Term Project Proposal
Exploring End-to-End Bottlenecks in NVMe SSDs

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1. Motivation & Goal

Modern NVMe SSDs expose massive internal parallelism while relying on deep host queues and on-board DRAM buffers to hide flash latency. However, it is often unclear which component actually becomes the bottleneck for a given workload: host-side NVMe queues, the SSD's DRAM data buffer/cache, or the backend flash parallelism (channels/ways). **This project aims to explore the bottlenecks using an SSD simulator, and to classify regimes where performance is limited by (1) host queueing, (2) DRAM buffering, or (3) flash parallelism.**

2. Simulator & Configurations

- Simulator: **MQSim**

Starting from the baseline(Using the "MQ-SSD" configuration described in the **original MQSim paper as a baseline**), we change the following parameters:

- **NVMe queueing (host-side)** : IO_Queue_Depth $\in \{1, 8, 32, 128, 256\}$
- **DRAM data buffer/cache** - Data_Cache_Capacity (on-board DRAM buffer size):
  - {0 MB (DRAM-less), 128 MB, 256 MB (baseline), 1 GB}.
- **Flash parallelism (channels/ways)**
  - Flash_Channel_Count: 4 , 8 (baseline), 16.
  - Chip_No_Per_Channel (number of ways): 2, 4 (baseline), 8.

3. Workloads & Metrics

3.1 Workloads

Synthetic workloads (fio-like patterns via MQSim)

- 4 KiB random read, 4 KiB random write and 70/30 mixed read/write with varying queue depth
- 128 KiB sequential read/write (throughput-oriented) with varying queue depth

Trace-driven workloads

- TPCC trace - Part of Microsoft Enterprise Traces

3.2 Metrics

For each (configuration, workload) combination, we collect the following metrics:

- **I/O statistics**
  - Throughput, IOPS, Latency.
- **Internal SSD statistics**
  - Statistics of user vs. GC vs. mapping transactions in the TSU queues
  - Per-package time fractions spent in command execution, data transfer, overlapped operation, and idle mode.
- **Power and energy (approximate)**
  - Using the above transaction counts and package busy/idle time fractions together, estimate relative energy-per-I/O