Viyojit: Decoupling Battery and DRAM Capacities for Battery-Backed DRAM

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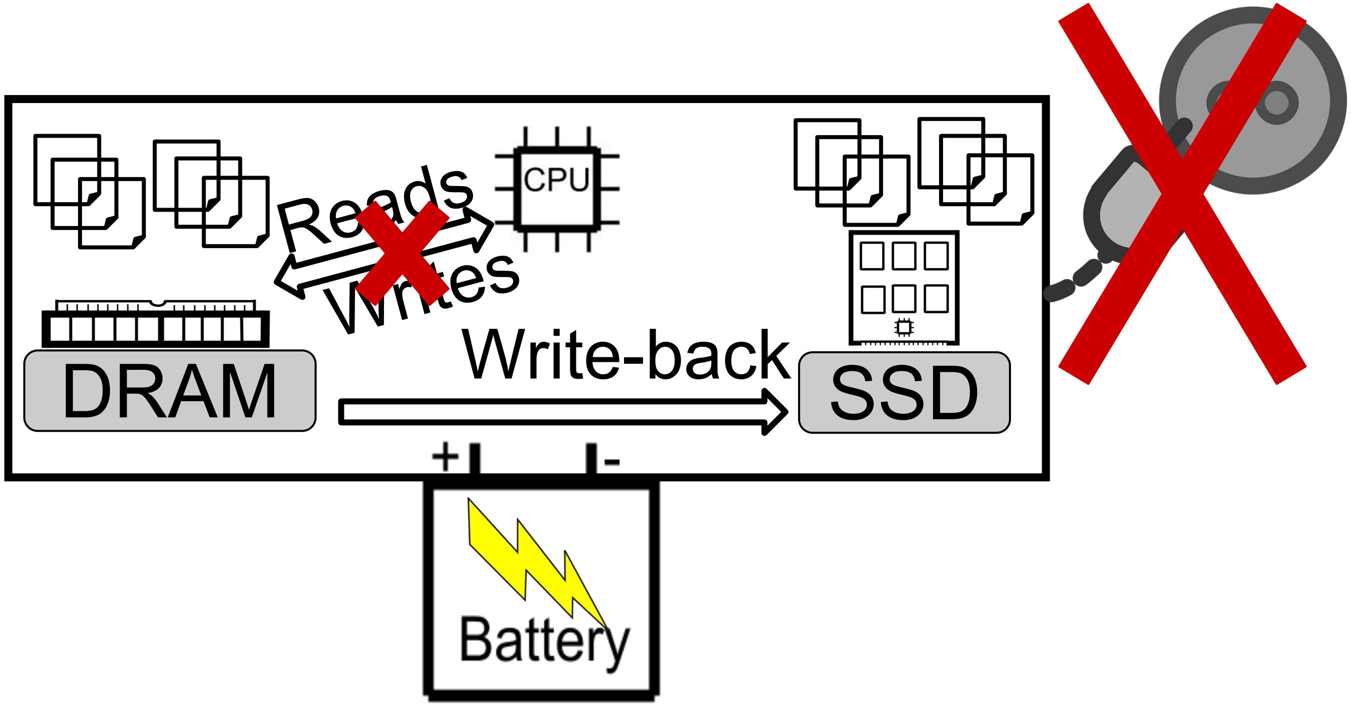
Overview

