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MAKING NAND BETTER

SSD Design Considerations for Ultra-Low Latency

Bernie Rub

Introduction

This presentation will touch on a few design considerations related to making SSDs faster and more responsive:

- How do latency and IOPS specs relate to actual usage?
- In the evolution towards lower latency, what's after PCIe?
- Is it better to have one high capacity device or many small ones?
- Why write intensive workloads benefit most from reduced latency
- How increasing IOPS impacts endurance

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Acknowledgement

- Some of the materials for this presentation have been provided by Diablo Technologies

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Increasing Demand for Fast & Responsive Storage

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Financial Services	Database/ Cloud	Virtualization	Blade Server	Big Data Analytics
				
• Low, deterministic latency transactions • Fast Interactive Data Analysis	• Increase Transactions per Second • Memcached consolidation	• Enable increased VMs per Node • Reduce capex and opex • Fast response times per VM	• Enable high density storage blades • Utilize empty DIMM slots	• Increase transactions per second • Reduce response times for analytics queries

Higher IOPS & Reduced, Deterministic Response Time

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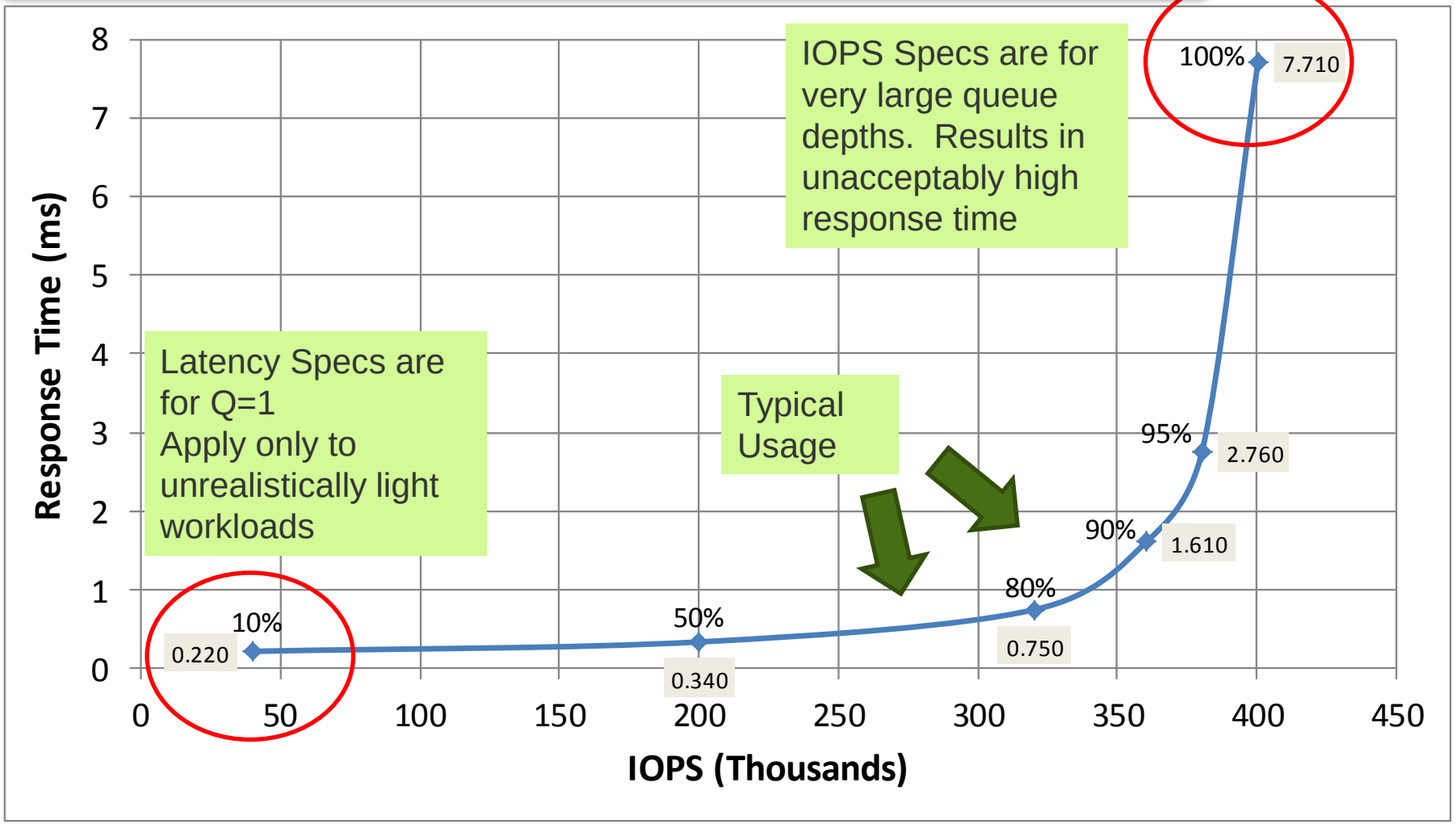
Typical Performance Curve

