



Flash Memory Summit

Tri-Hybrid SSD with storage class memory (SCM) and MLC/TLC NAND Flash Memories

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Outline

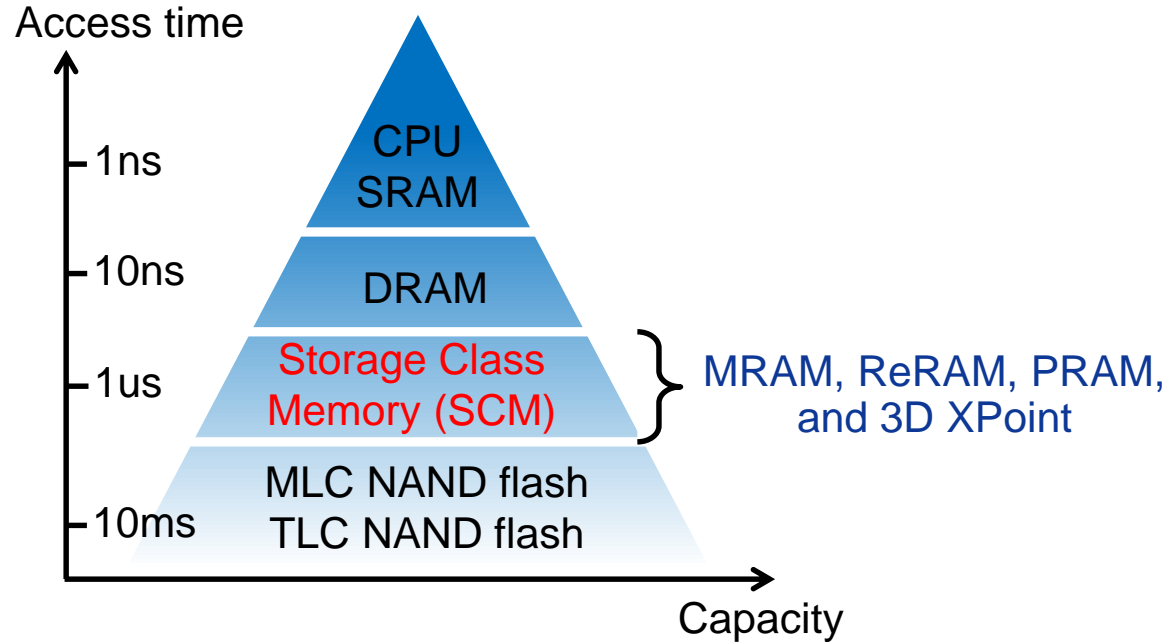
- Introduction
- Hybrid SSDs with
 1. MLC and TLC NAND flash memories
 2. SCM and MLC NAND flash memory
 3. SCM, MLC and TLC NAND flash memories
- Summary



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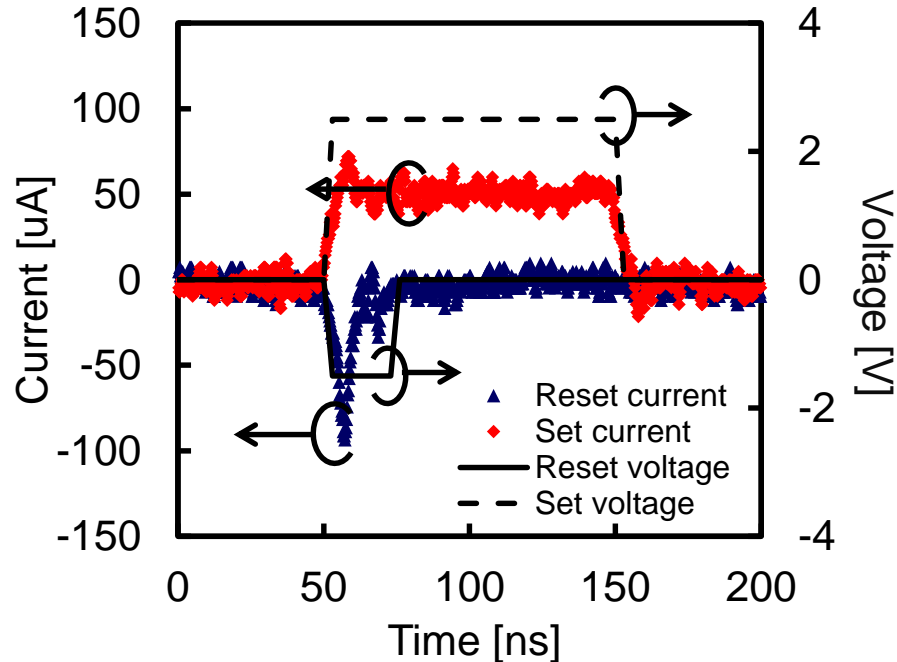
SCM and NAND Flash Memory in Memory Hierarchy