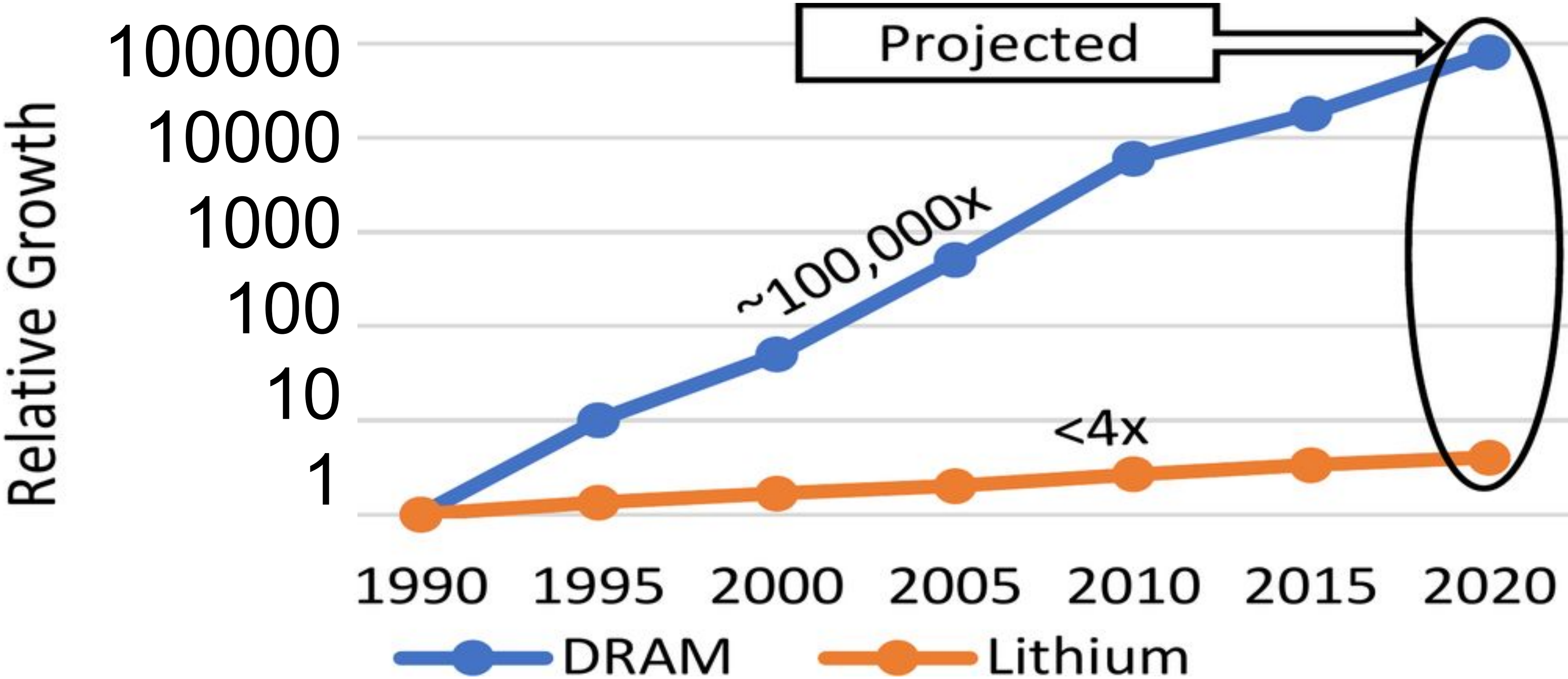
- Problem
  - Excellent performance with BB-DRAM
  - But, need large batteries for high capacity
- Observation
  - Typical battery used << Worst case
- Idea: Provision battery for typical requirement
- Challenge: Durability guarantee
- Solution: Viyojit, bound dirty data in BB-DRAM
- 89% smaller battery, only 7-25% throughput loss