Opposite Trends for IOPS and Response Time



Example: SPC Benchmark 1 Executive Summary
TMS RamSan-630

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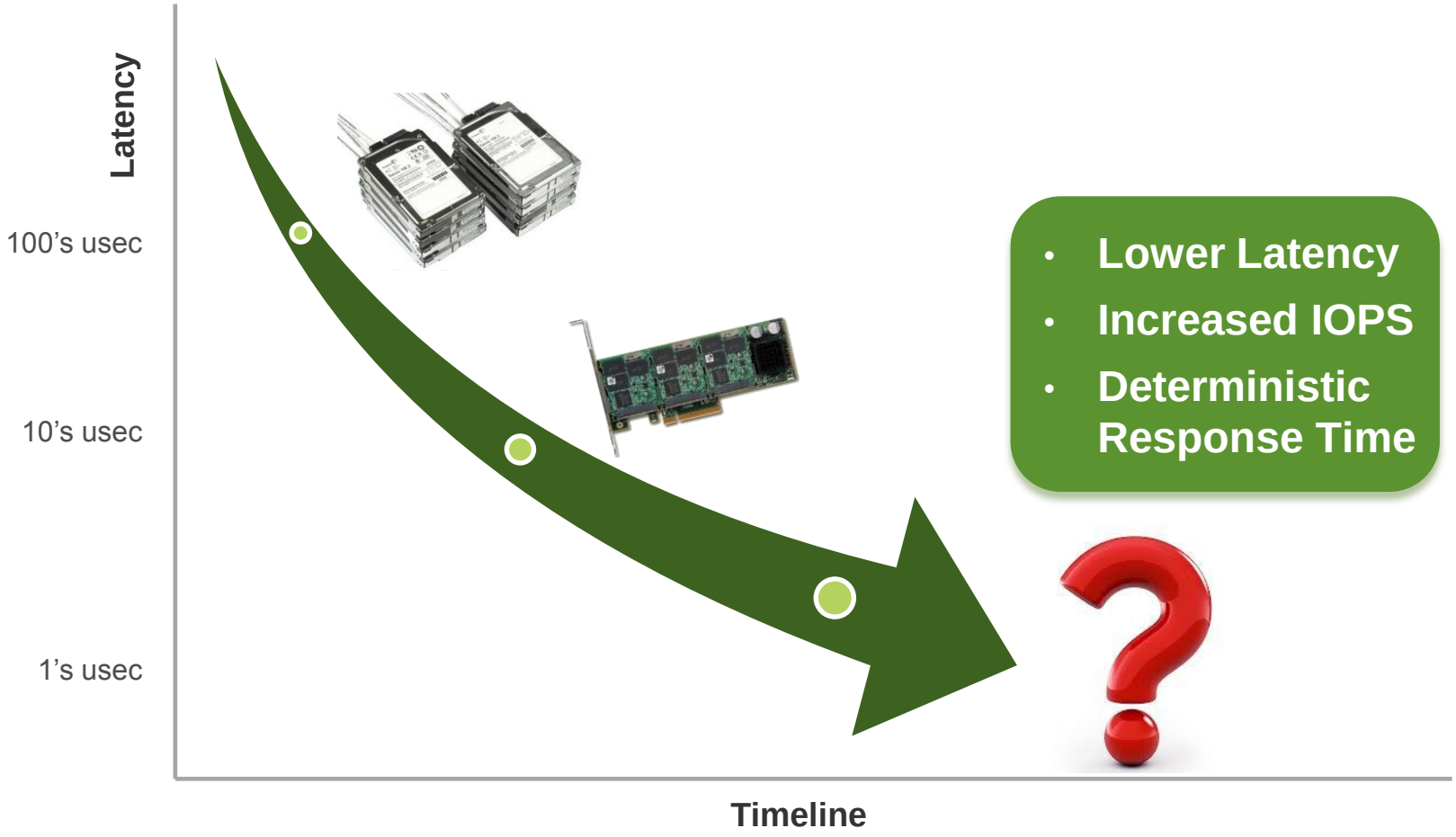
The Path to Ultra Low Latency



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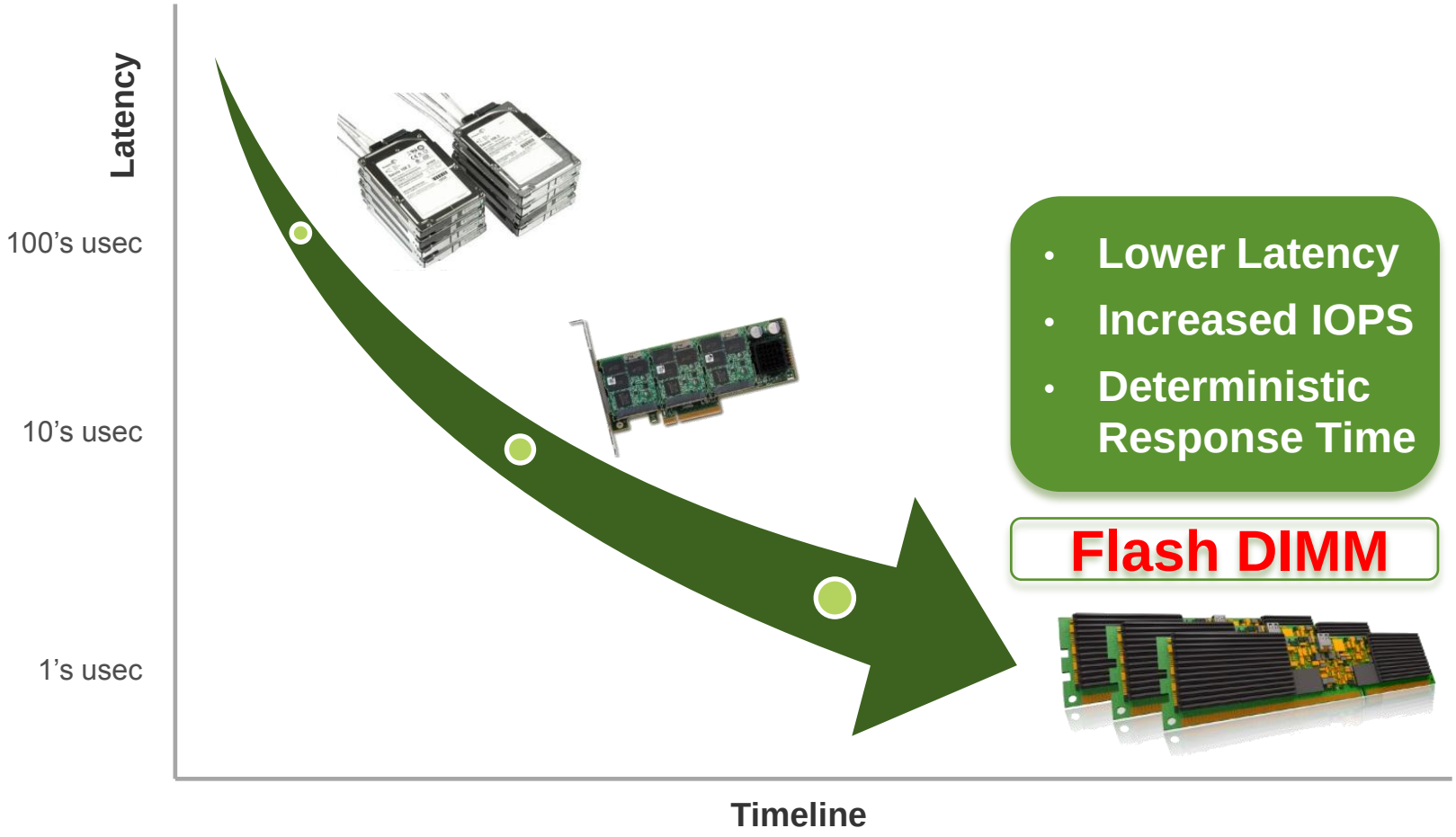

