KVell: the Design and Implementation of a Fast Persistent Key-Value Store

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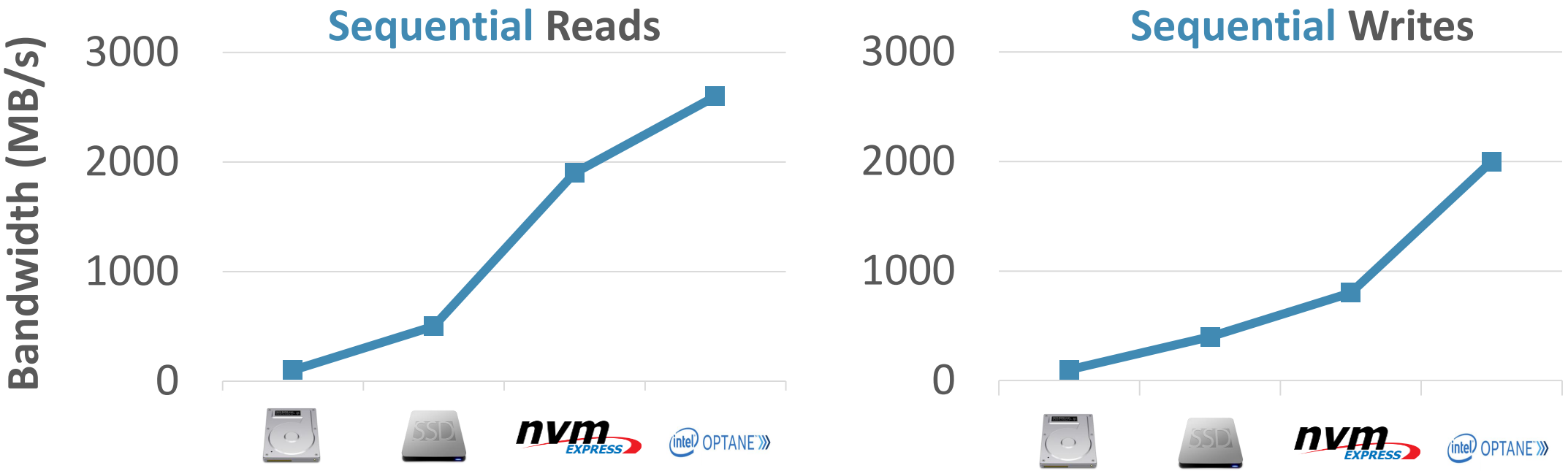
Single Machine Persistent KVs

Put(k, v)

Get(k)→ v

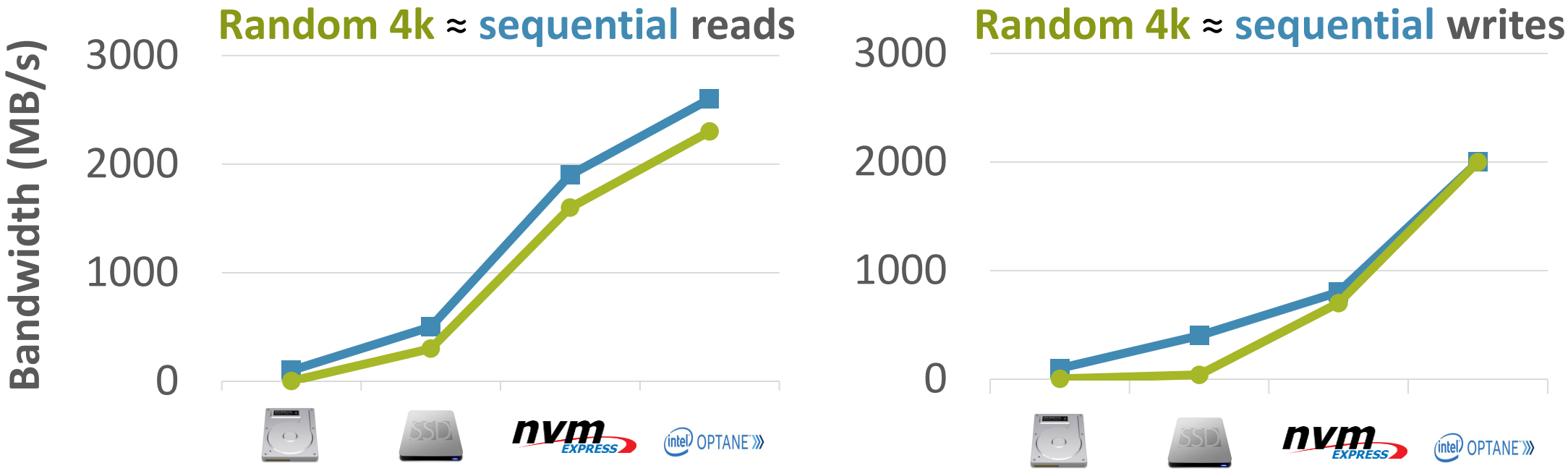
Scan(k_X, k_Y) → [k_X v_X , … , k_Y v_Y]

Disks are much faster



2010 2013 2016 2018

Random as fast as sequential



2010 2013 2016 2018

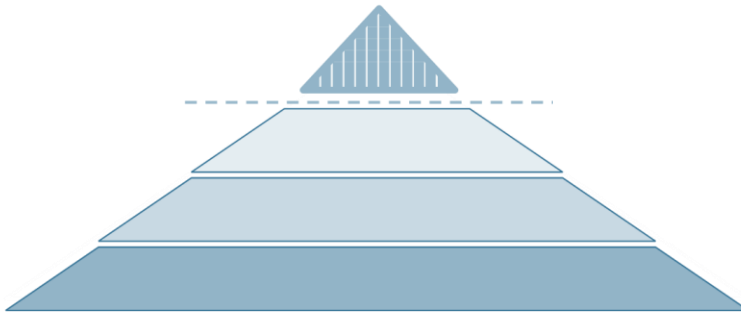
This Talk

Existing KVs not designed for fast drives

KVell: a new design for fast drives

Popular designs

Log Structured Merge Tree (LSM)