High performance storage with BB-DRAM



Widely used high performance NVM technology

Poor battery scaling limits BB-DRAM capacity

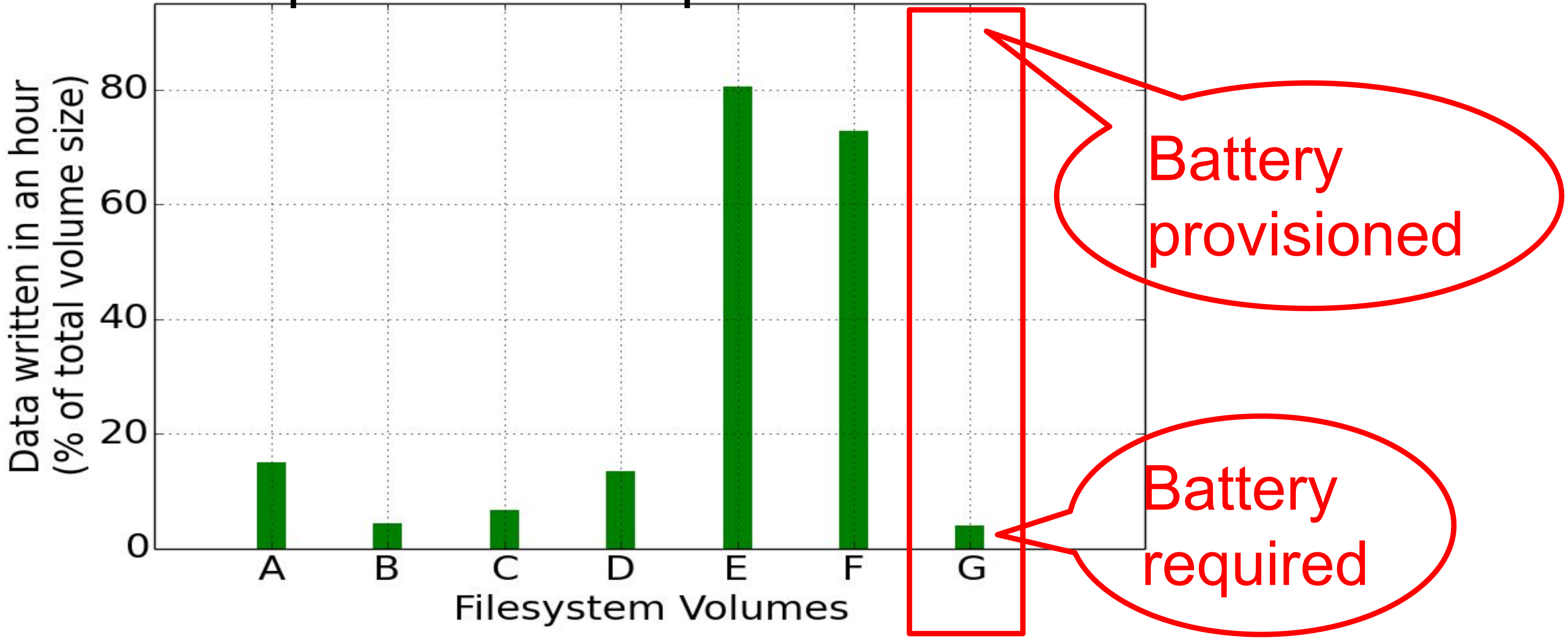


Challenging to provision high capacity BB-DRAM

Typical battery required is much smaller

- Need to flush only dirty data
- Typical workloads dirty only a small fraction of dataset

Microsoft production MapReduce like workload



Can provision small batteries

Viyojit ensures durability with small batteries

- 10 Clean BB-DRAM pages
- Battery for 2 Dirty pages
- Write protect all clean pages

C	C	C	C	C	C	C	C	C	C

D	C	C	C	C	C	C	C	C	C

(a) Write page 0

- Make page 0 writable

D	C	D	C	C	C	C	C	C	C

(b) Write page 2

- Make page 2 writable

C	C	D	C	C	C	C	C	C	D

(c) Write page 9

- Make page 0 clean
  - Write protect
- Make page 9 writable

Write protect pages to track and bound dirty data
Proactively write-back infrequently updated data

Viyojit writes-back infrequently updated pages

- Target Least Recently Updated (LRU) page
  - Motivated by Least Recently Used policy
- Consider only write accesses
  - Page always stays in memory
- Identify target page using dirty bit
  - Periodically read and reset dirty bit

Write-back Least Recently Updated pages

Viyojit avoids blocking applications on write-backs

- Background write-back thread
- Adapt aggressiveness based on “dirty pressure”
  - Expected number of new dirty pages
- Count new dirty pages in each period
- Predict new dirty pages in next period
  - Exponentially decaying average

Leave slack to absorb dirty pages w/o demand SSD write

Evaluation

Yahoo! Cloud Serving Benchmarks (YCSB): NoSQL workload
10 million ops, 16 Threads

In-memory key-value store (Redis)

Software persistent memory library (Intel's PMDK)

BB-DRAM (battery capacity ≡ database size) OR Viyojit (battery capacity ≡ fraction of the database size)