ReRAM Set/Reset Time

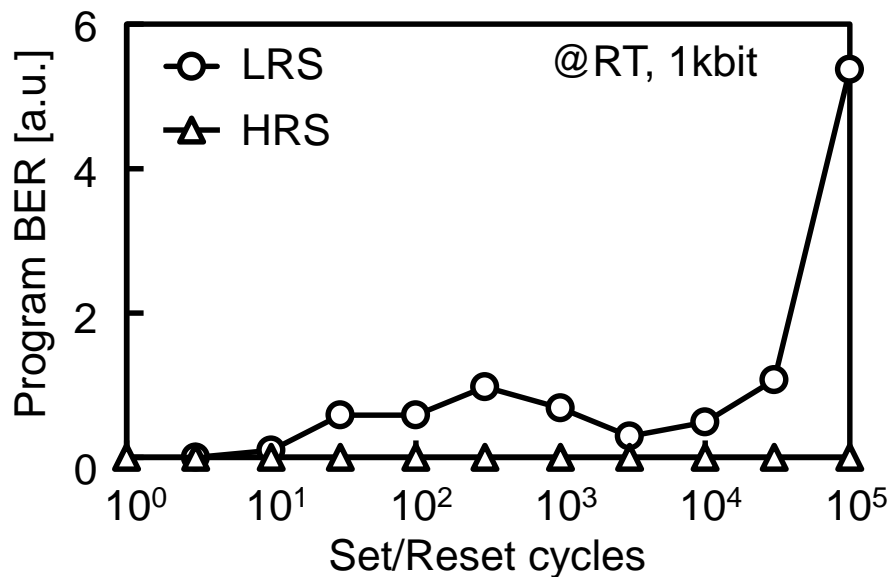
- Short set/reset time if no verify operation





Program Error in ReRAM

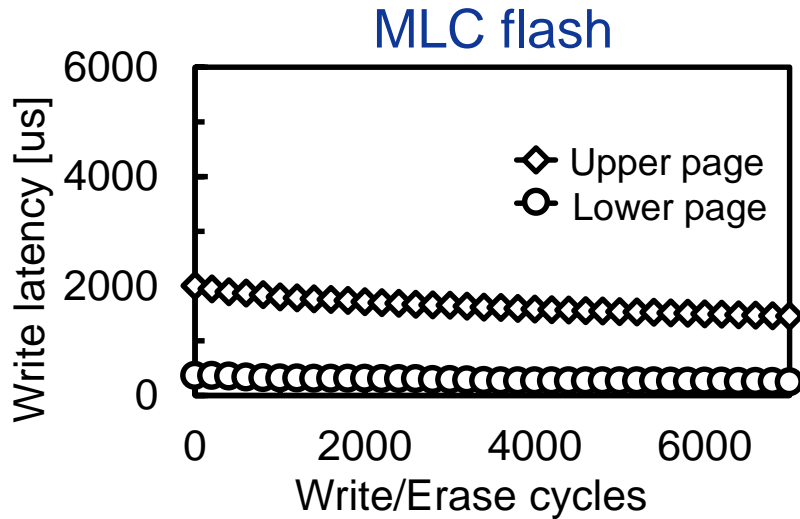
- Program BER increases with set/reset cycles



