Memory Expansion Technology Using Software-Controlled SSD

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Challenge

- Flash memory has about 1000 times slower performances than that of DRAM, so that it usually makes any system performance greatly degraded

Challenges to the performance gap:

- To avoid to store data in slower flash as much as possible?
- To have highly parallelism in hardware?
- To step away from FTL housekeeping operations?
- To wipe off frequent data transfer between flash and CPU?

The answer is … "Memory Expansion Technology," which we have developed

Memory Expansion Technology Architecture

- Data allocation control
  - Software control to allocate data to either DRAM or flash according to application data characteristics
- Flash IC manipulation
  - Dedicated highly parallel flash IC hardware in order to realize high BW and to control the data allocation
  - SW takes over GC/WL-like housekeeping operation
- Hardware accelerator (HW-ACC)
  - Near data processing, with accelerators close to flash, can easily wipe off data transfers btw flash and CPU

We developed "Software-Controlled SSD" hardware to realize the memory expansion technology
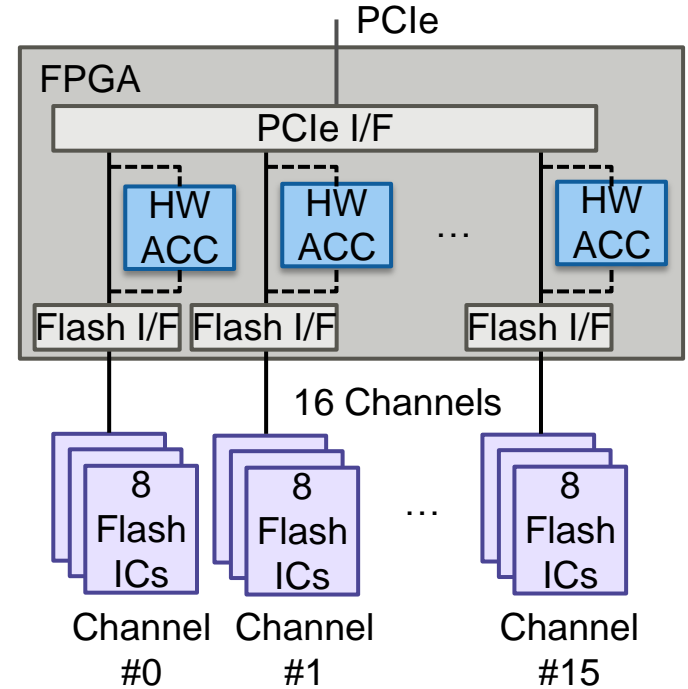

Software

Hardware

Application
Data Allocation

Flash Control Software

HW-ACC

DRAM

Flash ICs

Software-Controlled SSD
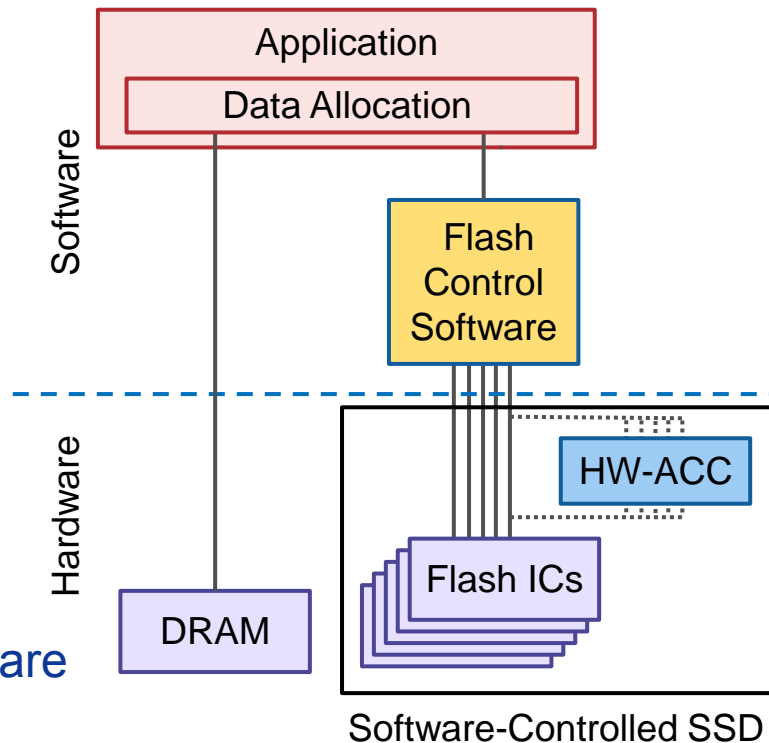
Software-Controlled SSD

- 128 parallel flash-ICs controlled by software
- 16 parallel hardware accelerator

PCIe Gen3 x 8
8 TB
FHHL form factor

PCIe

FPGA

PCIe I/F

HW ACC   HW ACC   ...   HW ACC

Flash I/F   Flash I/F   Flash I/F

16 Channels

8 Flash ICs   8 Flash ICs   ...   8 Flash ICs

Channel #0   Channel #1   Channel #15

Case 1: Memcached Server

- Memcached server is in-memory KVS, and usually used as a cache server for web services

- In terms of large-scale web services, several thousand cache server units operates at a time in order to increase cache capacity