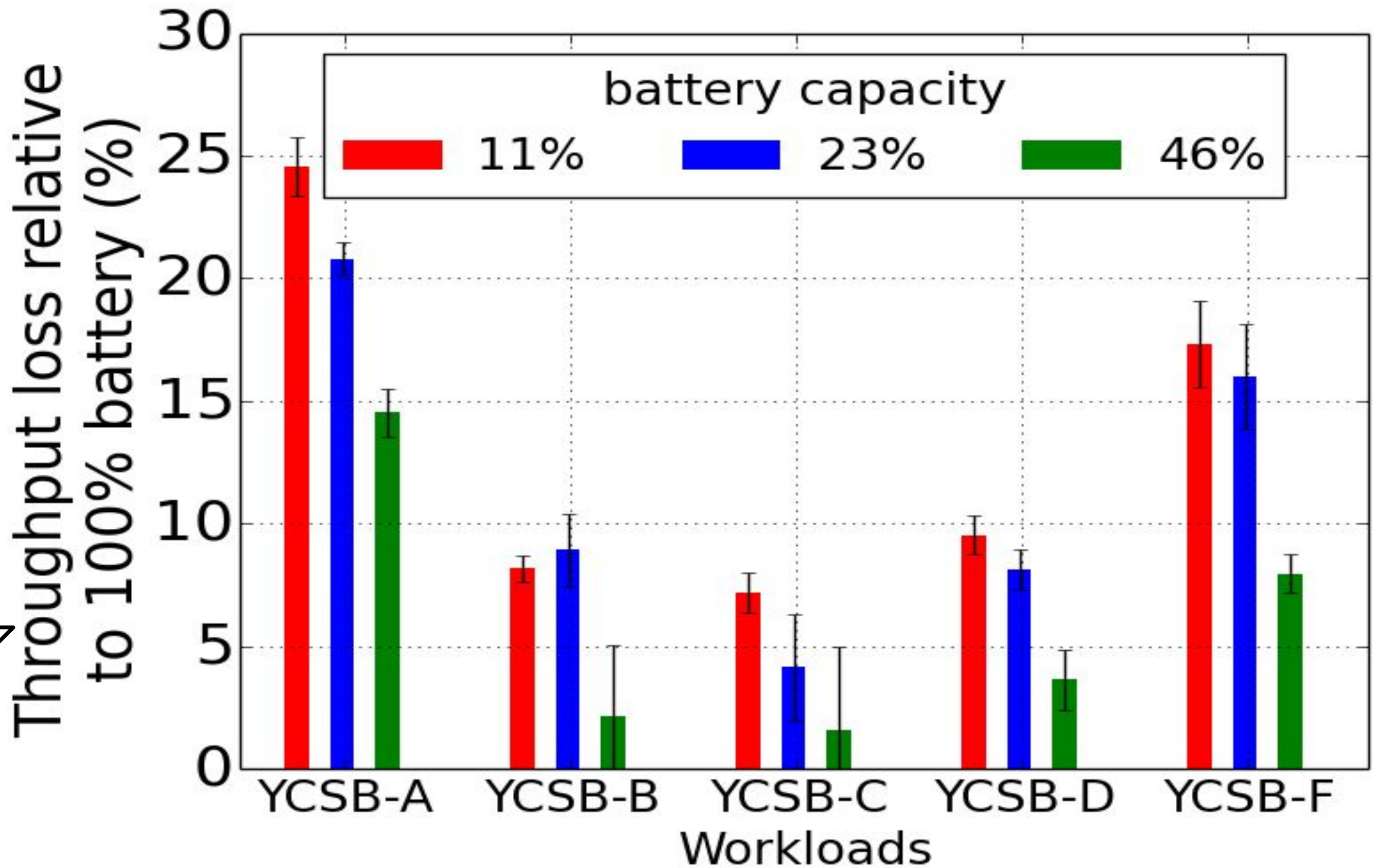
- 20 cores; 140 GB DRAM; 280 GB SSD

Metrics:

- Throughput
- Latency (average and tail)
- SSD write traffic

Effect of smaller battery on application throughput

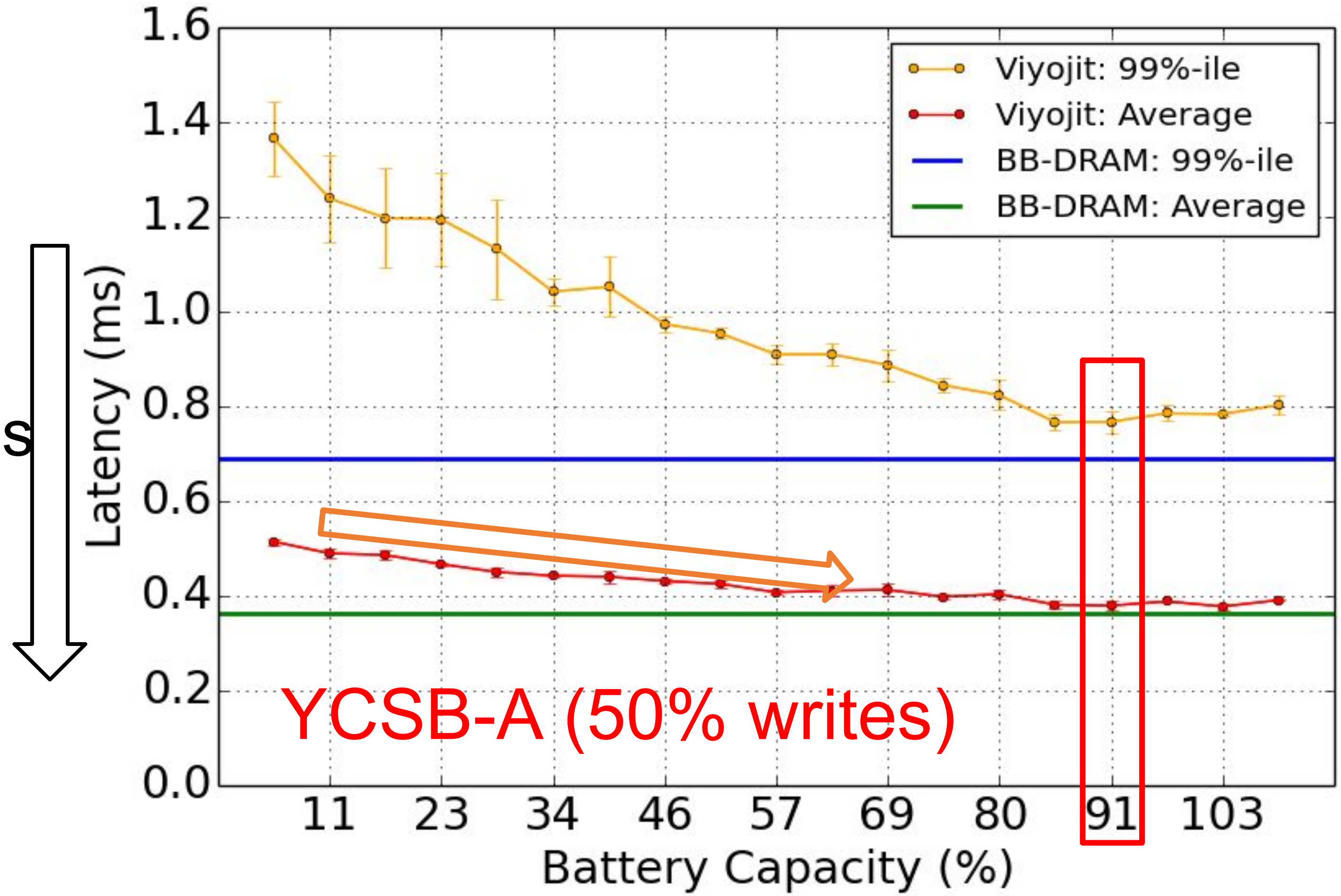
Lower is better



Low overhead (7-25%) with 89% smaller battery

Effect of smaller battery on average and tail latency

Lower is better



Write traps to track updates lead to high tail latency

Takeaways from Viyojit's results

- Key takeaway: Big reduction in battery; low overheads
  - 89% smaller battery, only 7-25% throughput loss
- Other results:
  - Overheads decrease as battery capacity increases
  - Overheads decrease as write skew increases
  - Overheads decrease as BB-DRAM size increases

Conclusion

- Excellent performance with BB-DRAM
  - But, battery scaling is problematic
- Typically, small battery can suffice
  - If an upper bound could be ensured
- Viyojit bounds number of dirty BB-DRAM pages
- 89% smaller battery, only 7-25% throughput loss