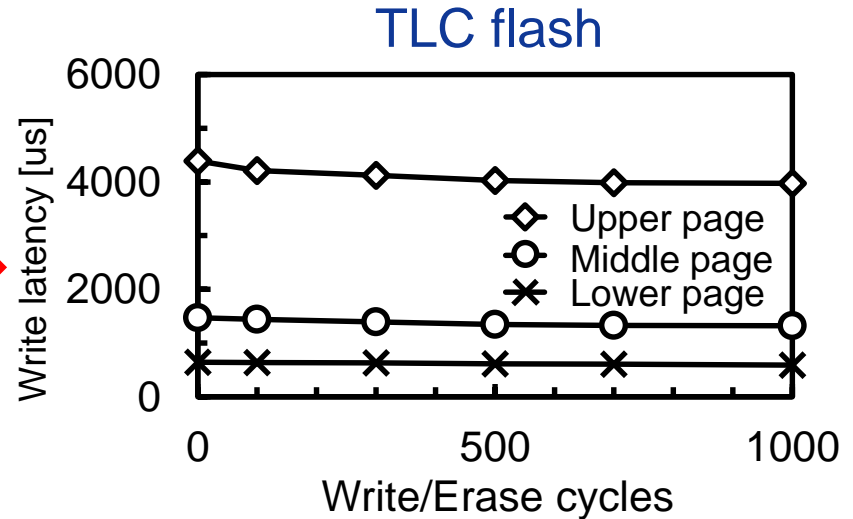


MLC and TLC NAND Flash Latency

- TLC flash has longer read/write latency than MLC flash



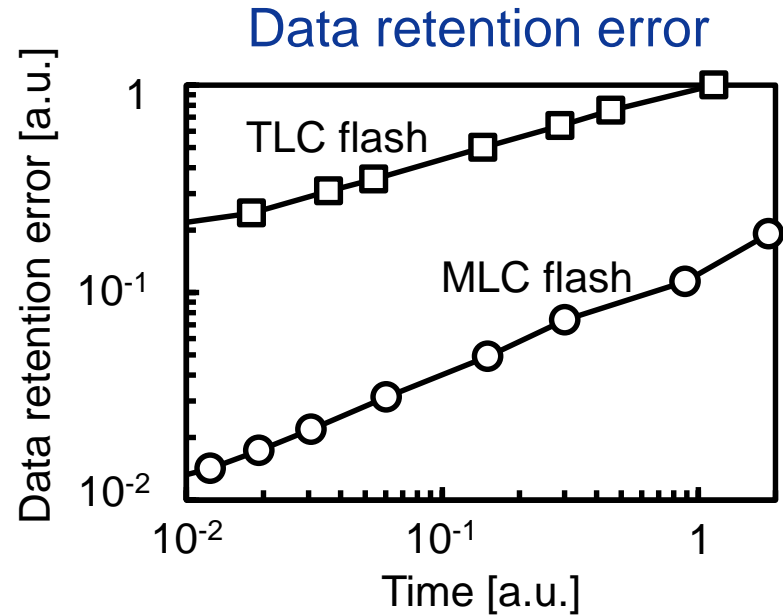
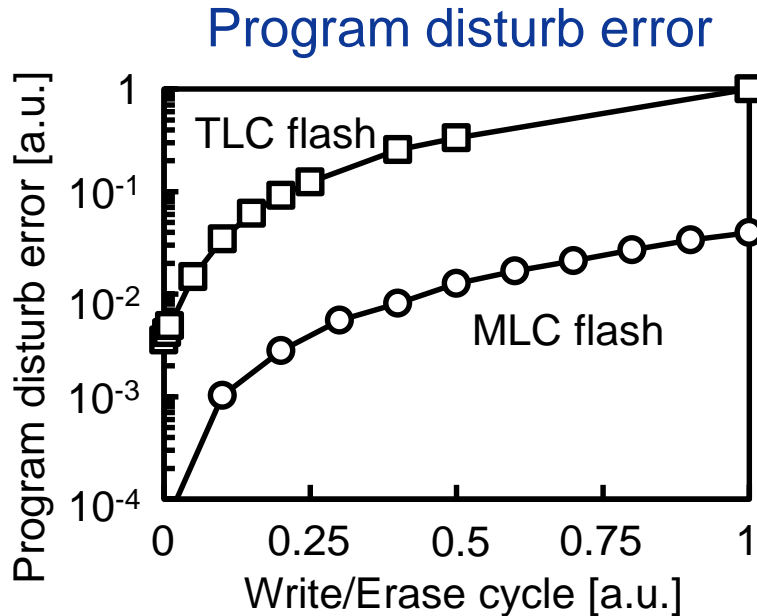
1.5x longer





Errors in MLC and TLC NAND Flash

- TLC flash has higher error rate than MLC flash



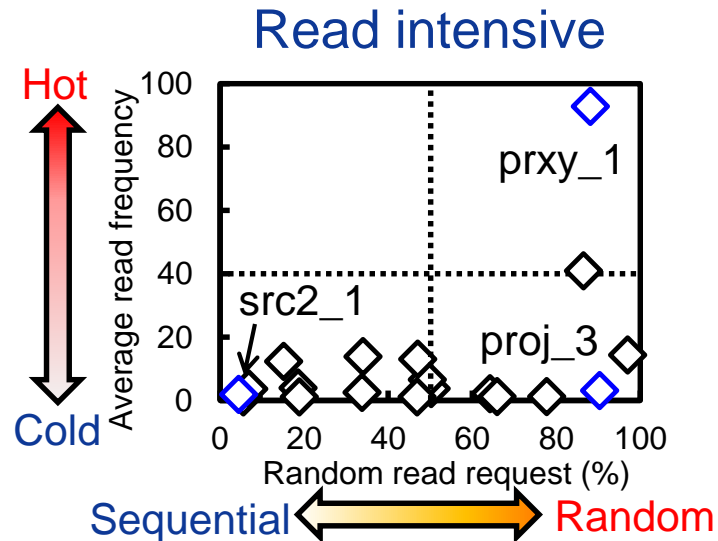
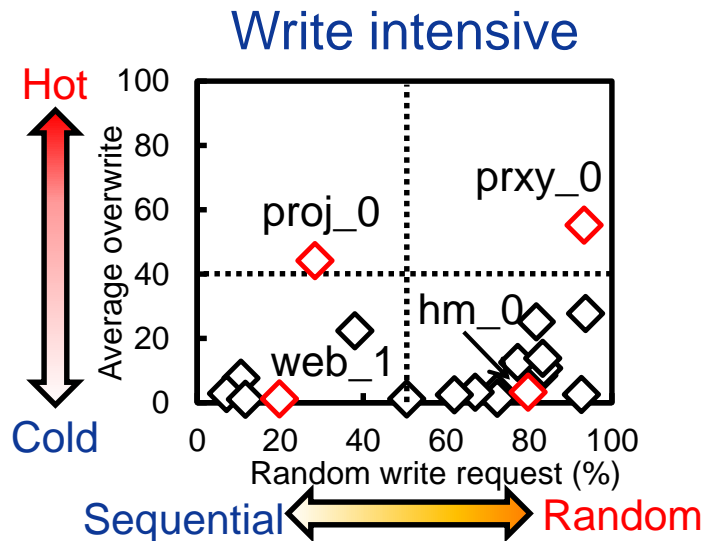