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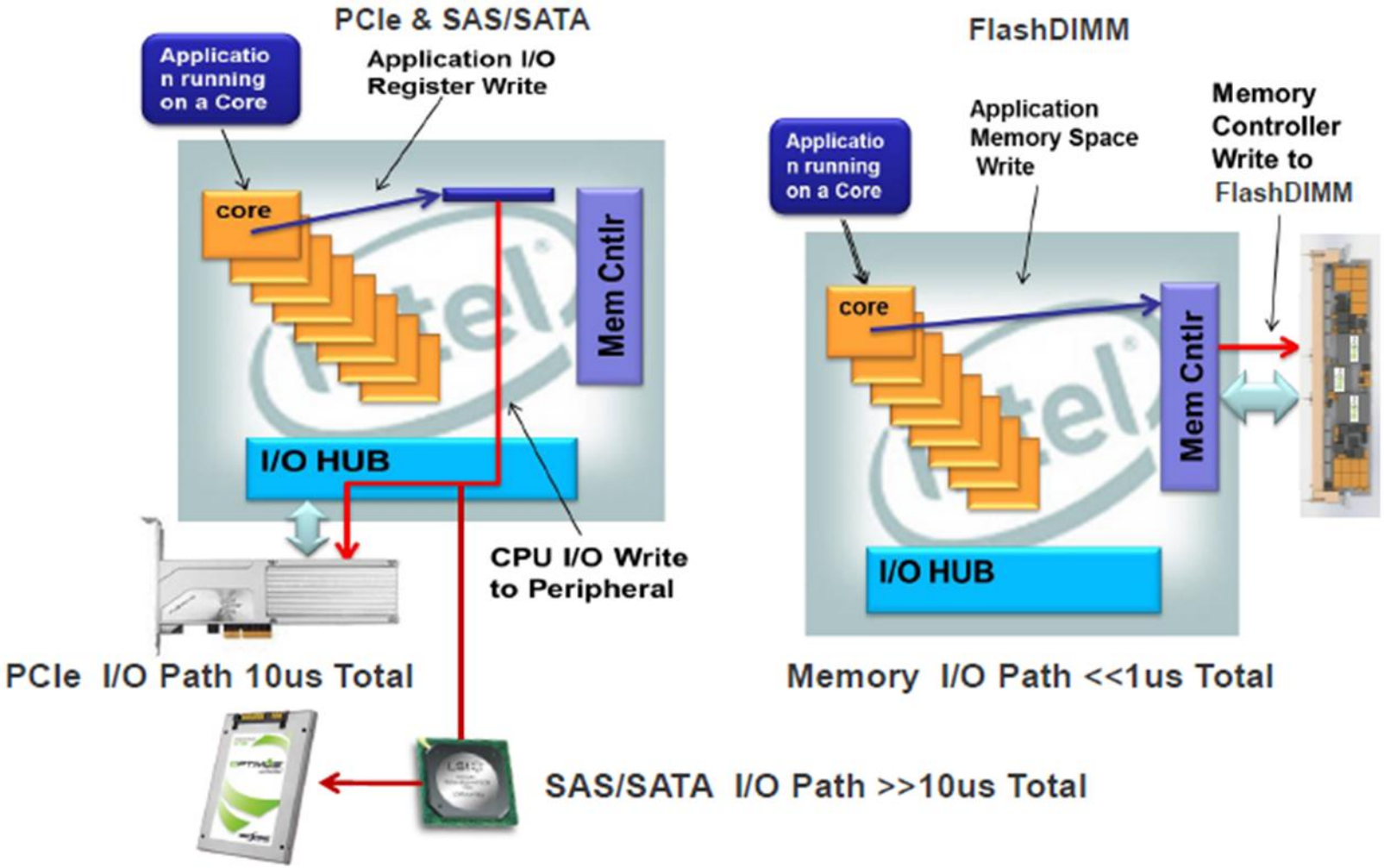
FlashDIMM Principle



Memory Controller Path provides > 10X lower latency and 2X higher bandwidth

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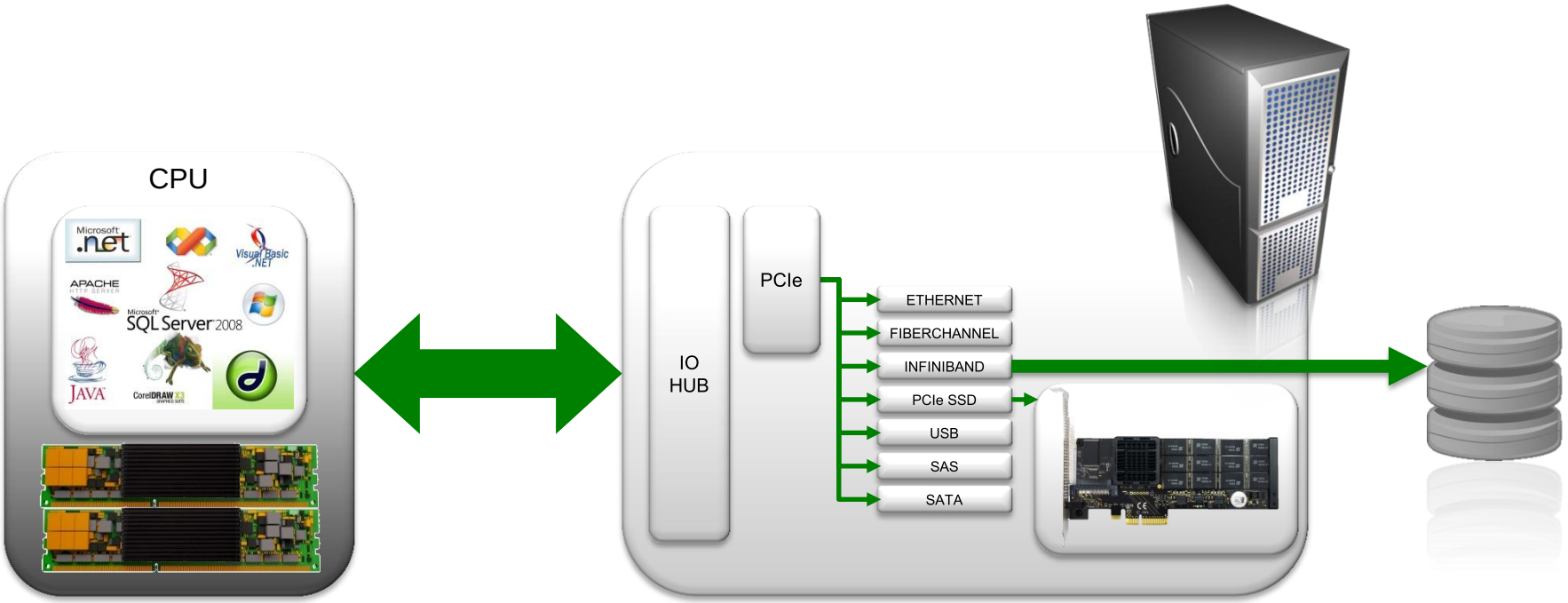
Reducing Latency and Improving Predictability



