Enhancing Endurance of SSD Based high-performance Storage Systems using Emerging NVM Technologies

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HPC Applications and Storage Systems

• Data Intensive HPC applications introduces substantial stress on Storage system
• Storage performance a key factor in overall performance
• Emerging Non-volatile Memory Technologies (ENVM)
  • Multiple bits/cell SSD Technologies
  • Optane Memory
What is the study about?

- Achieve high overall storage performance
- Effectively deal with low endurance of SSDs
- Minimize data loss

How to deploy ENVM in storage hierarchy to:
- ENVM as next level cache to DRAM
- ENVM as Write only cache

Two High Performance Storage (HPS) logical architectures considered
How HPS architectures are managed?

**Two different mechanisms are proposed**
- Performance-centric mechanism
  - Efficient Write back management
- Endurance-centric mechanism
  - Efficient write budget estimation procedure to measure safe and critical write amount

**Three different policies are proposed**
- Policy I: ENVM as oblivious cache
- Policy II: ENVM as next level cache without immediate persisting of write data
- Policy III: ENVM as next level cache with immediate write data persist
Experimental Setup

**Implementation Setup**

Experimental System: Intel 1TB QLC, Samsung 1TB TLC SSD and Intel Optane forming storage hierarchy

Simulation: To explore various multi bits/cells SSD including PLC.

**Evaluation Metrics**

Performance centric metrics: Average read and write latency, tail latency

Endurance centric metrics: ENVM write, SSD write

Data loss metric: Average data loss risk

**Dataset Considered**

Systor 2017 Trace considered: Traffic classified as busy, average, low

Systor 2017 Trace modified: Magnified two(2X), four(4X) and sixteen(16X) times
Evaluation Results

• Performance Evaluation
  • Three policies are compared with the base policy (absence of ENVM)
  • Policy III generates least average read latency compared to others
  • Policy III generates higher average write latency than policy I and II
  • All three policies yield approximately the same read tail latency

• Data loss Evaluation
  • Policy III has no data loss
  • Policy I and II involves same amount of data loss

• Endurance Evaluation
  • SSD write amount is much larger for Policy III than policy I and II
  • ENVM write amount is much larger for Policy I than Policy II and III
Evaluation Results Cont’d

SSD Write for magnified trace

- 16X magnified trace: All policies experience critical writes. Larger SSD suggested

Estimated ENVM size for SLC, MLC, TLC, QLC and PLC

- Simulated Result
  - SLC requires smallest ENVM compared to the others
  - 1Xnm requires more ENVM for SLC, TLC, QLC and PLC than 2Xnm and 3Xnm
## Conclusion

### Benefits of incorporating ENVM in HPS architecture

- Enhances overall performance
  - Caches relevant data in ENVM
- Maintains overall endurance
  - Controls persisting modified data at ENVM and underlying SSD according to I/O size
- Minimizes data loss
  - Persists modified data immediately at ENVM

### Estimates the required ENVM size

- Uses a write budgeting algorithm
- Considers workload and SSD characteristics
- Considers ENVM endurance rating