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Application Characteristics



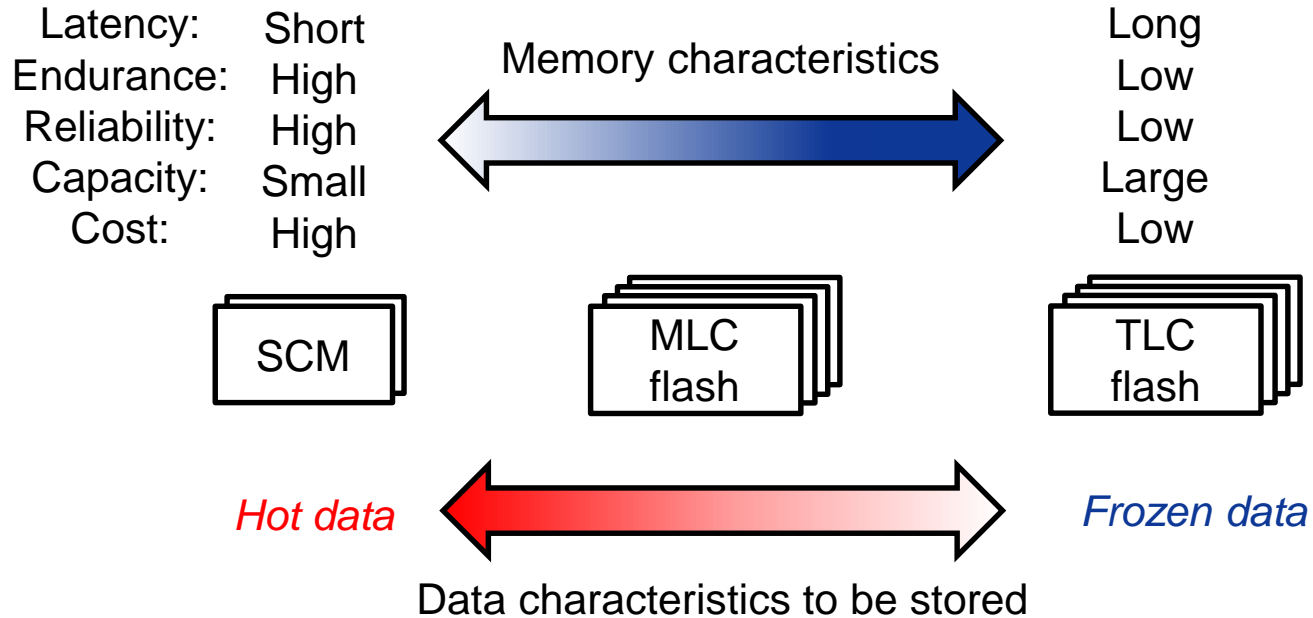
Application characteristics defined by

- Average overwrite = Total write data size / user data size
- Average read frequency = Total read data size / user data size
- Random: data size is 8KB or less (half of page size)



Data Management Strategy

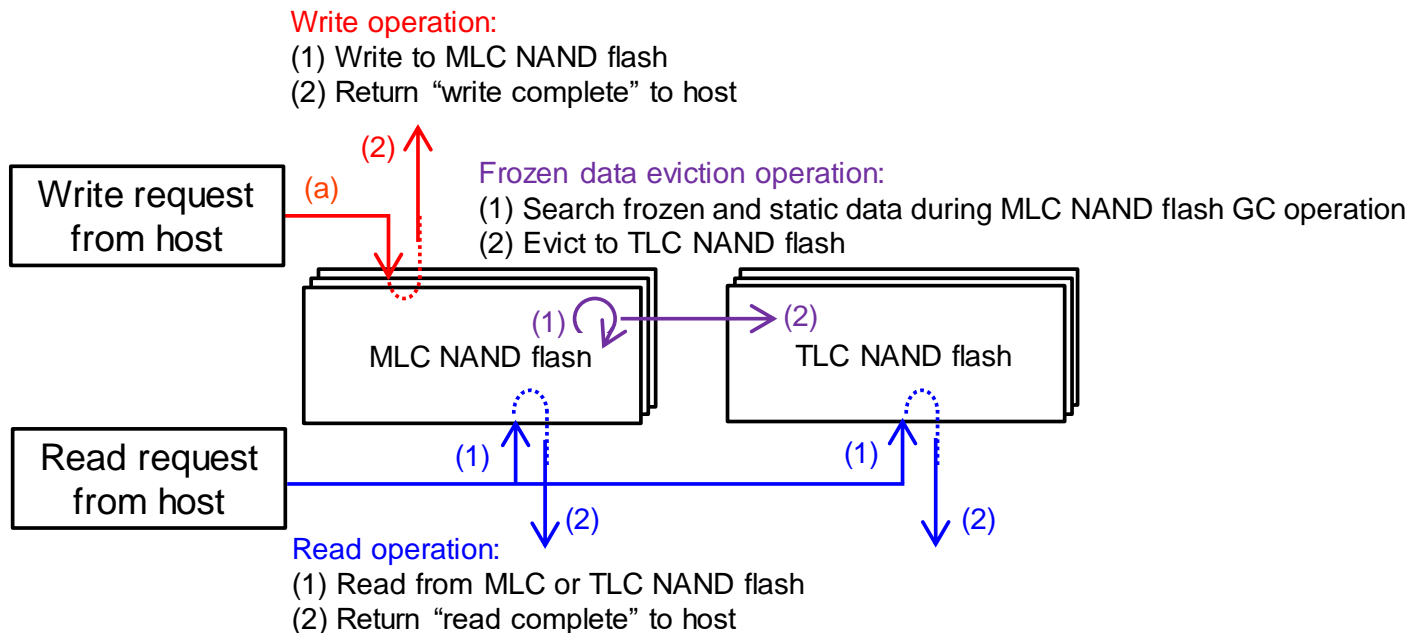
- Determined by memory characteristics used in hybrid SSD