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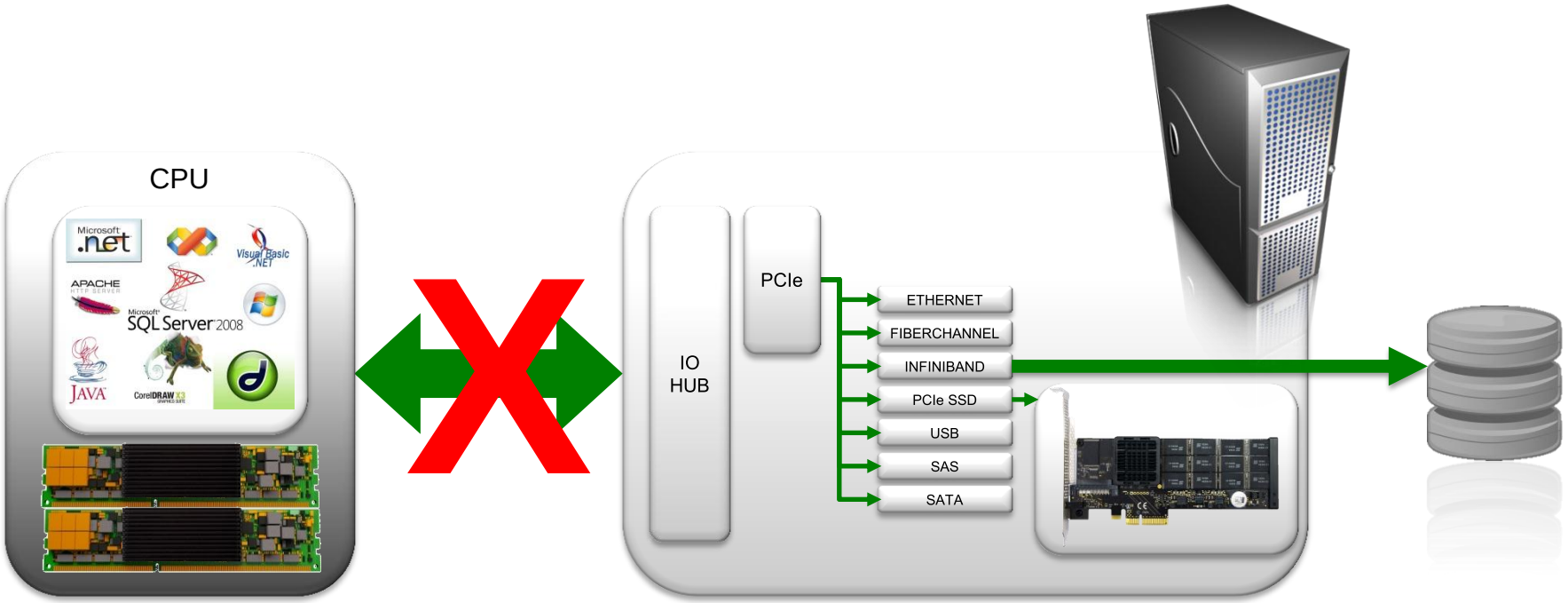
Reducing Latency and Improving Predictability



Connecting Flash to the Memory Bus eliminates arbitration and data contention on the I/O hub

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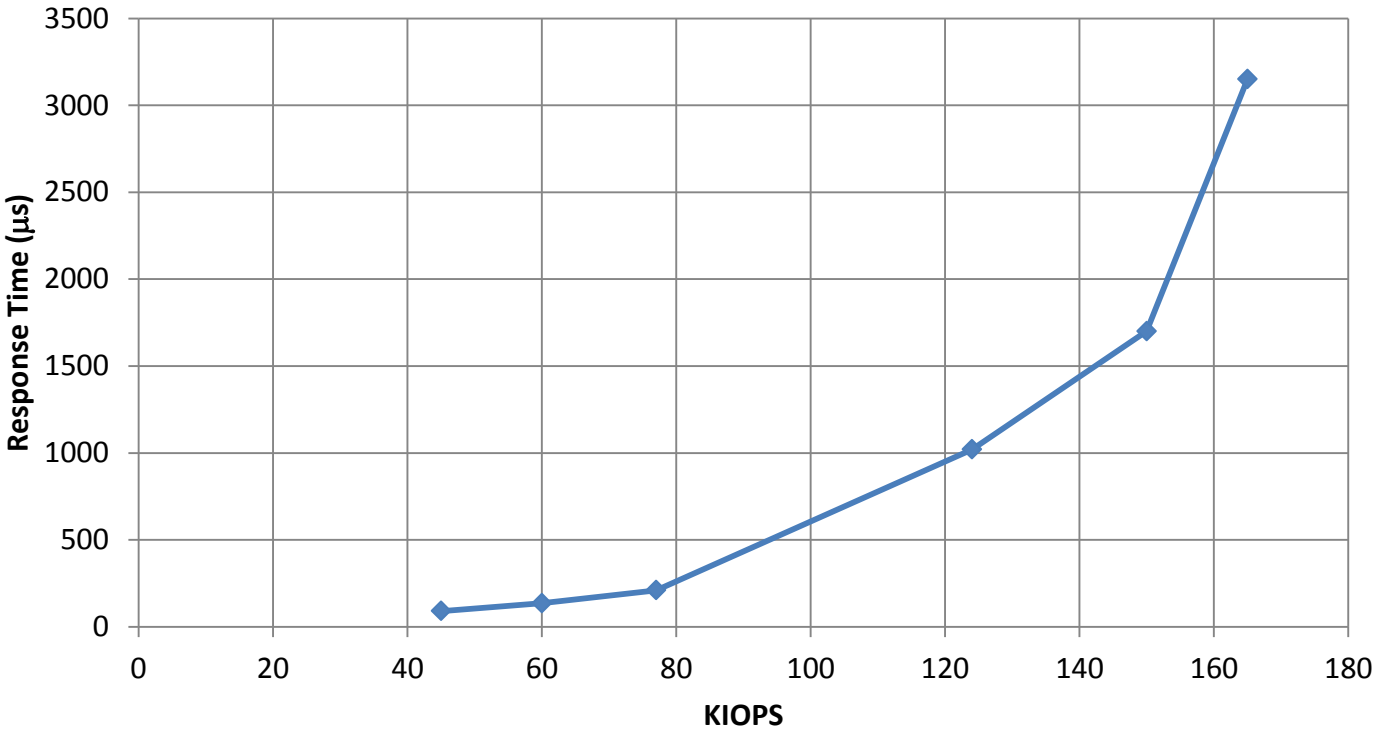
Measured Performance on PCIe SSD



- Mixed Workload: 70% Read / 30% Writes
- Response time with very light loads (latency) is dominated by flash read time
- Huge increase in response time with heavy loads