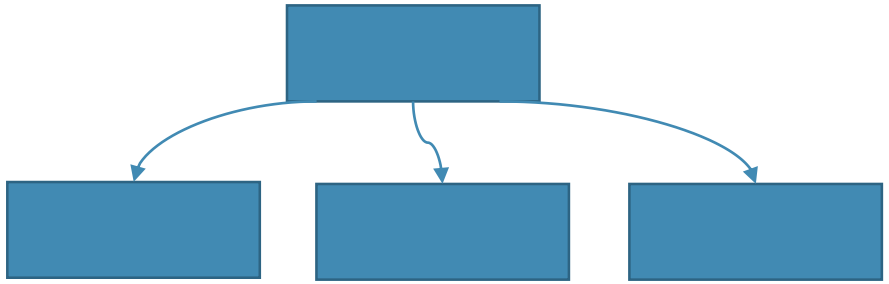


cassandra

RocksDB

LEVELDB

B+ Tree

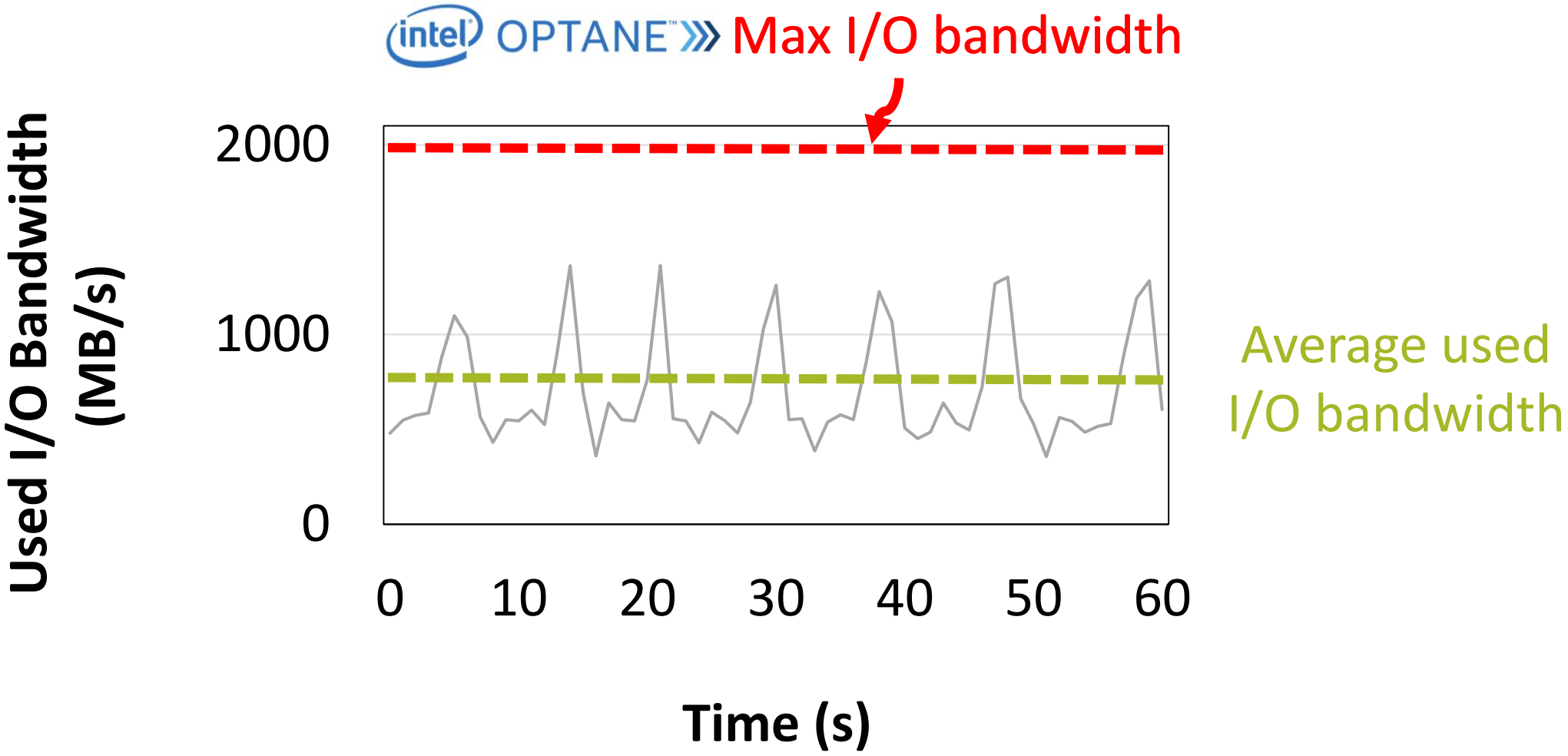


WT

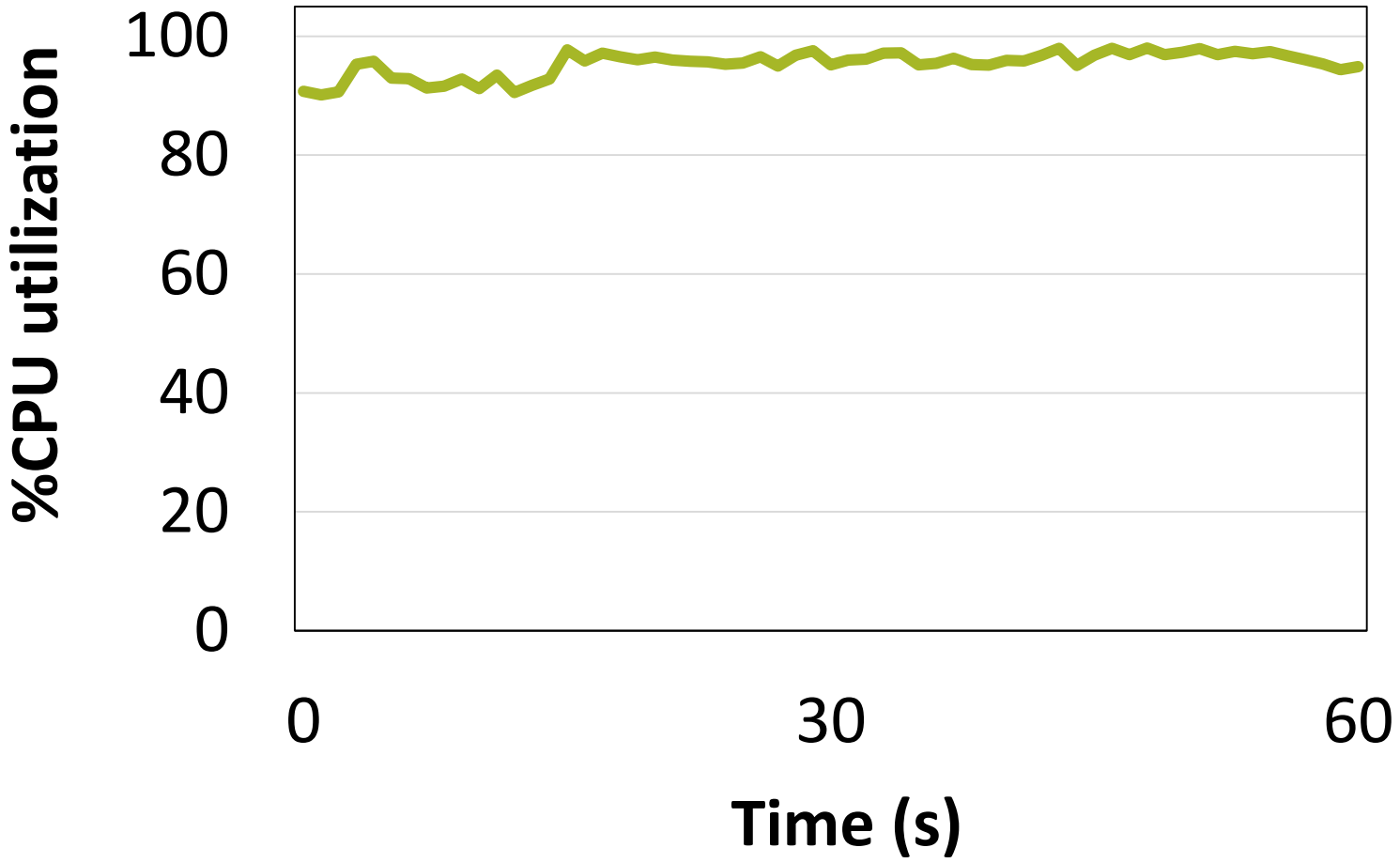
mongoDB.