1) MLC and TLC NAND Flash Hybrid SSD

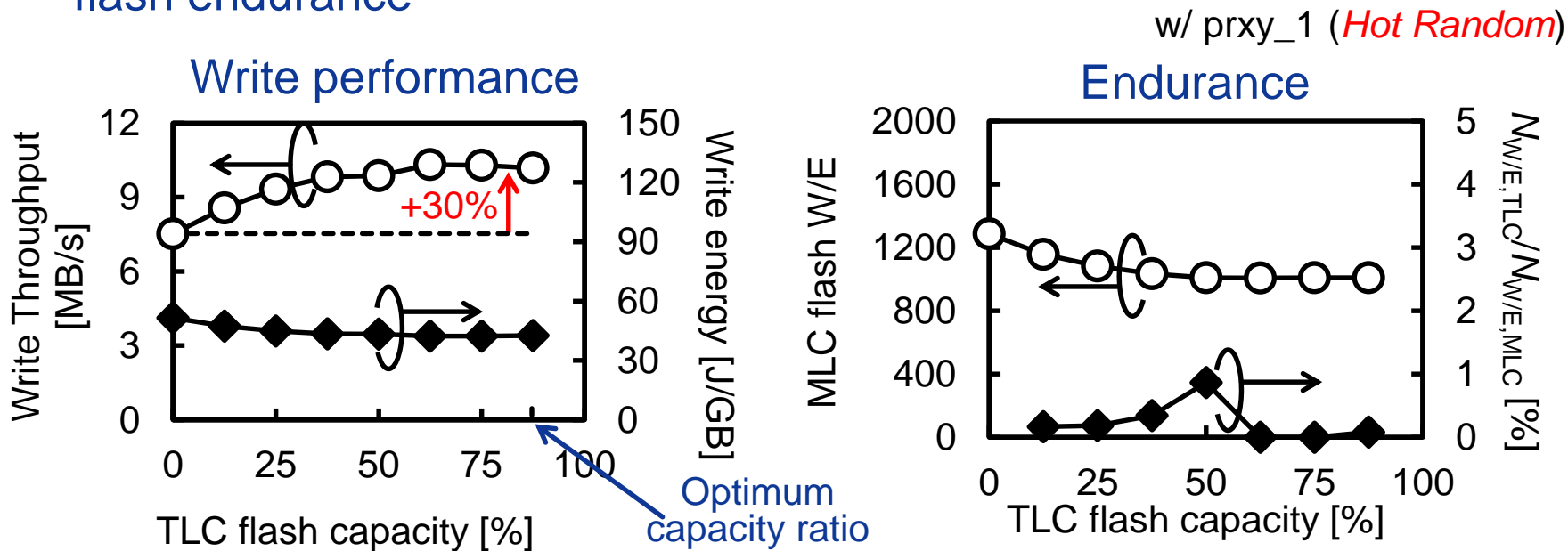
- Frozen data are collected in TLC NAND flash when MLC Flash GC