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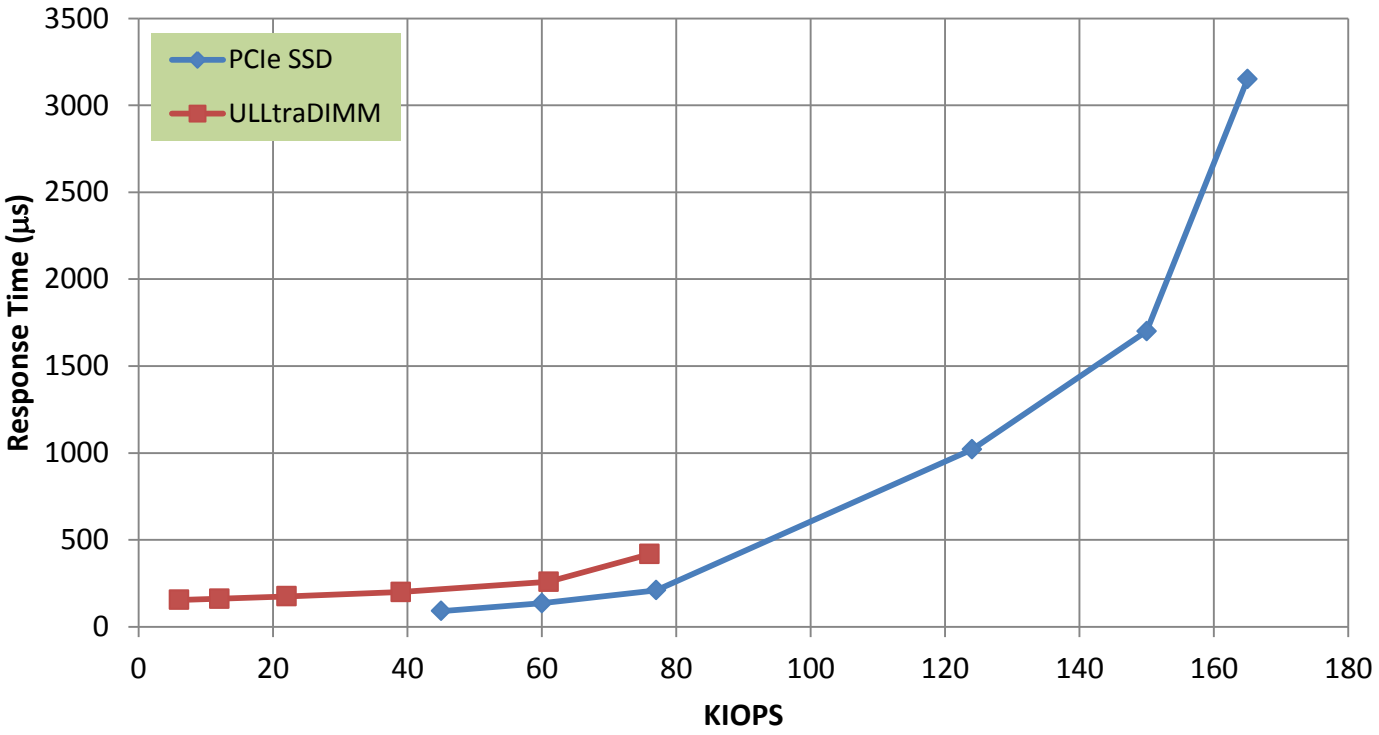
PCIe SSD vs. Flash DIMM
(70/30 workload)



- For mixed workloads, latency is dominated by flash read time
- In this example, FlashDIMM with MLC has higher latency than PCIe SSD with SLC

*** ULLtraDIMM is a Flash DIMM product jointly developed by Smart Storage Systems and Diablo Technologies**

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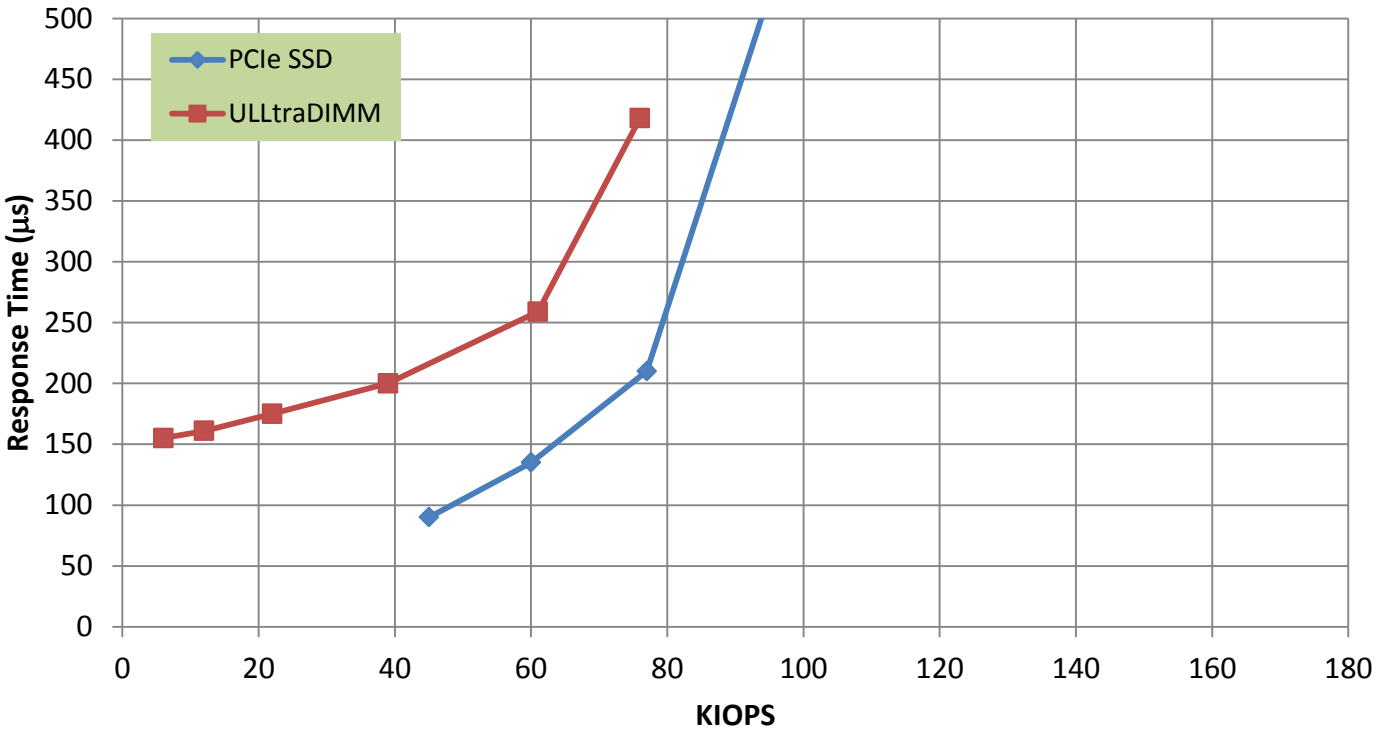
PCIe SSD vs. Flash DIMM
(70/30 Workload – Expanded View)