- The memory expansion technology can reduce memory cost of servers

Memcached Server
DRAM

In-Memory

Memcached Server	
DRAM	Flash

Memory Expansion
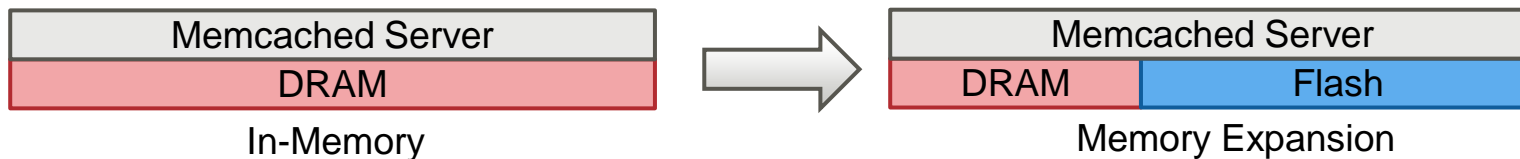
Memcached Performance Evaluation

- Even when 87% of DRAM is replaced with flash, evaluation results show that performance degradation can be practically suppressed to less than -10%
- Estimated memory cost goes around 1/6

Throughput [MB/s] chart:
- Proposed (DRAM:Flash=13:87)
- In-Memory (DRAM:Flash=100:0)
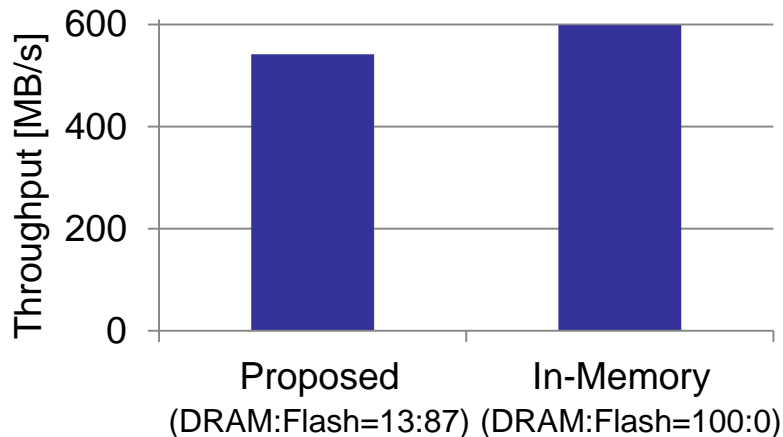
Case 2: Genome Analysis

- Genome-wide association study
  - Search and find out correlations between disease and gene variant (GV)
  - Aggregation function (AF) for GV database (GVDB): 500GB per 100K people
  - Statistical analysis (SA) for aggregation result (AR) : 640MB

- Approach
  - Place GVDB in flash
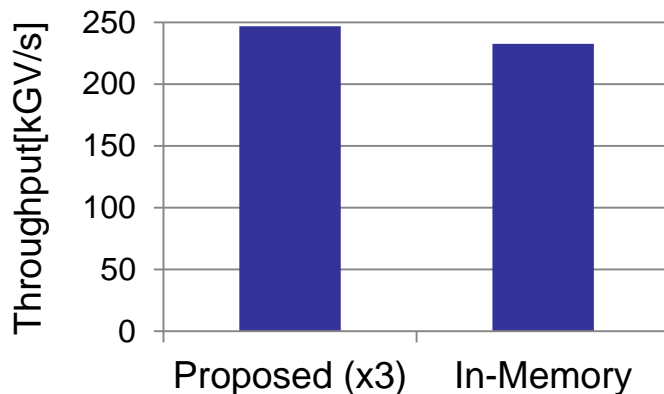 - Process AF with hardware accelerator

In-Memory

Memory Expansion 7
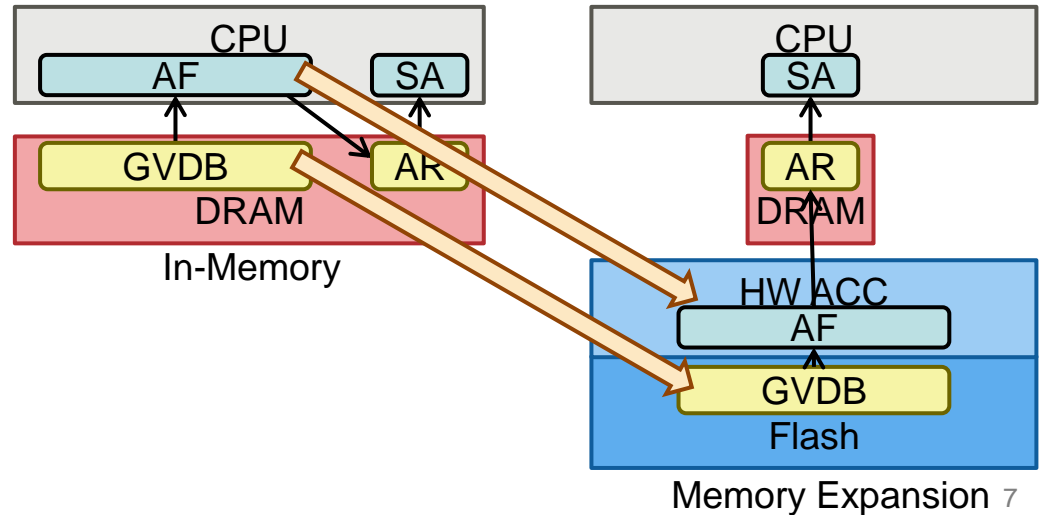
Genome Analysis Performance Evaluation

- Using three software-controlled SSDs in parallel
- Evaluated throughput is almost equivalent to "in-memory processing" results
- Estimated memory cost goes around 1/7
- Resultantly, DRAM can be well replaced with the memory expansion technology

Summary

- Developed "Memory Expansion Technology" using software-controlled SSD
  - Try to fill performance gap between DRAM and flash

- Applied to both memcached server and genome analysis applications
  - Proposed "Memory Expansion Technology" can practically reduce memory cost of servers, at the expense of around -10% performance degradation

Thank you!