1) MLC and TLC NAND Flash Hybrid SSD

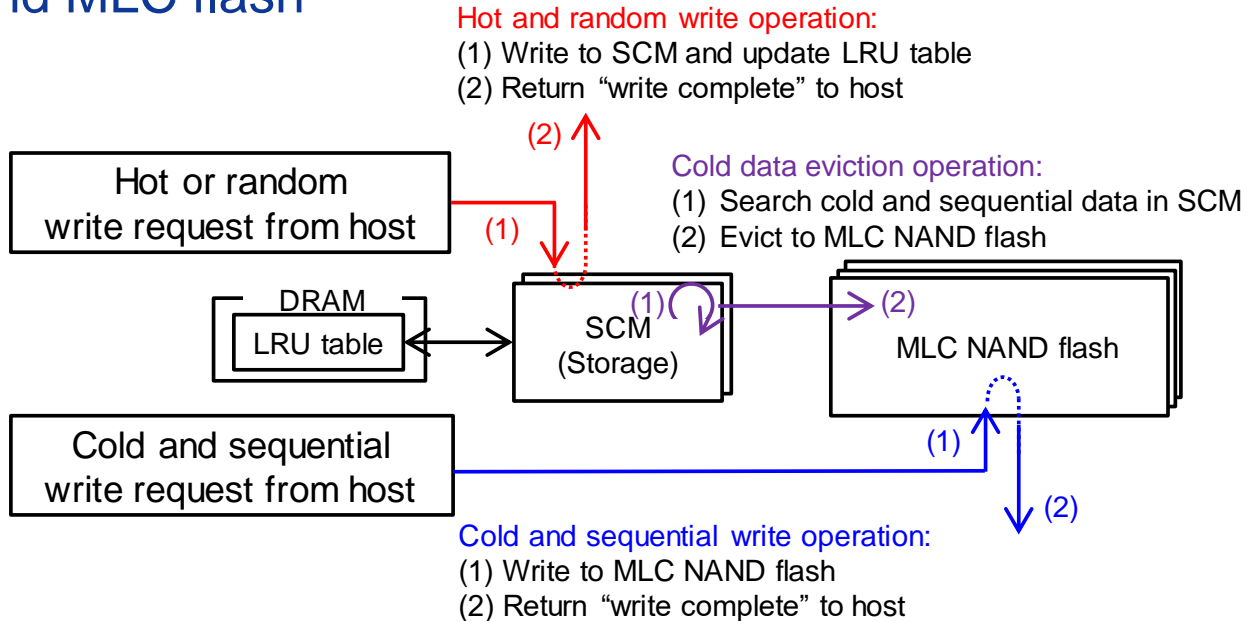
- TLC flash improves the hybrid SSD performance and prolongs MLC flash endurance





2) SCM and MLC NAND Flash Hybrid SSD

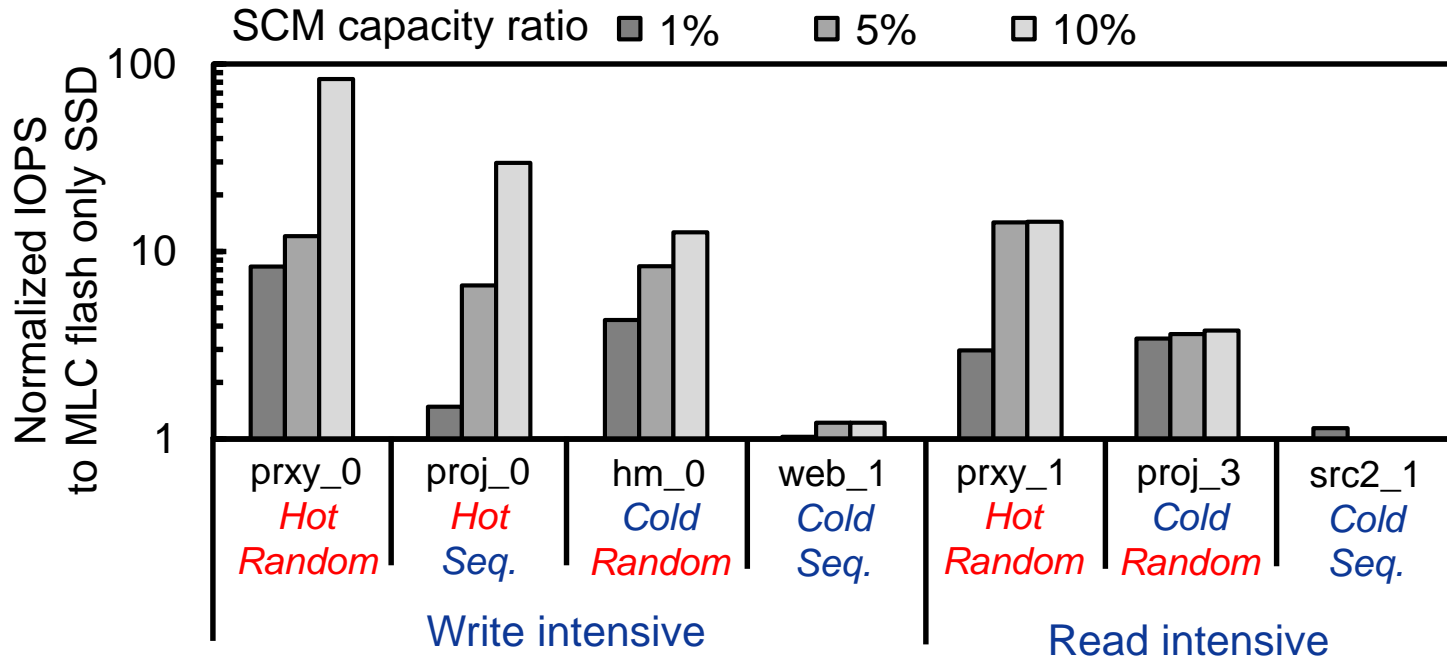
- SCM stores hot or random data. No data deduplication in between SCM and MLC flash