- For read or mixed workloads, latency is dominated by flash read time
- In this example, FlashDIMM with MLC has higher latency than PCIe SSD with SLC

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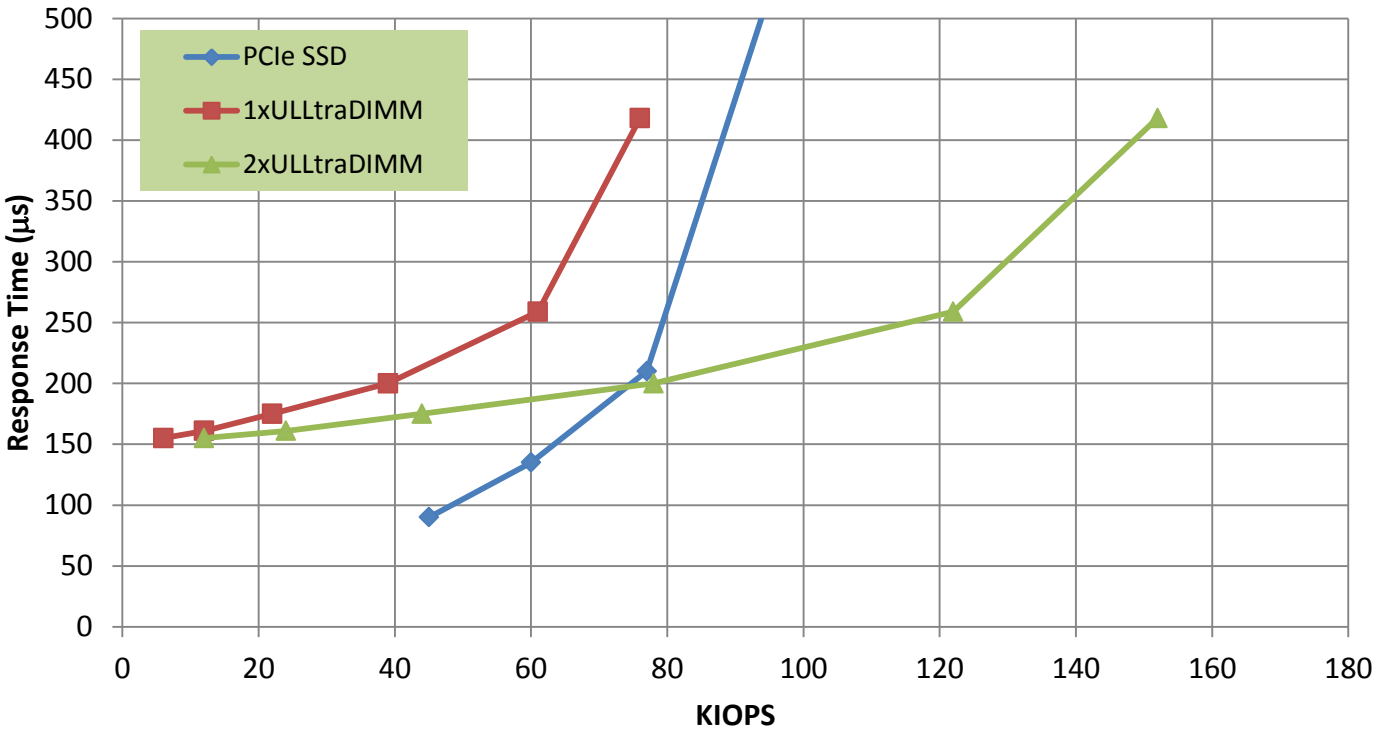
PCIe SSD vs. Flash DIMM



Linear scaling of IOPS with constant Response Time

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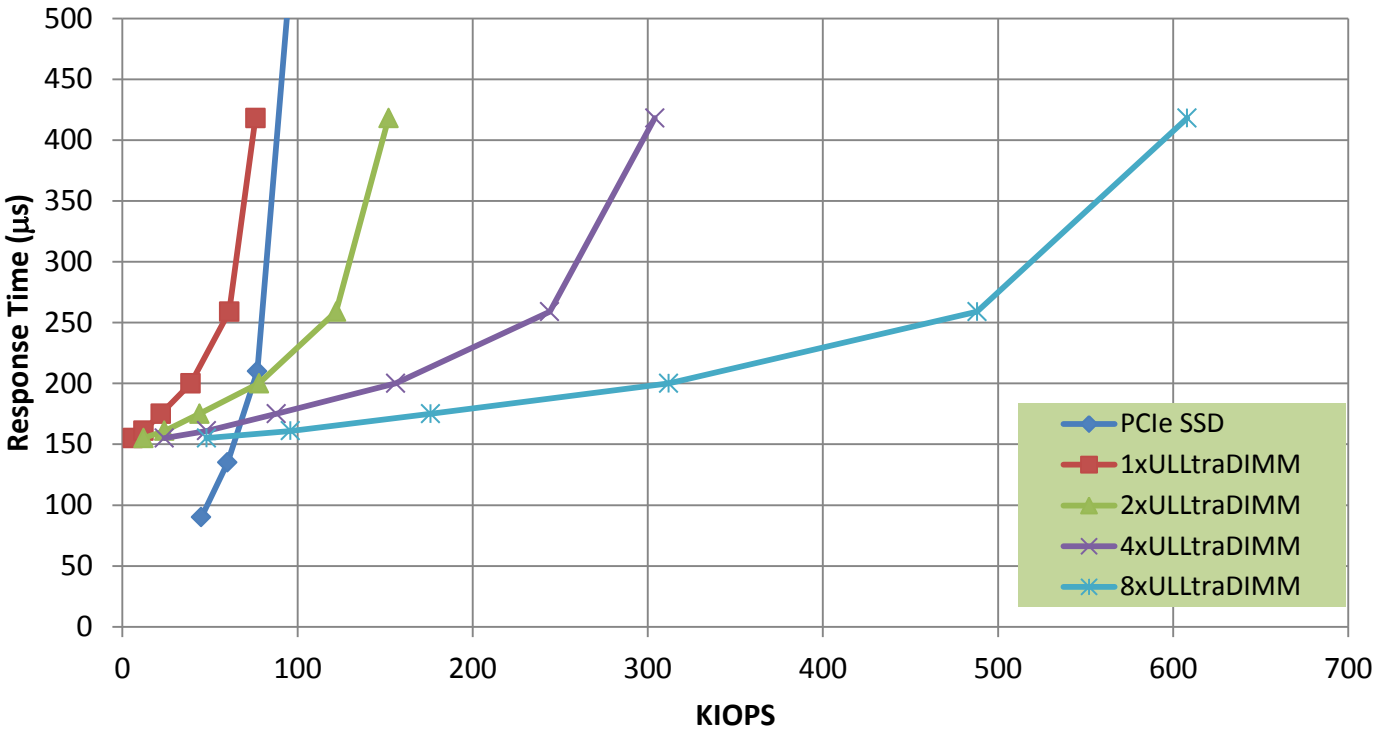
Scaling with 8 Flash DIMMs



Linear scaling of IOPS with constant Response Time

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Flash DIMM Advantage for Write Workloads

- Many applications are sensitive to write latency
  - Processes that wait for writes to complete, e.g.
    - ✓ Transactional Databases logging
    - ✓ Virtual Desktop check pointing
- Write latencies in storage devices
  - Most storage devices incur significant latency performing the physical write to the media
  - High performance SSDs significantly reduce this latency
    - ✓ Write data is immediately saved in power safe storage within controller
    - ✓ Return of status is not gated by writing to flash
    - ✓ Response time is dominated by IO Path
- By drastically reducing the IO path delays, Flash DIMM can achieve write latency << 10 μs!