PERCONA TokuMx

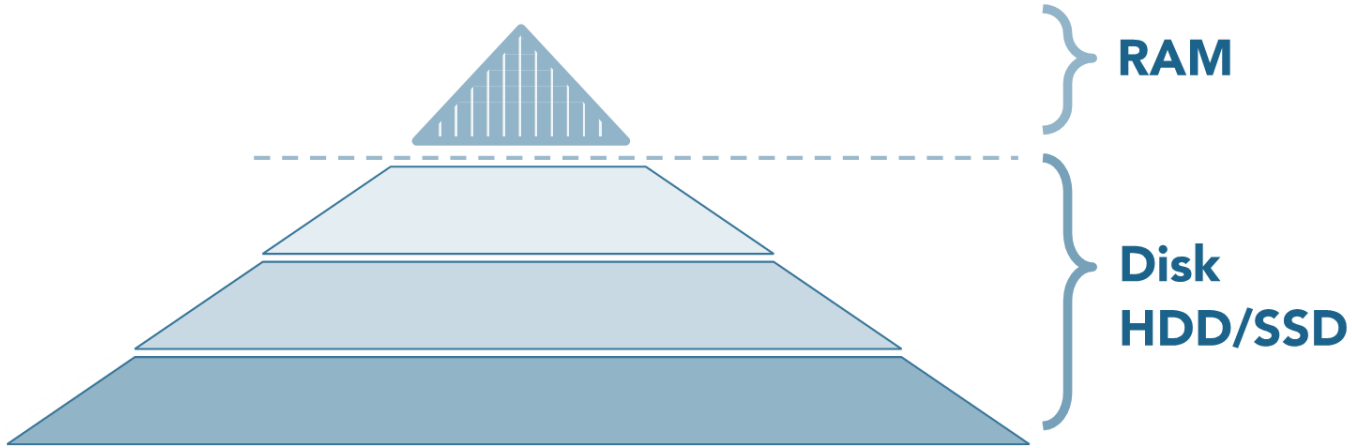
RocksDB 50% GET, 50% PUT



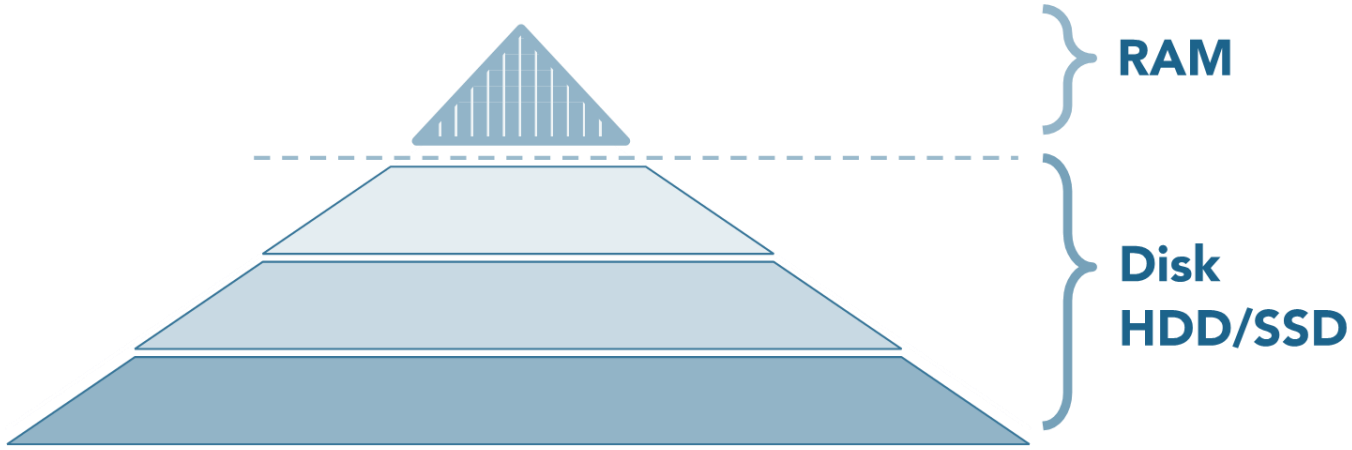
RocksDB is CPU-bound



Popular design #1: LSM

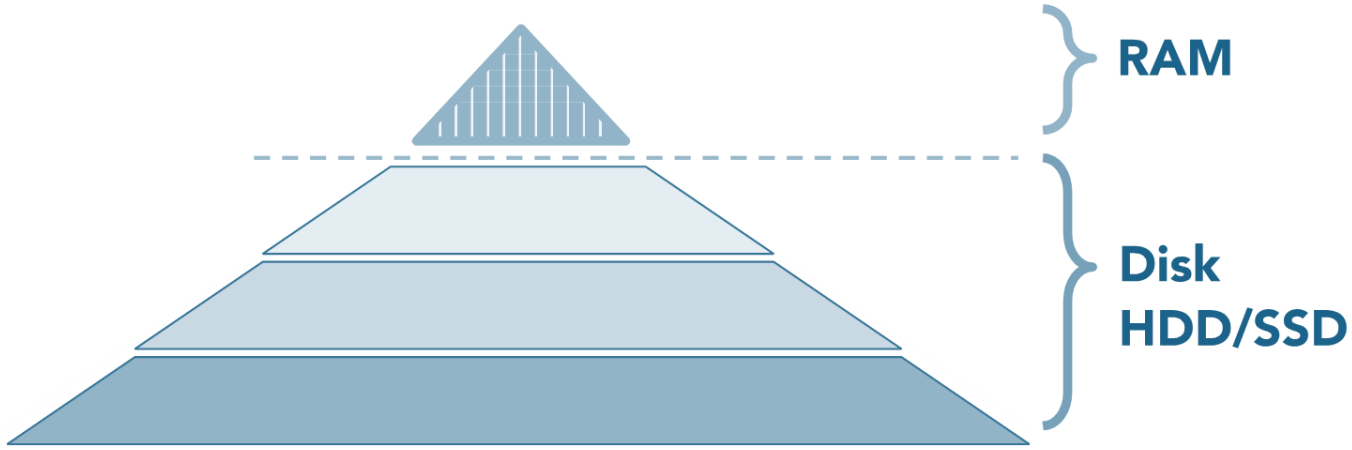


Popular design #1: LSM



Data **ordered by key**
in RAM and on disk

Popular design #1: LSM

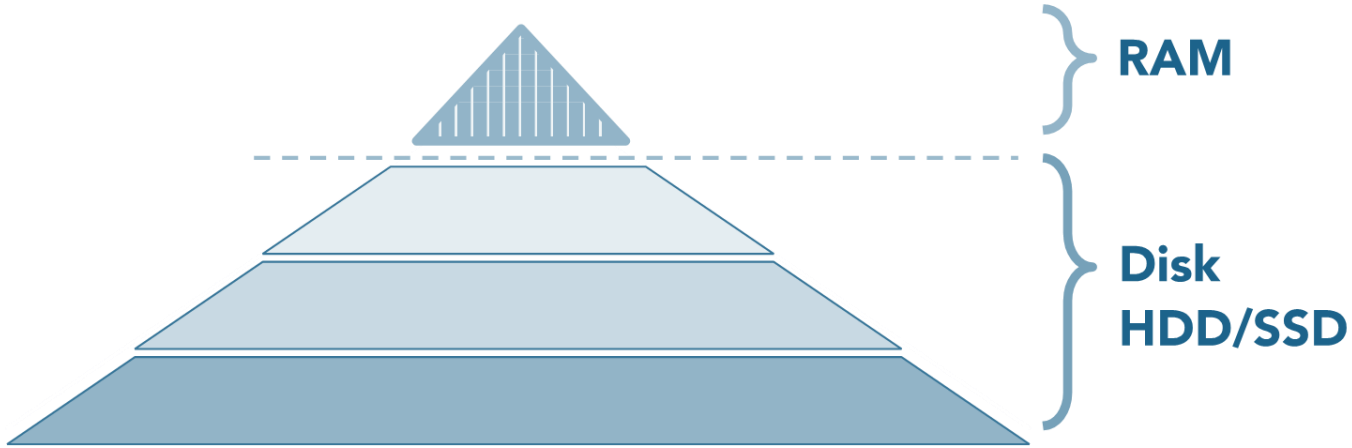


Updates **buffered** in RAM.

RAM flushed to disk

➔ **Large sequential IO**

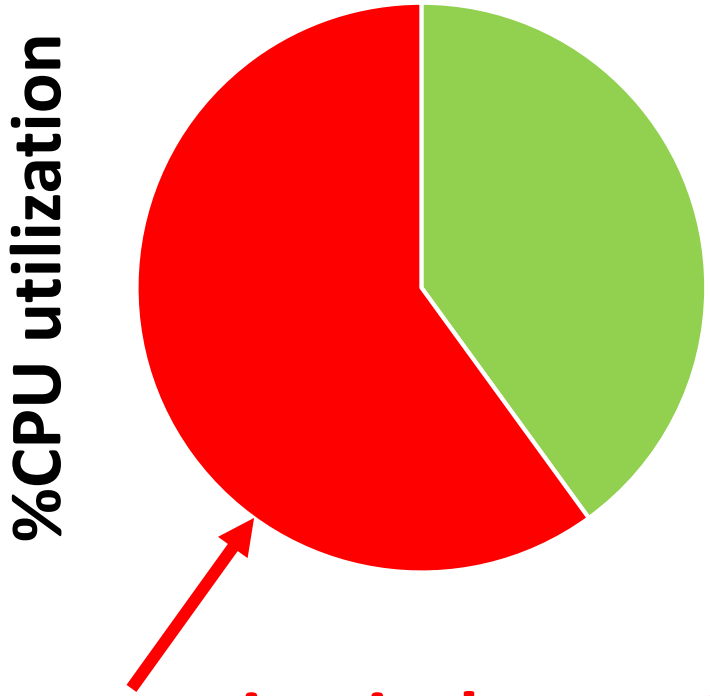
Popular design #1: LSM



Updates **buffered** in RAM.

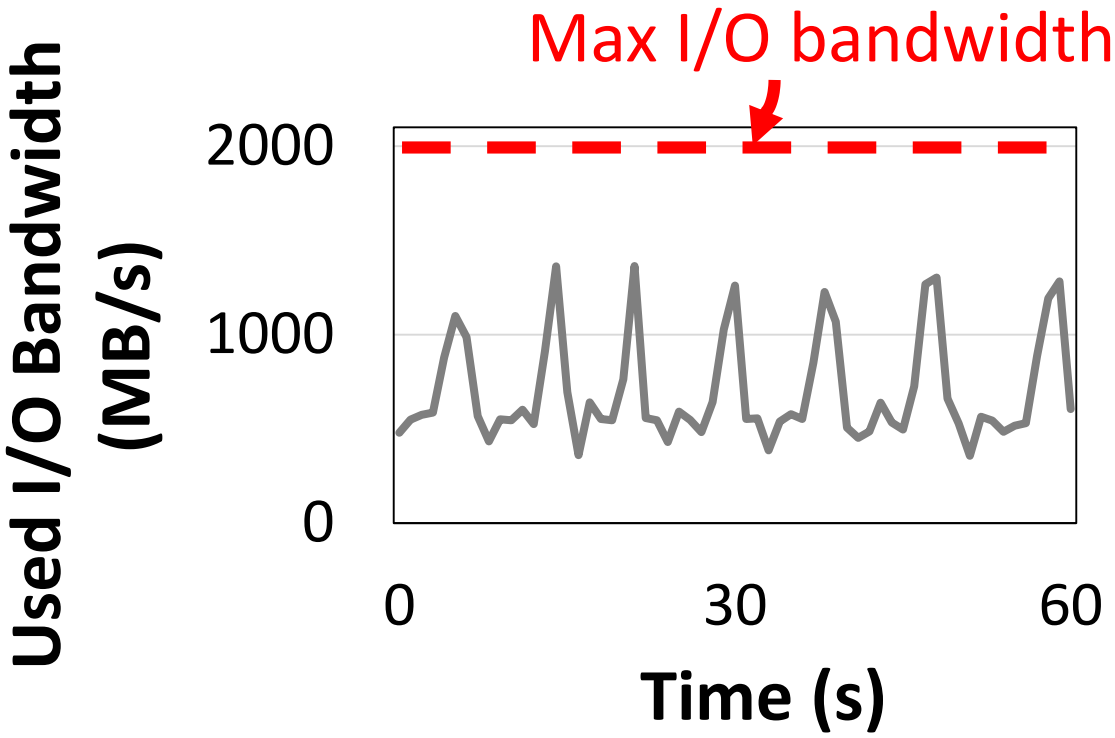
RAM flushed to disk,
merged in the **ordered** main structure (**compaction**)