2) SCM and MLC NAND Flash Hybrid SSD

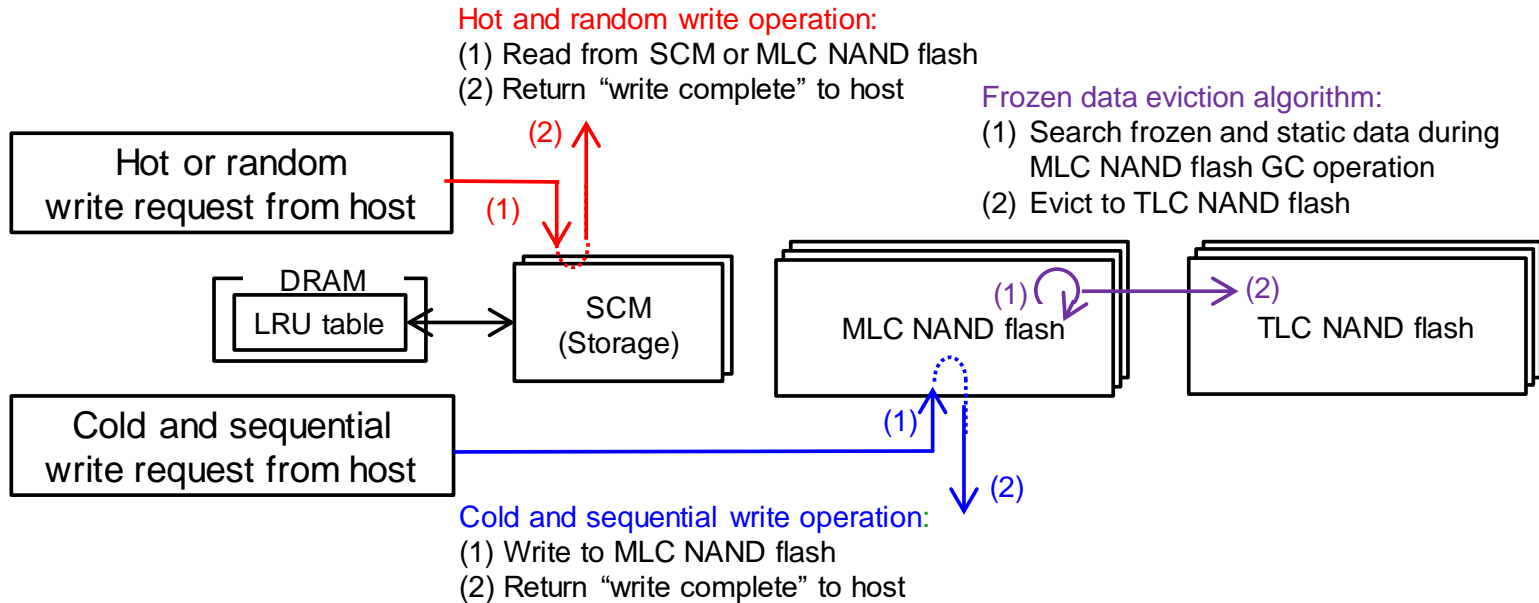
w/ SCM read/write latency 100ns





3) SCM and MLC/TLC NAND Flash Tri-hybrid SSD

- SCM stores hot or random data, and TLC stores frozen data



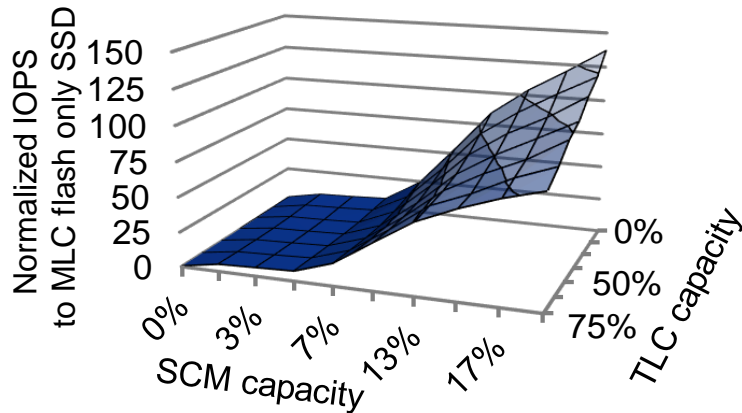


3) SCM and MLC/TLC NAND Flash Tri-hybrid SSD

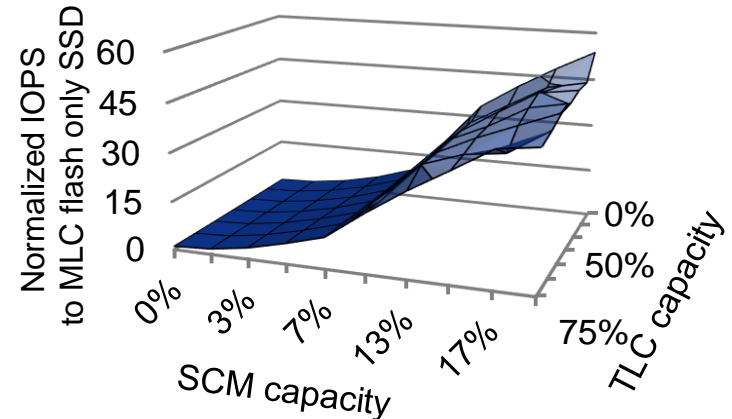
- SCM improves SSD performance of hot applications

w/ SCM read/write latency 100ns

prxy_0 workload
(Hot Random)

