will have significant contribution to the benchmark score

System Details:
Platform : Intel® 9 Series
CPU : Intel® Core™ i7-8700
DDR: 16GB DDR-4
Source: Intel tested

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MobileMark14*

Queue Depth - MobileMark14

FREQUENCY (y-axis: 0.00% to 100.00%)

Telemetry Data
Total Test Time: 2 hour 28 minutes
Seeks: Sequential 34.01% & Random 65.99%
Total Read Operations76,794
Total Write Operations: 64,393
Data read: 1.97GB (4,140,697 sectors)
Data Written: 2.81GB (5,893,318 sectors)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
■ Flush Ops	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
■ Write OPs	36.	3.5	1.5	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
■ Read OPs	48.	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

NUMBER OF PENDING REQUESTS

Key Learnings:

- MobileMark14 is dominated by QD=1, more than 80%

- Performance of the SSD at lower QD will have significant contribution to the benchmark score

System Details:
Platform : Intel® 9 Series
CPU: Intel® Core™ i5 processor
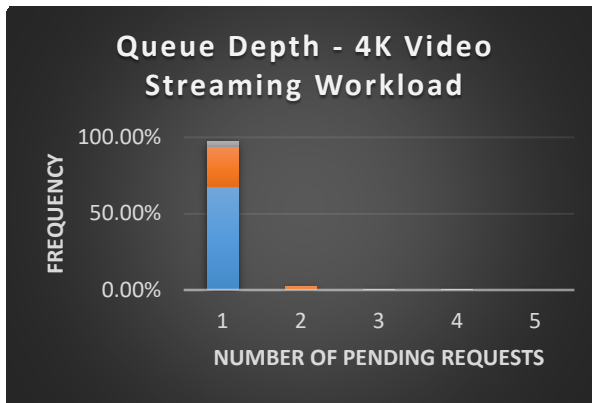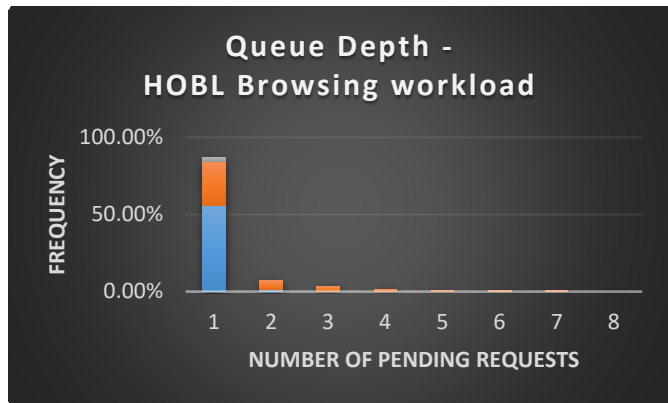DDR: 16GB DDR-4
Source: Intel tested

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Real-life client workloads: No surprises! QD=1 dominates.

HOBL = Hours of Battery Life; workloads defined by Microsoft

Key Learnings

- Each of these typical client workloads are dominated by QD=1
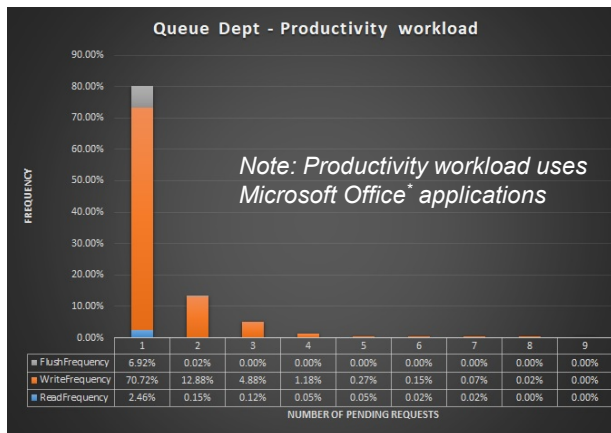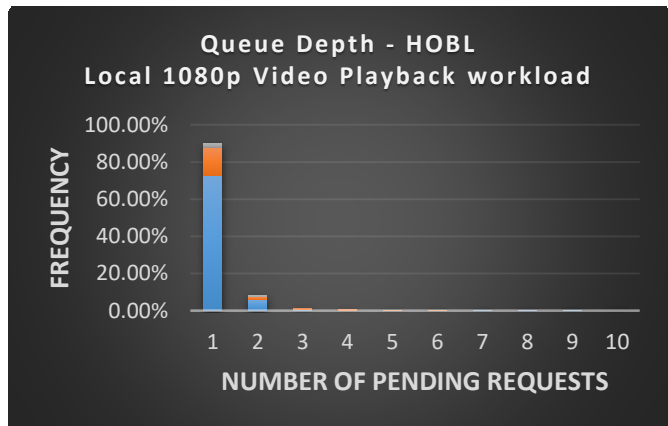
System Details:
Platform : Intel® 8 Series
CPU: Intel® Core™ i5 processor
DDR: 16GB DDR-4
Source: Intel tested

Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance. Consult other sources of information to evaluate performance as you consider your purchase. For more complete information about performance and benchmark results, visit www.intel.com/benchmarks

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

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Conclusion

Summary & Conclusion

- Summary of workload analysis:

  - All the workloads under test show "lower queue depth", especially QD=1-4, is of prime importance for client platforms

  - None of these workloads show any activity in storage subsystem above QD >16, typically above QD=8

- Conclusion:

  - SSD design focus with higher performance at lower queue depth enhances user experience due to improved responsiveness for client workloads.

  - Evaluation and benchmarks of SSD's performance in client usage should focus on lower Queue Depth operations rather than higher QD.

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Questions?