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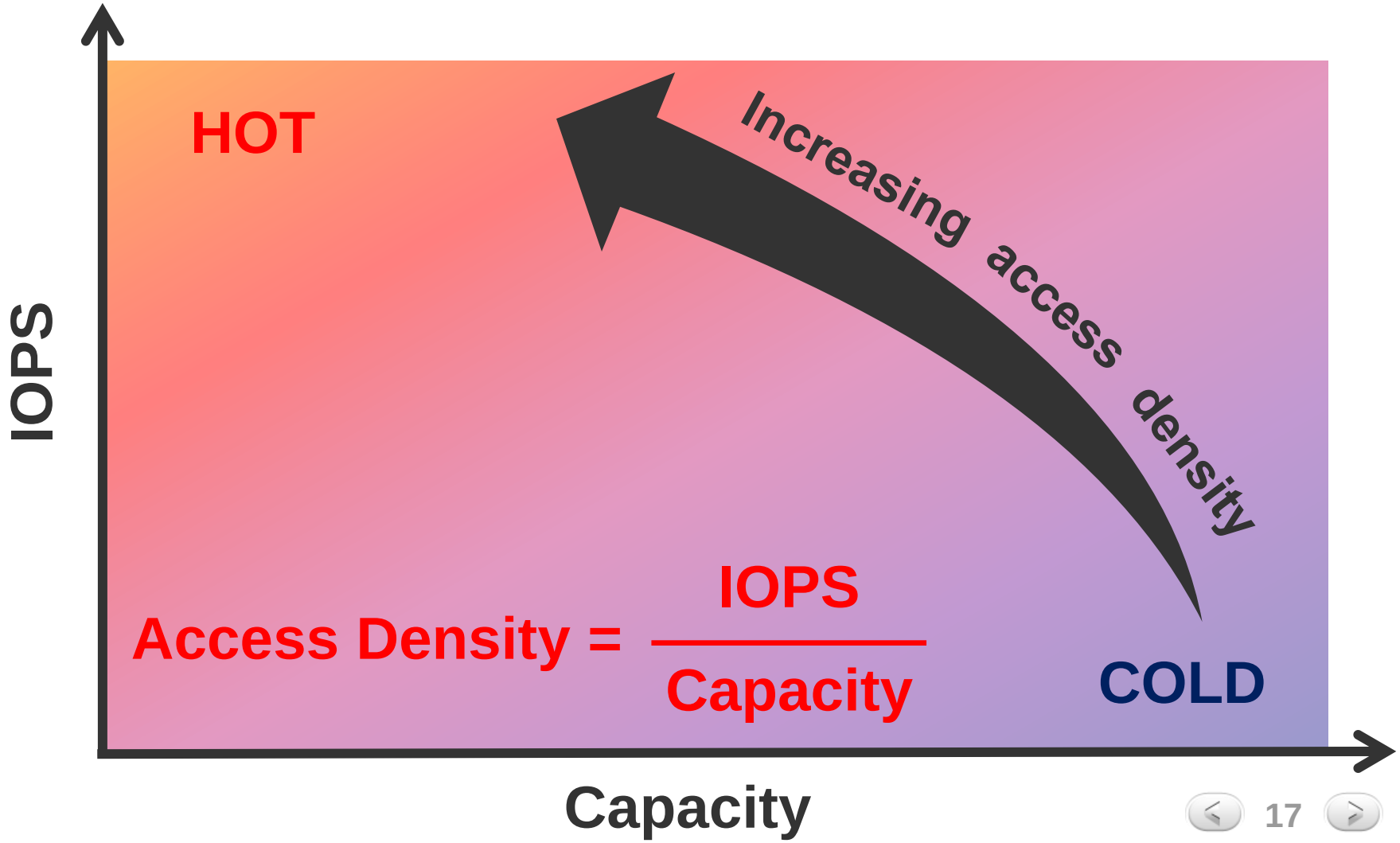
Impact of Increasing Access Density