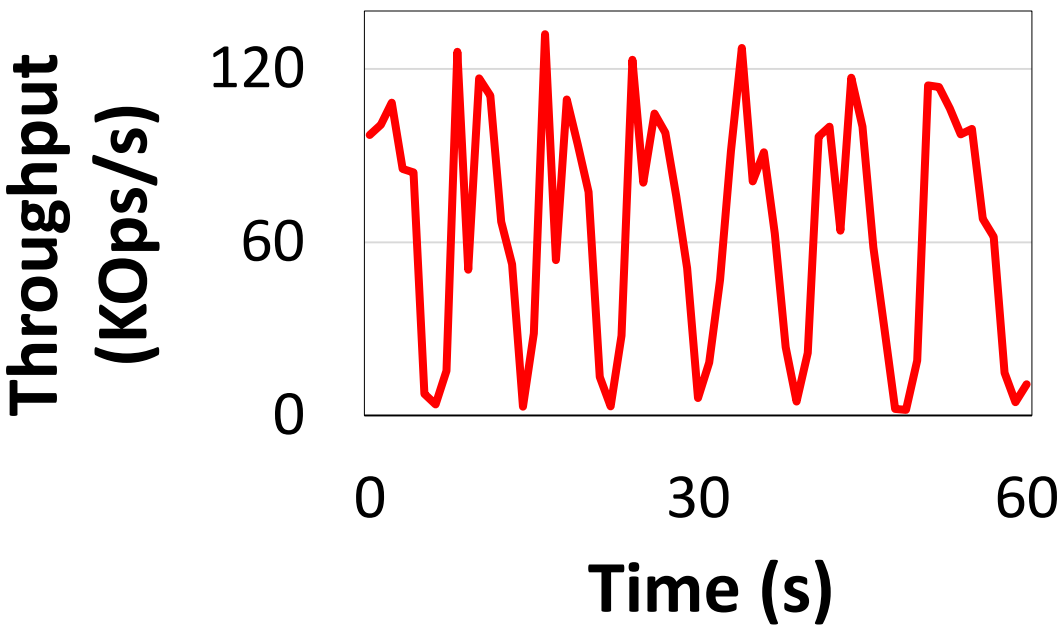
RocksDB is CPU-bound



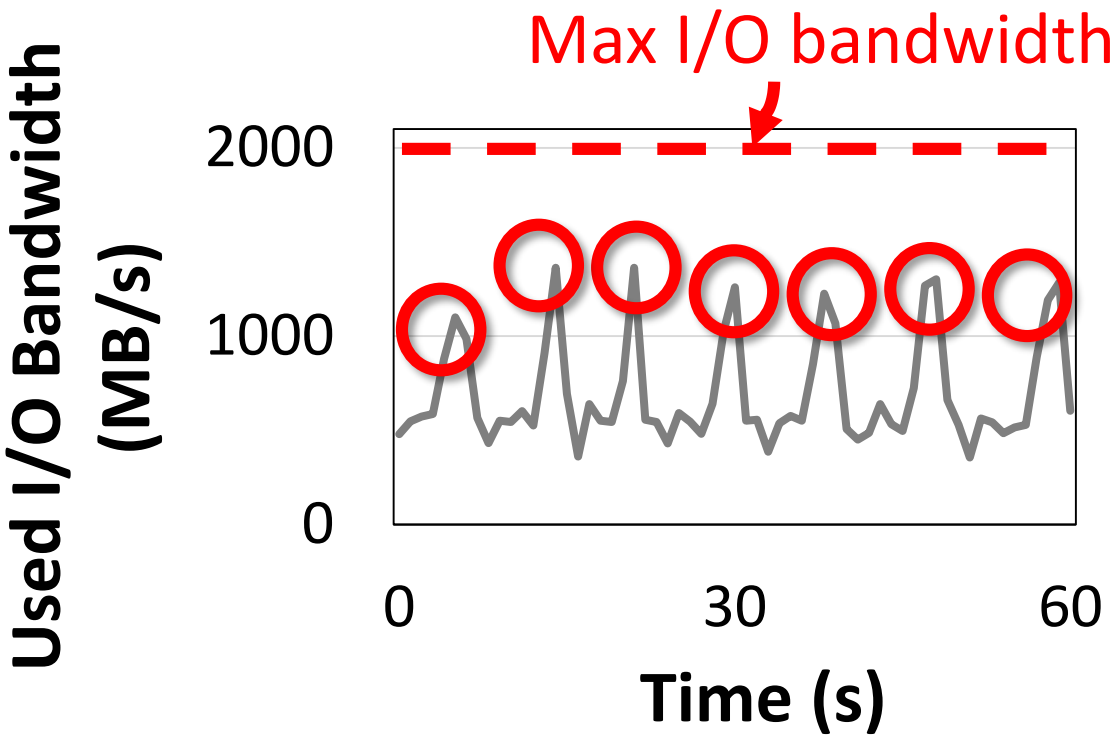
60% - merging + creating indexes of the disk structure

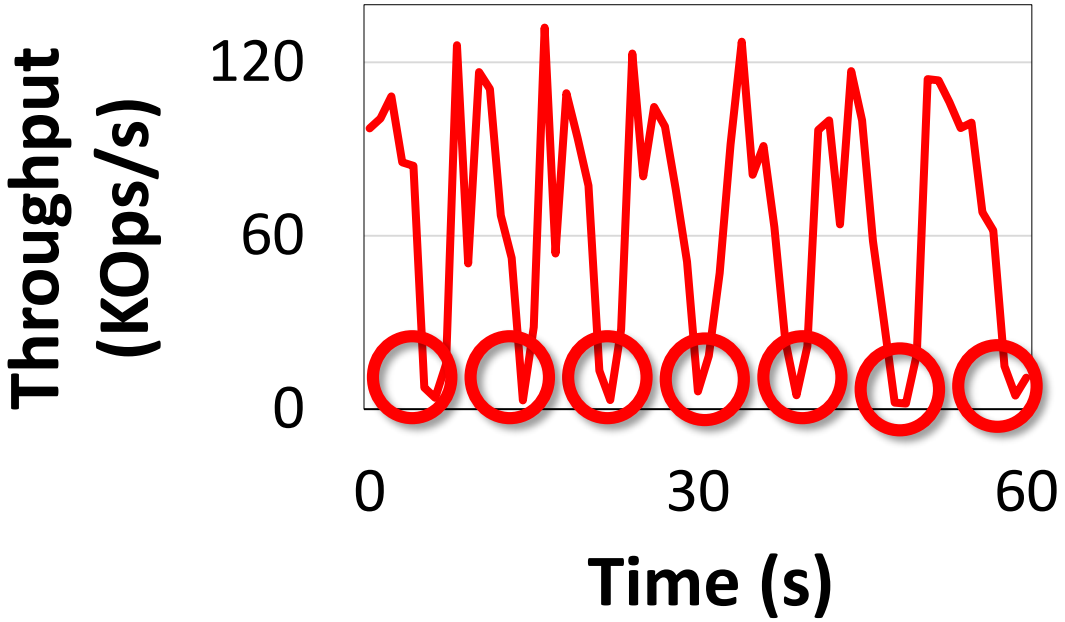
RocksDB's performance fluctuates





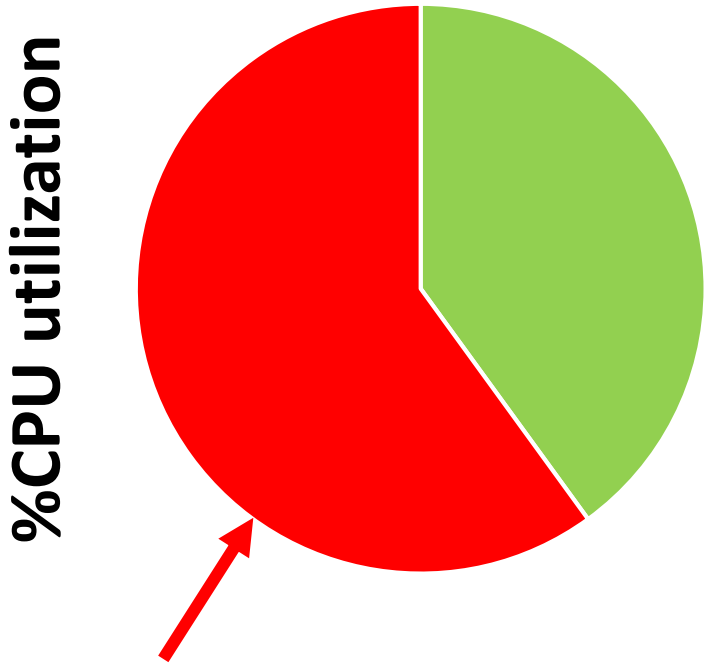
RocksDB's performance fluctuates





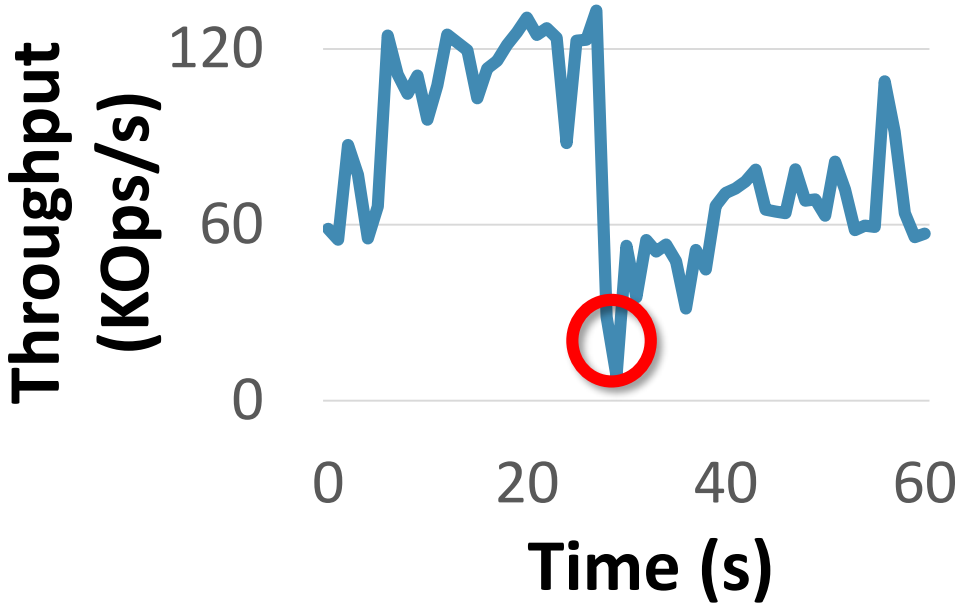
1 flush = large backlog of work

Popular design #2: B+ Trees



60% - Contention on shared data structures

➔ low average throughput



Large buffers

➔ fluctuations

Lessons learned

- ✗ Ordering
- ✗ Contention

→ low average throughput

- ✗ Large buffers

→ fluctuations

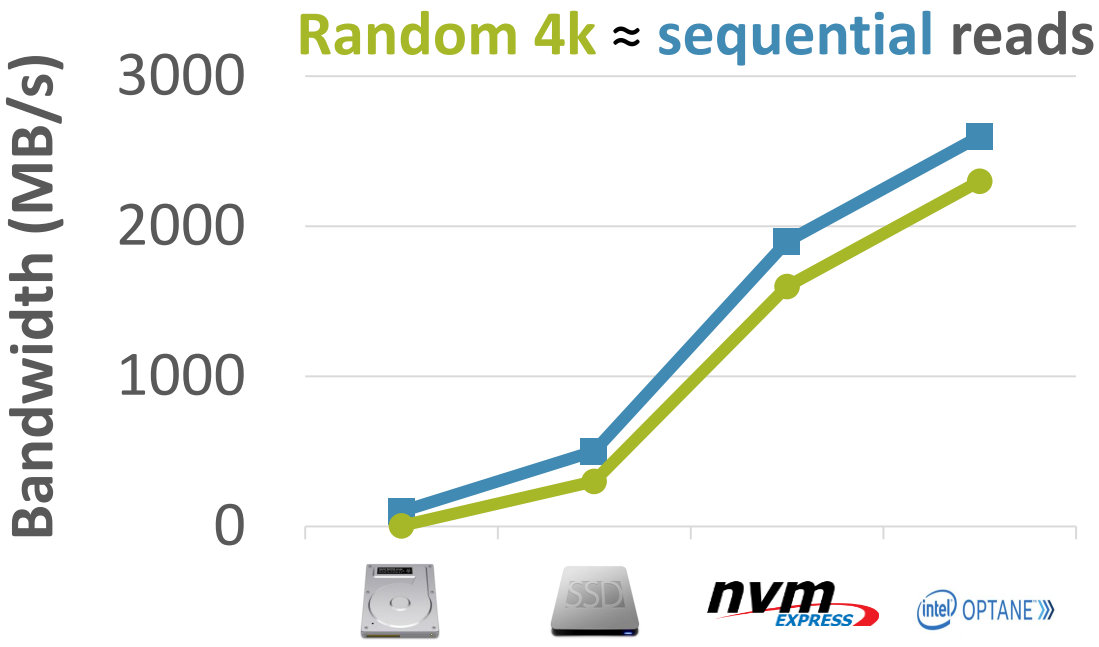
How to design an efficient KV for very fast drives?

