Multi-Stream Write SSD
Increasing SSD Performance and Lifetime with Multi-Stream Write Technology

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Agenda

- NAND flash characteristics
- Multi-Stream Write
  - Multi-Stream Write concept
  - Multi-Stream Write system architecture
  - Multi-Stream Write operation
- Performance benefit
- Standards
- Summary
- Q&A
NAND Flash Characteristics

- Operation: Read/Program/Erase
- Operation unit
  - Read/Program: Page
  - Erase: block (= multiple pages)
- Out-of-place update: in-place update (=overwrite) NOT allowed
  - Invalidate overwritten data
- Page MUST be erased before programming (writes)
  - Program/Erase (P/E) cycles
  - Need garbage collection operation

Efficient data placement increases performance with reduced garbage collection overhead
NAND Flash Characteristics (Cont’d)

- Limited number of Program/Erase cycles

Efficient data placement increases lifetime (endurance) of SSD
Multi-Stream Write

- Provide better endurance, improved performance, and consistent latency
  - Allow host to associate each write operation with a stream
  - All data associated with a stream is expected to be invalidated at the same time (e.g., updated, trimmed, unmapped, deallocated)
  - Align NAND block allocation based on application data characteristics (e.g., update frequency)
Multi-Stream Write Operation

- Mapping data with different update frequency to different streams

- Provide hint about data update frequency
- Place data with similar update frequency into same erase unit

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Operation Example

- Efficient data placement with Multi-Stream Write
  - Reduce GC overheads -> better performance and lifetime!

**Legacy: Without Stream**

**Multi-Stream**

For effective multi-streaming, proper mapping of data to streams is important!

Reduce valid pages to copy
FIO Performance Measurement System

- **Hardware**
  - Quad Core Intel i7-4790 CPU 3.60GHz
  - 16GB memory

- **Software**
  - Ubuntu 14.04 LTS, v4.0.3 Kernel with Multi-Stream Write patch
  - FIO 2.2.5 with Multi-Stream Write patch

- **Device**
  - Multi-Stream Write enabled NVMe SSD
Performance Measurement Configuration

- Four sequential write jobs six random read jobs
  - Different data lifetime: 1x, 10x, 33x, 55x
- Precondition
  - 2 hours with four-write jobs
Four Streams – Read/Write (70% / 30%)

**Reads**
- Jobs: 6
- Block size: 4k
- Iodepth: 64

** Writes**
- Jobs: 4
- Block size: 128k
- Iodepth: 1

Read IOPS

![Graph showing Read IOPS comparison between Multi-Stream Write and Legacy]

Write Throughput

![Graph showing Write Throughput comparison between Multi-Stream Write and Legacy]

WAF

![Graph showing WAF comparison between Legacy and Multi-Stream Write]

\[ WAF = \frac{\text{Amount of data written to NAND}}{\text{Amount of data written by host}} \]
Cassandra

- Free open-source distributed NoSQL DB
- Provide high availability with no single point of failure
- Support clusters across multiple data centers
- Scalable
- Fault tolerant with automatic replication
- Support query language (CQL: Cassandra Query Language)
Performance Measurement Configuration

- **Hardware**
  - Dell Precision T7810 Workstation
  - Intel Xeon E5-2630 CPU 2.40GHz
  - 64GB RAM

- **Software**
  - Ubuntu 16.04 LTS, v4.6.0 Kernel with Multi-Stream Write patch
  - Cassandra 3.5.0 w/ Multi-Stream Write Patch

- **Benchmark**
  - Cassandra built-in tool (cassandra-stress)
  - 50%/50% Read/Write
  - Total records: 1M

- **Device**
  - Multi-Stream Write enabled SAS SSD 480GB
  - 4 hour pre-conditioning with 100% write
Cassandra Architecture

- Level-tiered compaction
Cassandra in Legacy SSD

- Legacy SSD (same as a single stream ID case)
Assign stream IDs according to file write characteristics.
Cassandra Performance

- 45% performance improvement
- 2x lifetime
- More than 50% READ latency reduction

WAF = \( \frac{\text{Amount of data written to NAND}}{\text{Amount of data written by host}} \)

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Standards

- **SCSI/SAS**: Completed in May, 2015
  - Standard spec: [http://www.t10.org/cgi-bin/ac.pl?t=f&f=sbc4r10.pdf](http://www.t10.org/cgi-bin/ac.pl?t=f&f=sbc4r10.pdf)

- **NVMe**: standardization in final review stage
Summary

- With Multi-Stream Write, SSDs can be more efficiently used for
  - Consistent better performance
  - Better endurance (=better SSD lifetime)

- With Multi-Stream Write
  - FIO: more than 2x SSD lifetime in addition to the decent I/O performance enhancement
  - Cassandra: 2x SSD lifetime as well as 45% I/O performance improvement
THANK YOU