Access density quantifies the IO intensity of a workload



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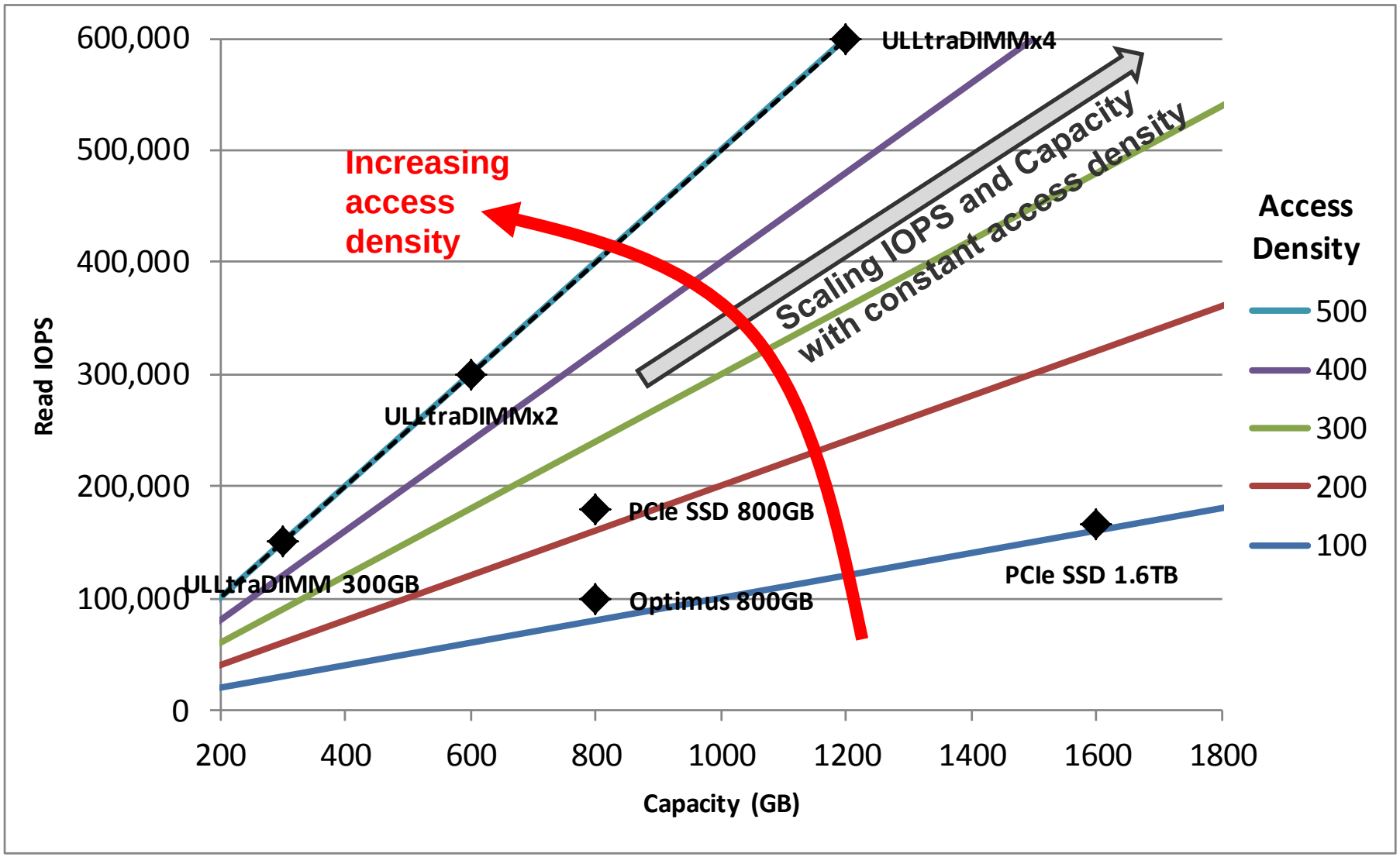

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Endurance vs. Access Density

Drive Writes per Day for Sustained 70/30 Read/Write Workload

4KB Seconds per day

$$DWPD = \frac{\text{Write IOPS} \cdot \text{IOSize} \cdot 86{,}400}{\text{Capacity(B)}}$$

$$\text{Write IOPS} = \text{Read IOPS} \cdot \rho \cdot \%\text{Write}$$

Relative IOPS for 70/30 workload

30%

$$DWPD = \frac{\text{Read IOPS}}{\text{Capacity(GB)}} \cdot 5.3\text{E-}2$$

Access Density

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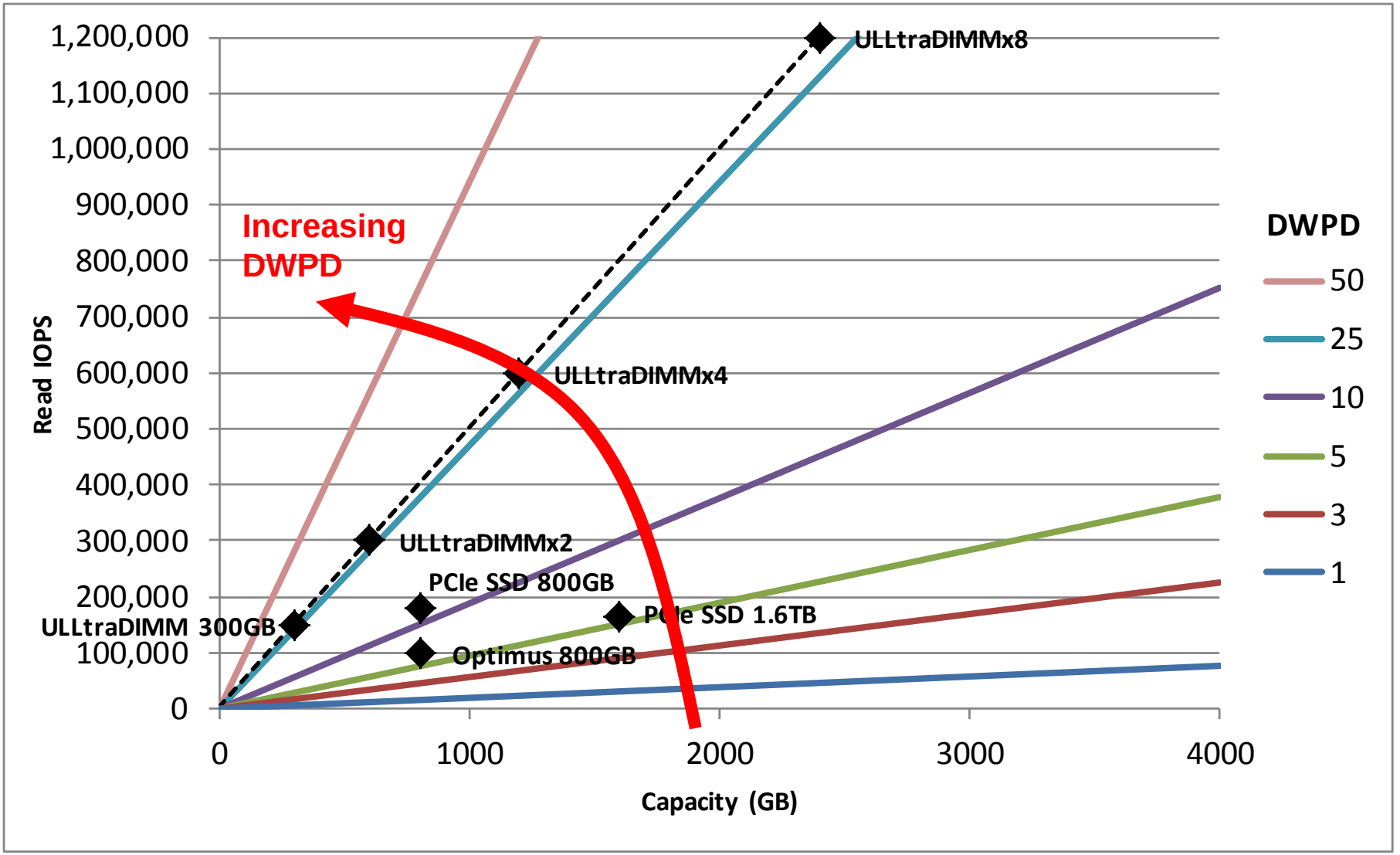
Endurance vs. Access Density



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Summary

- FlashDIMM reduces the IO overhead by connecting directly to the memory controller and bypassing the IO hub
- Modular storage elements scale IOPS without increasing latency
- Multiple FlashDIMMs outperform a single larger capacity PCIe SSD
- Required endurance is proportional to the access density
- Higher endurance is required to service “hotter” workloads

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