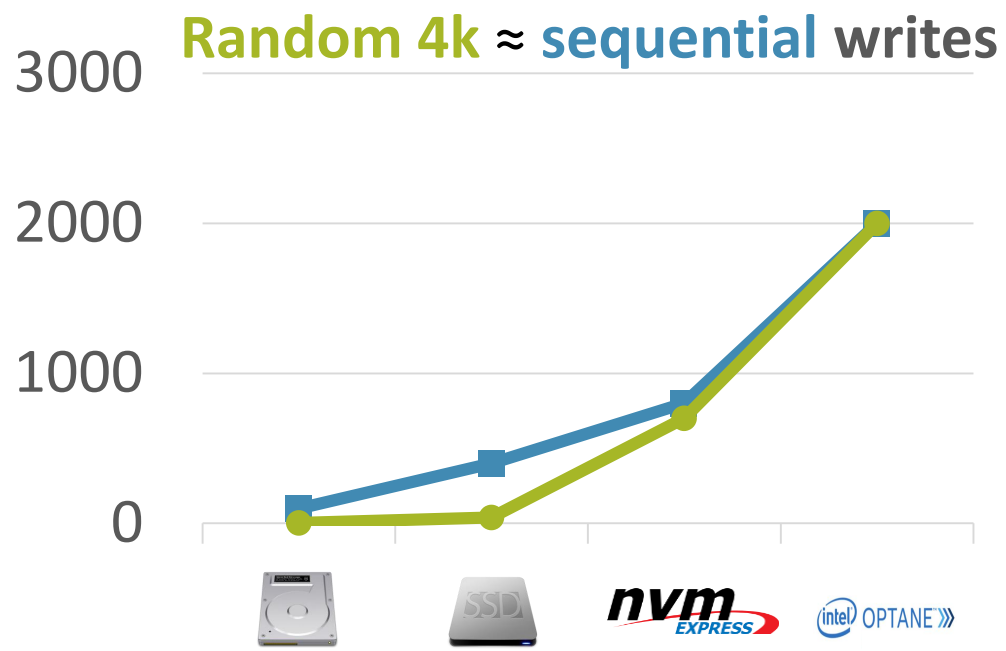
Key ideas

- ~~Ordering~~
- ~~Contention~~
- ~~Large buffers~~

- Data unsorted on disk (but sorted in memory)
- Shared-nothing
- No buffering

Key idea #1 – data unsorted on disk





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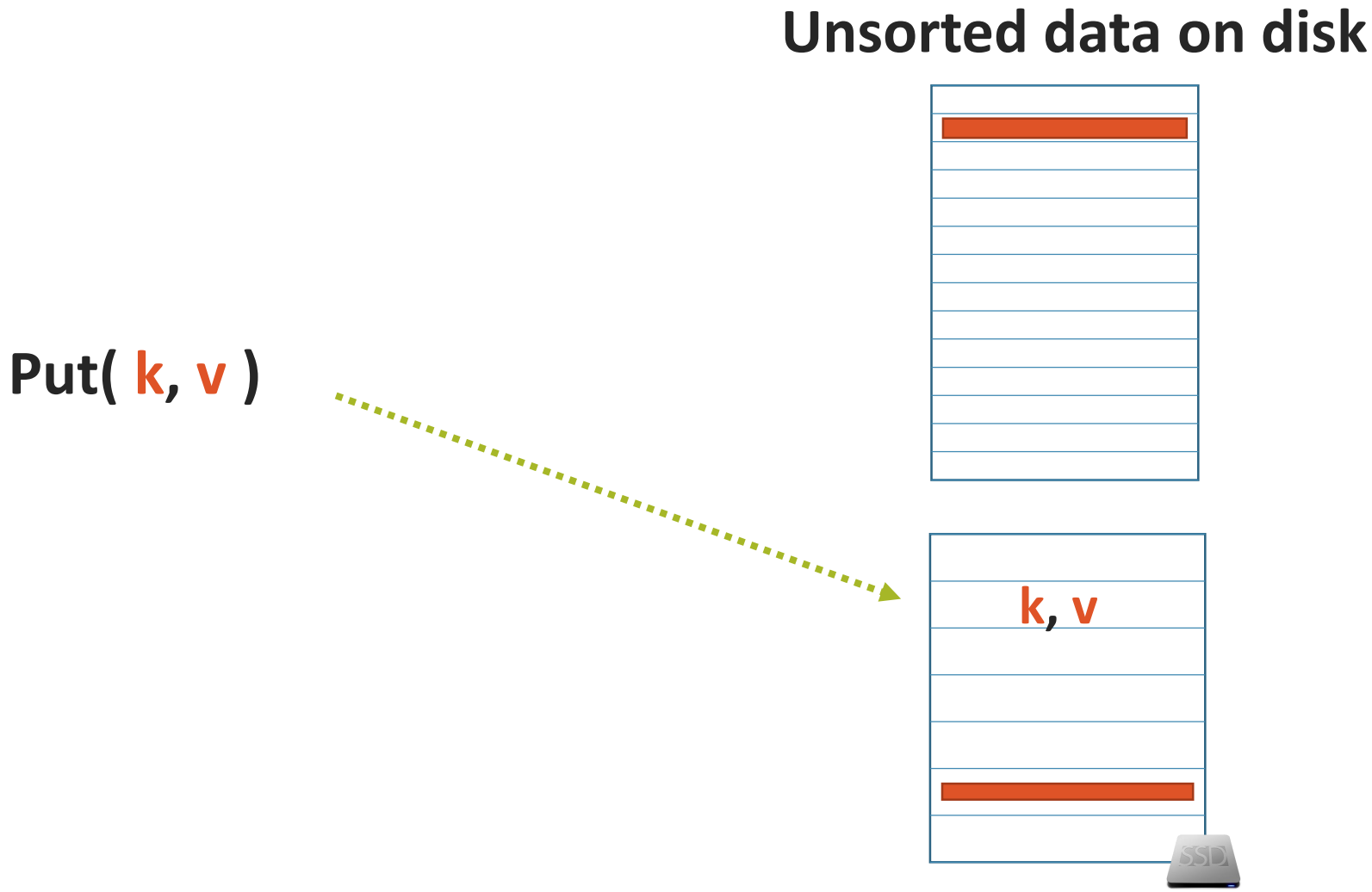
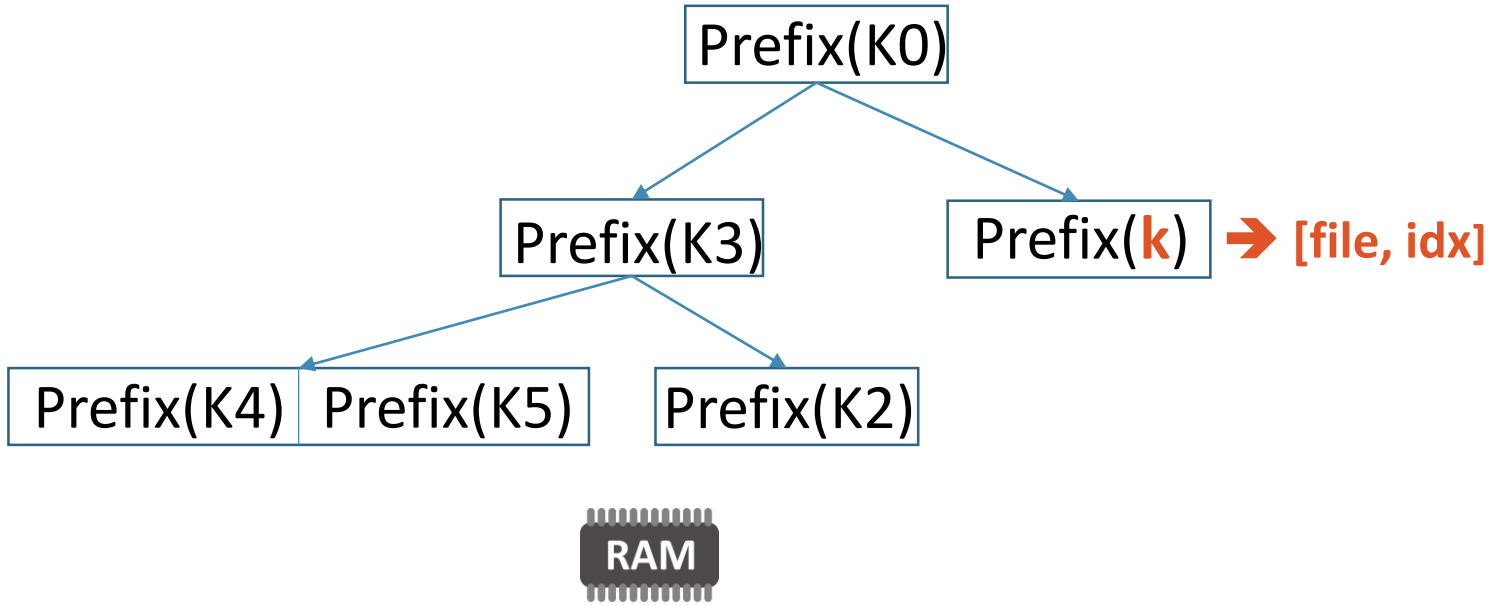
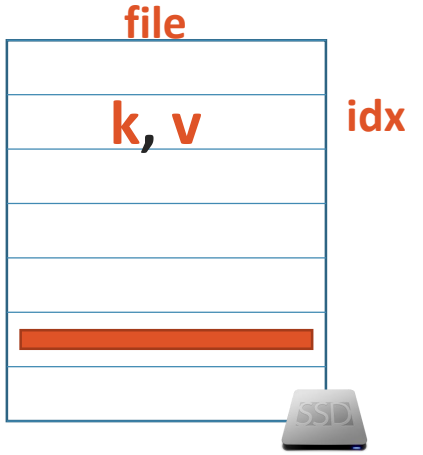