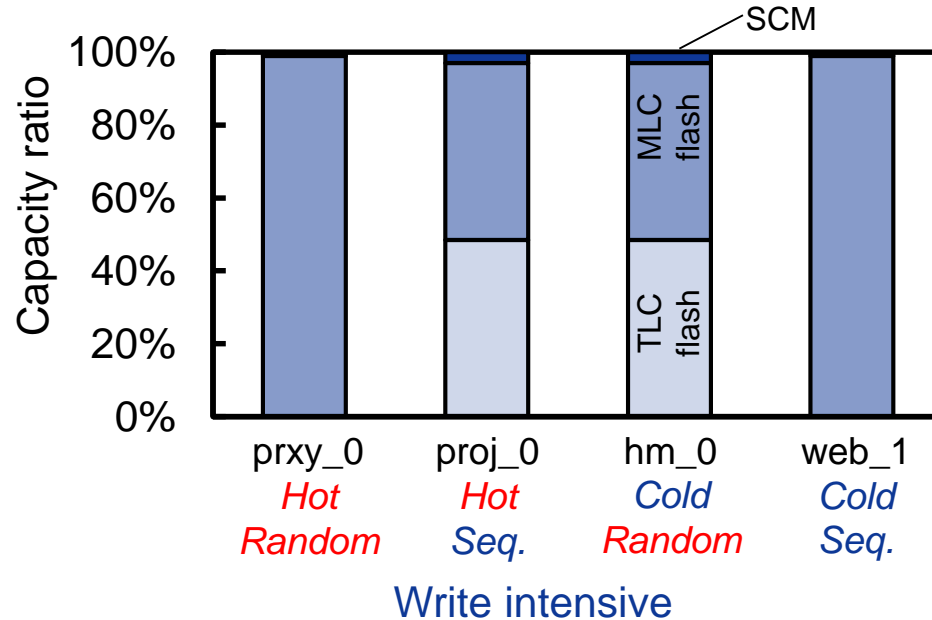


proj_0 workload
(Hot Seq.)



3) Optimal Memory Capacity in Tri-hybrid SSD with 1.1-times Cost

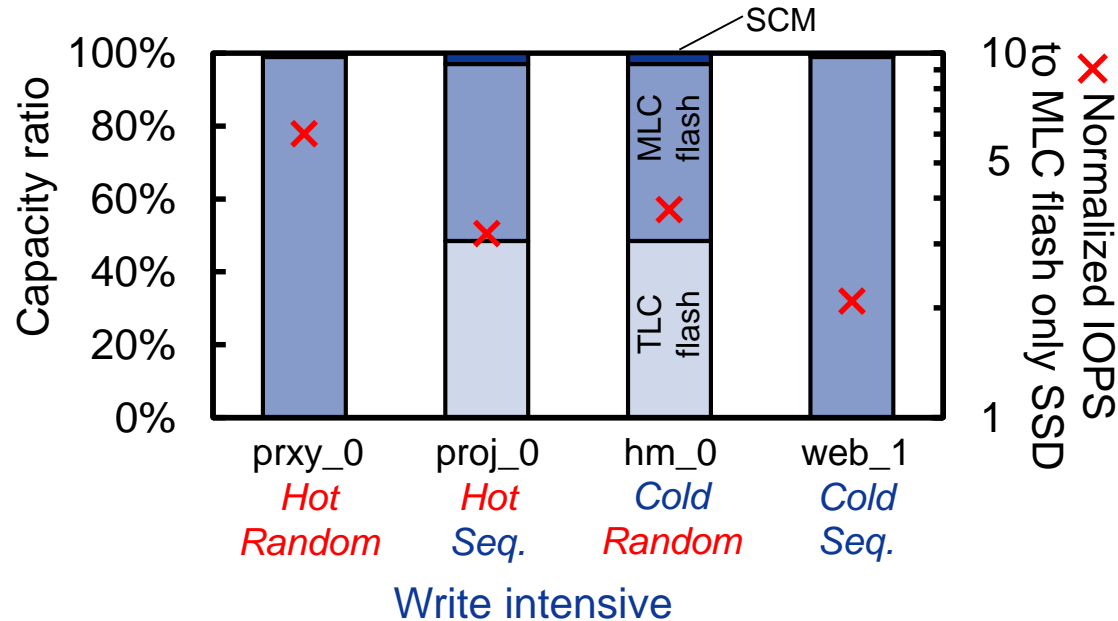
w/ SCM read/write latency 100ns



Storage class memory	10
MLC flash	1
TLC flash	2/3

3) Tri-hybrid SSD Performance with 1.1-times Cost

w/ SCM read/write latency 100ns





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Summary

- SCM and TLC flash store hot and frozen data, respectively in tri-hybrid SSD
- If 10% SSD cost increase is allowed:
 - Small capacity of SCM boosts SSD performance by 6 times for hot random application
 - Hot sequential or cold random applications require mix of SCM, MLC and TLC NAND flash memories
 - Small SCM capacity is enough for cold sequential application



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Acknowledgement

This presentation is based on results obtained from a project commissioned by the New Energy and Industrial Technology Development Organization (NEDO).