Key idea #1 – data unsorted on disk

In-memory B tree index

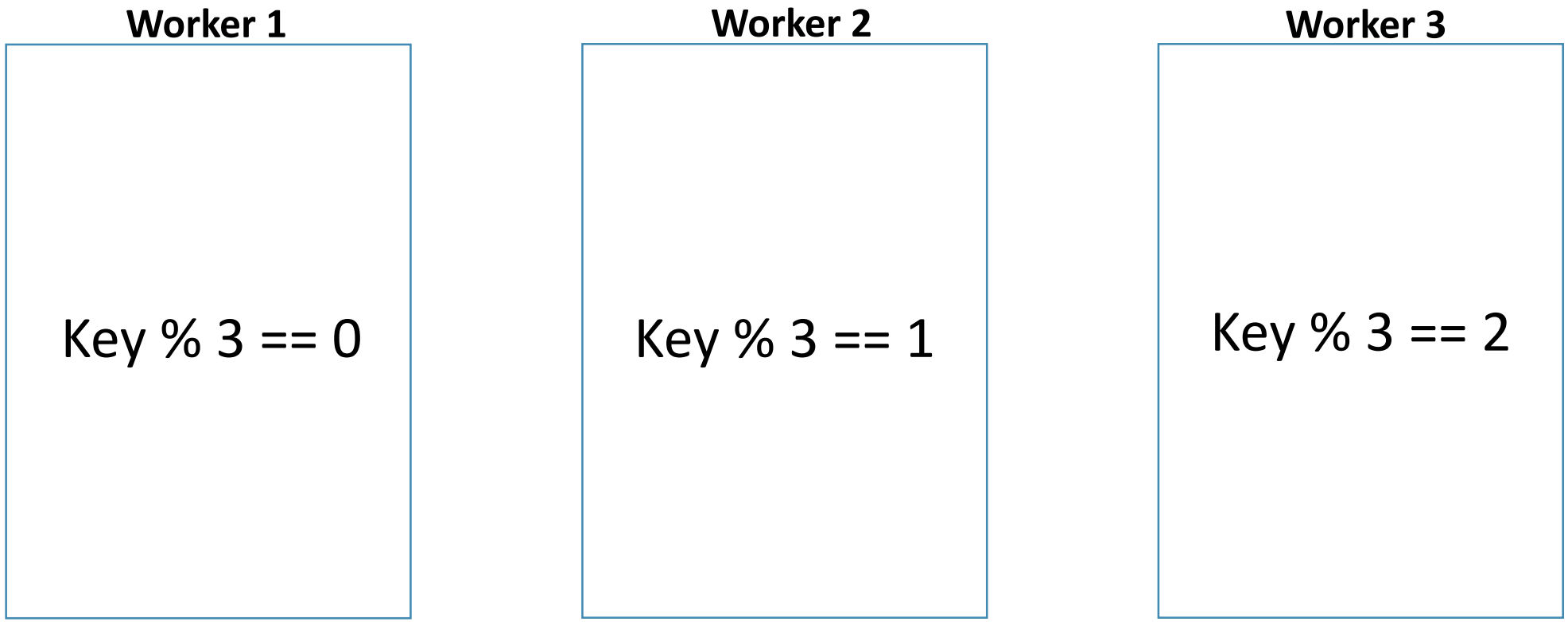


Unsorted data on disk



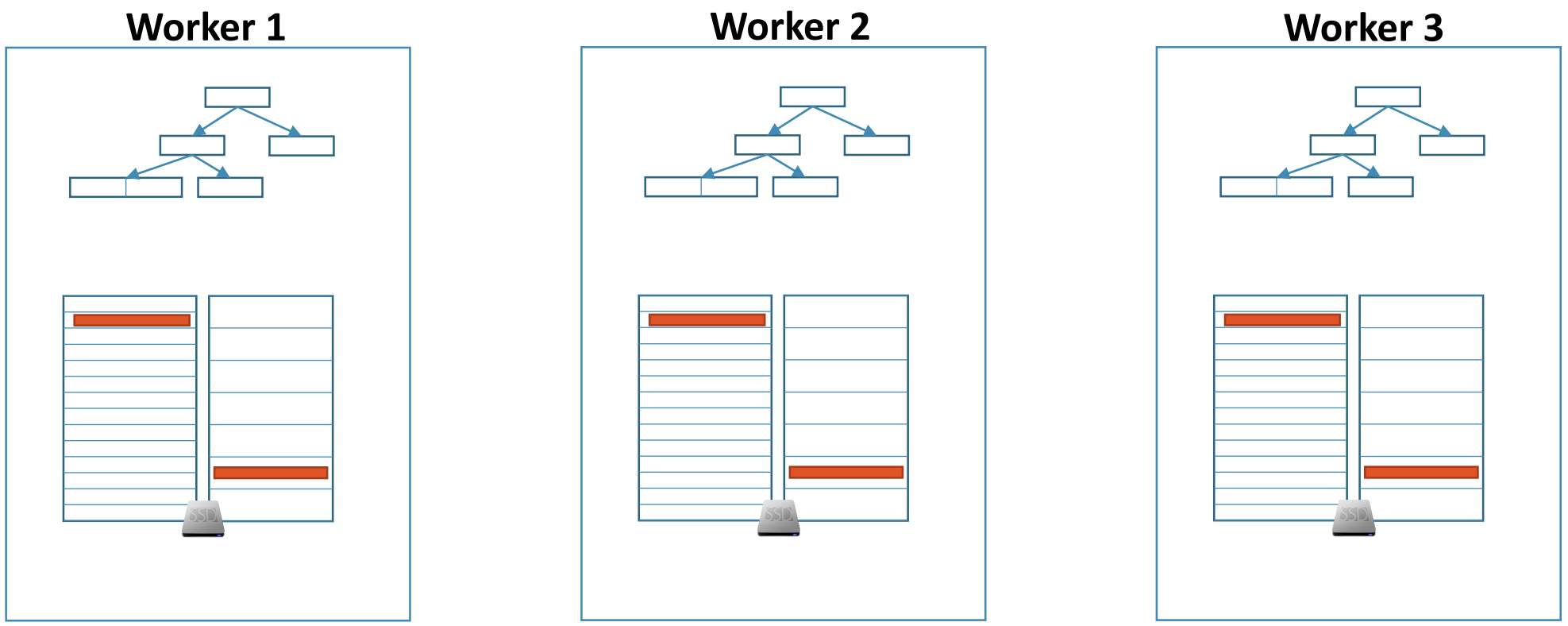
Key idea #2 – no sharing

Sharding (static partitioning) - N independent workers



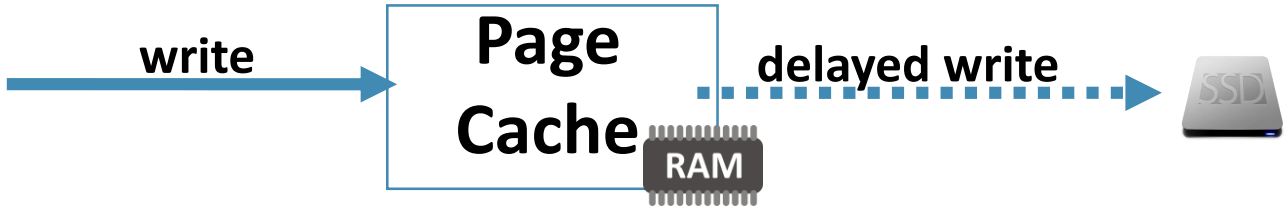
Key idea #2 – no sharing

Workers have their own index and files



Key idea #3 – no buffering

Traditionally



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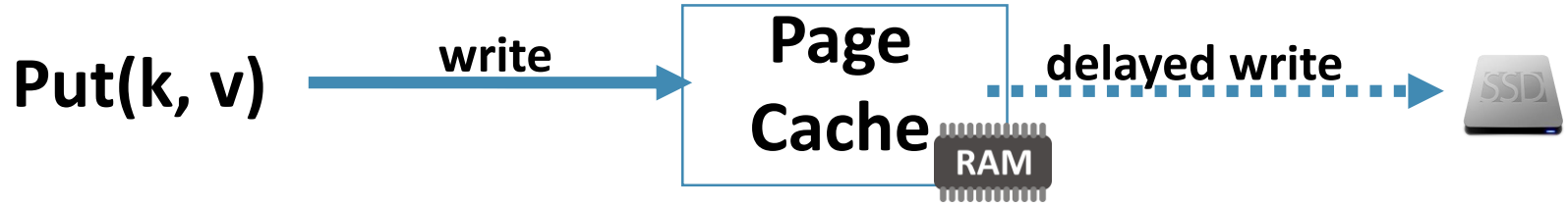
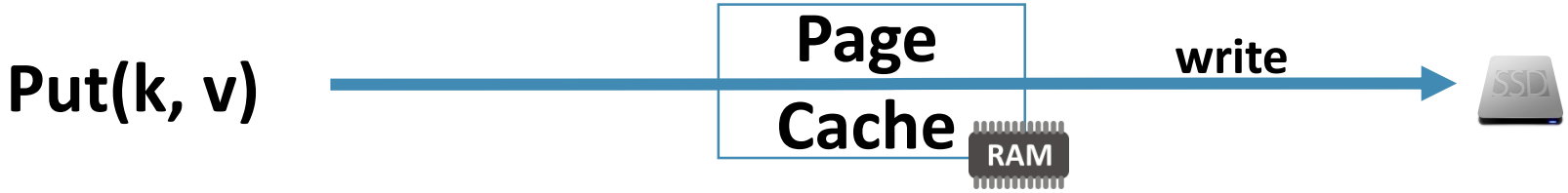


KVell



Implementation challenges

Syscall cost

Data structures

Latency vs. Bandwidth

Latency spikes

Evaluation

Machines:

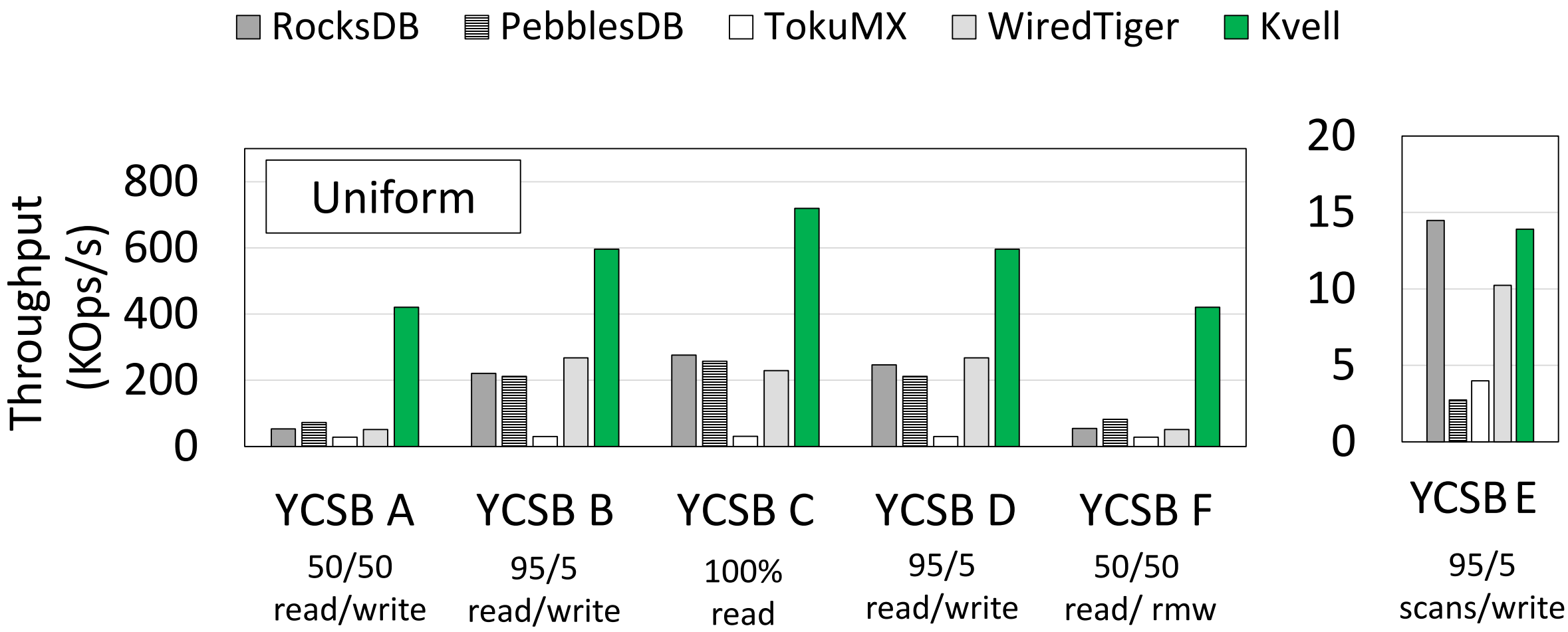
4 cores, 32GB RAM, Optane 905P drive (**500K IOPS**, 2GB/s)

Benchmark:

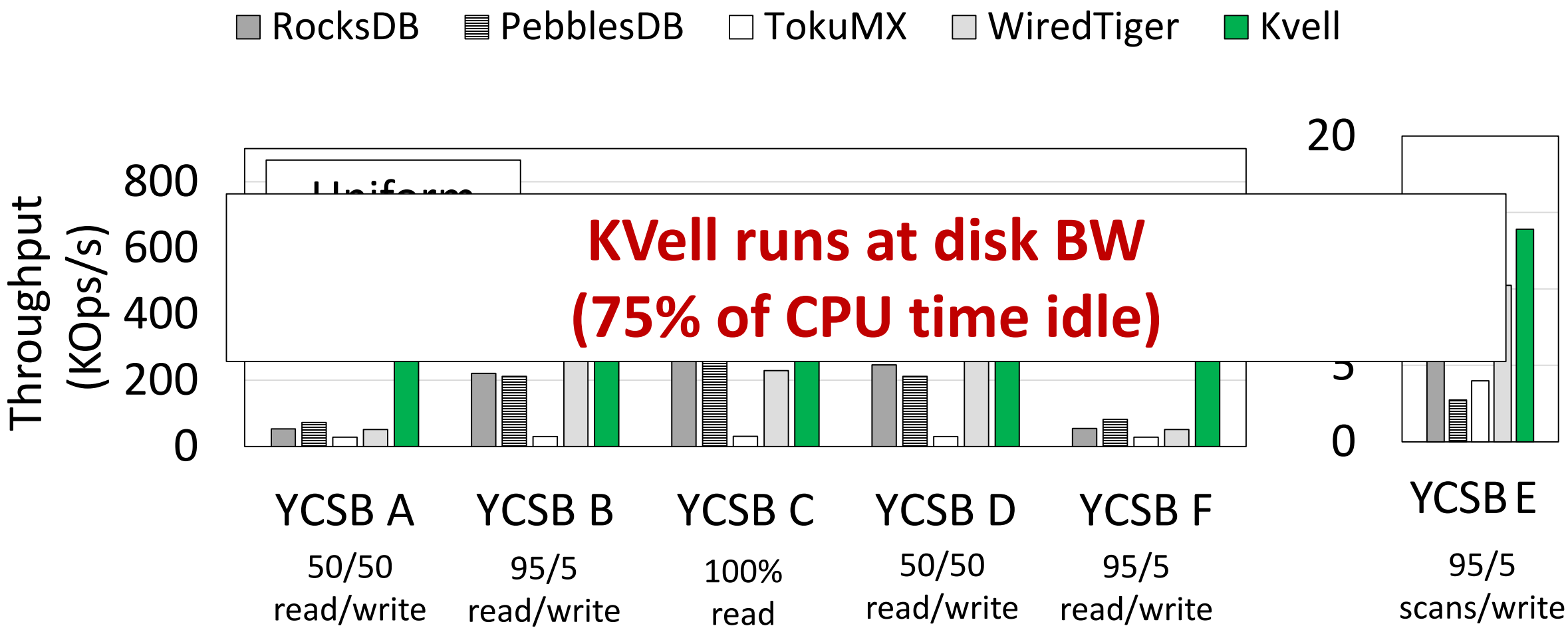
YCSB – 1KB items, 100M elements (100GB)

Competition:

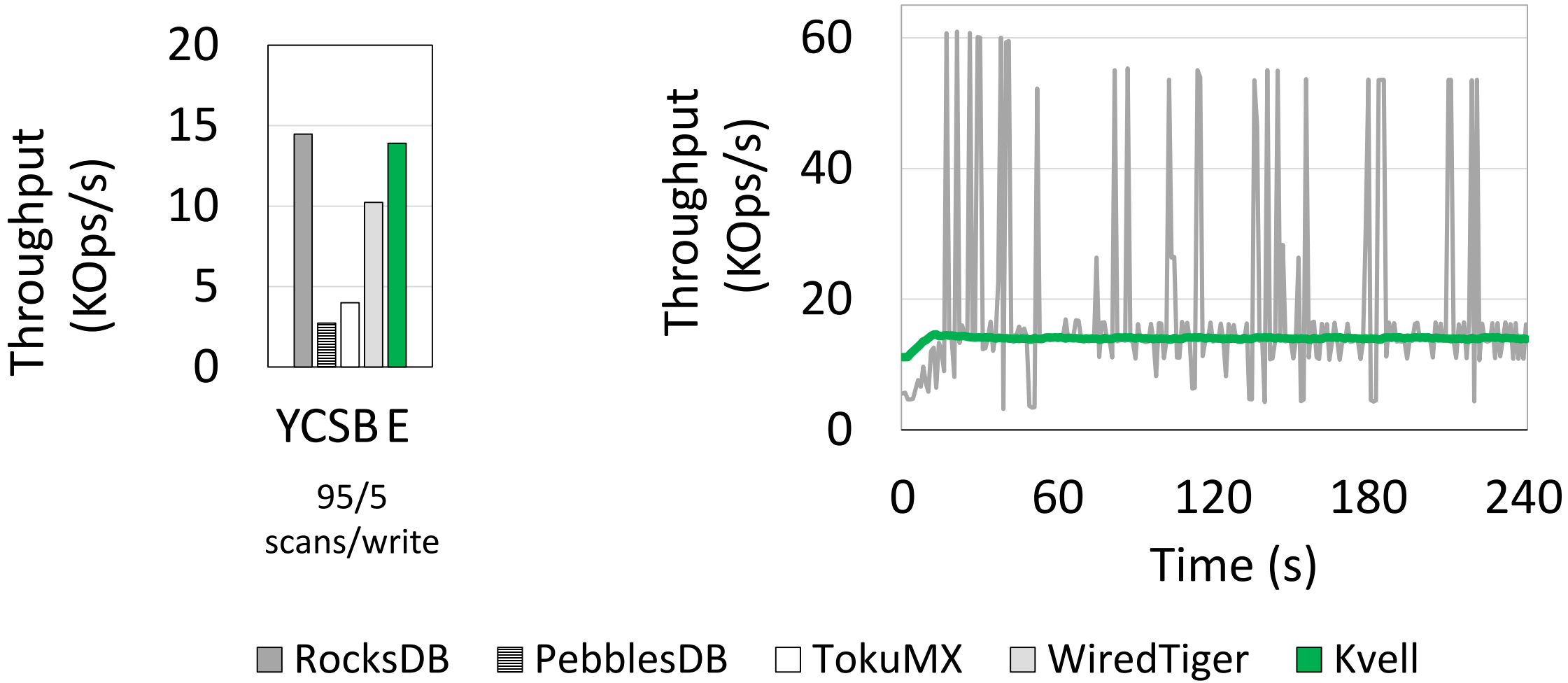
Evaluation – YCSB



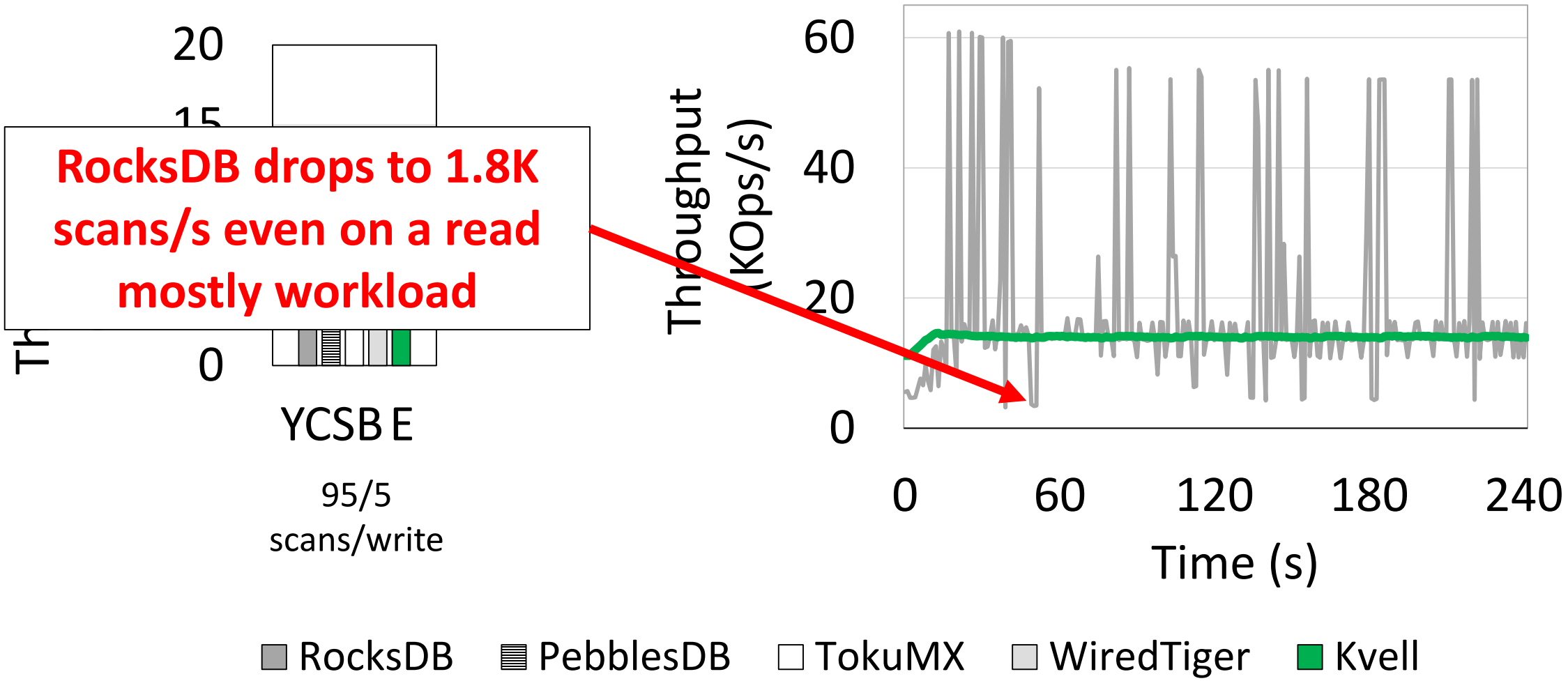
Evaluation – YCSB



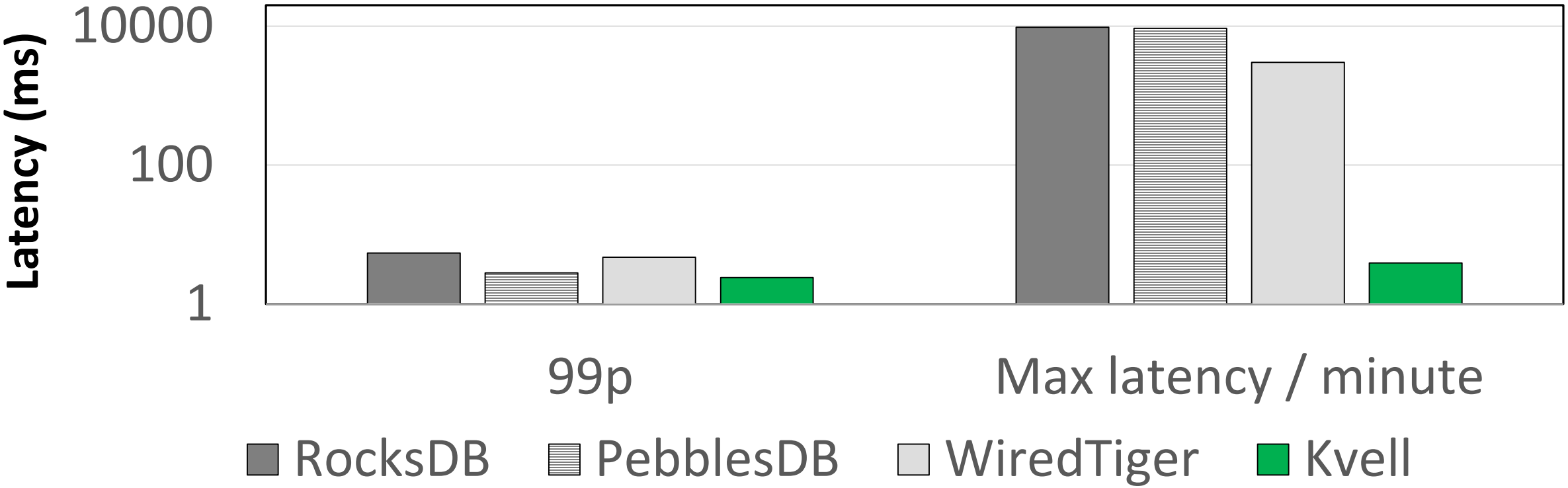
Evaluation – YCSB – Scans



Evaluation – YCSB – Scans



Evaluation – YCSB – Latency



In the paper

- Limitations:
  - Indexes have to fit in memory
  - Suboptimal scans for small items
- AWS machine, 15GB/s, 5TB dataset
- Production workload
- Recovery time

…

Conclusions & take away messages

- **Ordering data is expensive**
- **Buffering** kills performance

- Optimizing for **CPU utilization is key**

https://github.com/BLepers/KVell

Code and scripts to reproduce results on AWS

To kvell: to feel happy and proud

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Kvelt

Evaluation – A word on recovery time

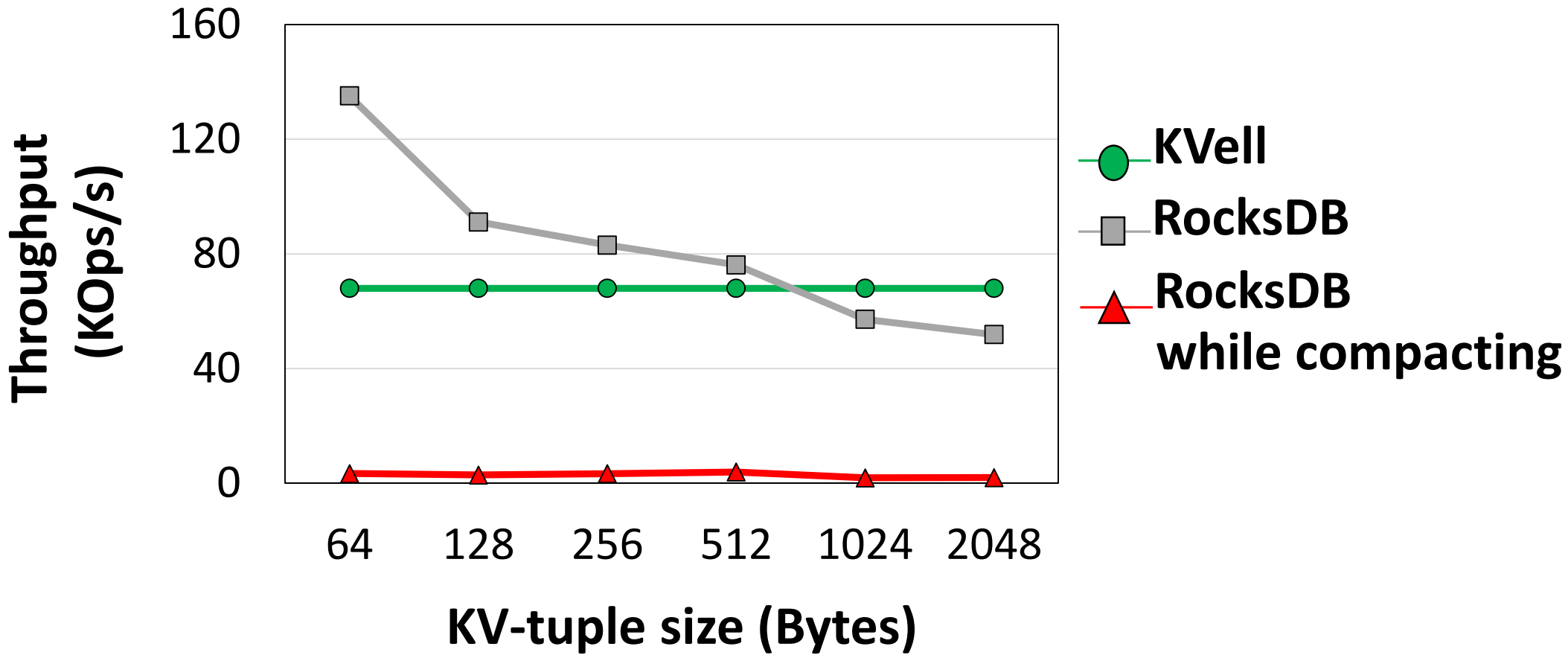
KVell recovery time is bounded by disk speed

100GB database – 100M elements – i3.metal

System	Recovery time
RocksDB	18s
WiredTiger	24s
KVell	**6.6s**

Surprisingly, scanning the whole database (efficiently) is faster than recovering from commit logs (inefficiently)

Evaluation – Scans



Key idea #1 – data unsorted on disk

Location information **= 19B per item**
Typical item size on disk = 400B-1KB

100 millions items = 1.7GB in memory