NVMKV: A Scalable and Lightweight Flash Aware Key-Value Store

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Introducing KV Stores

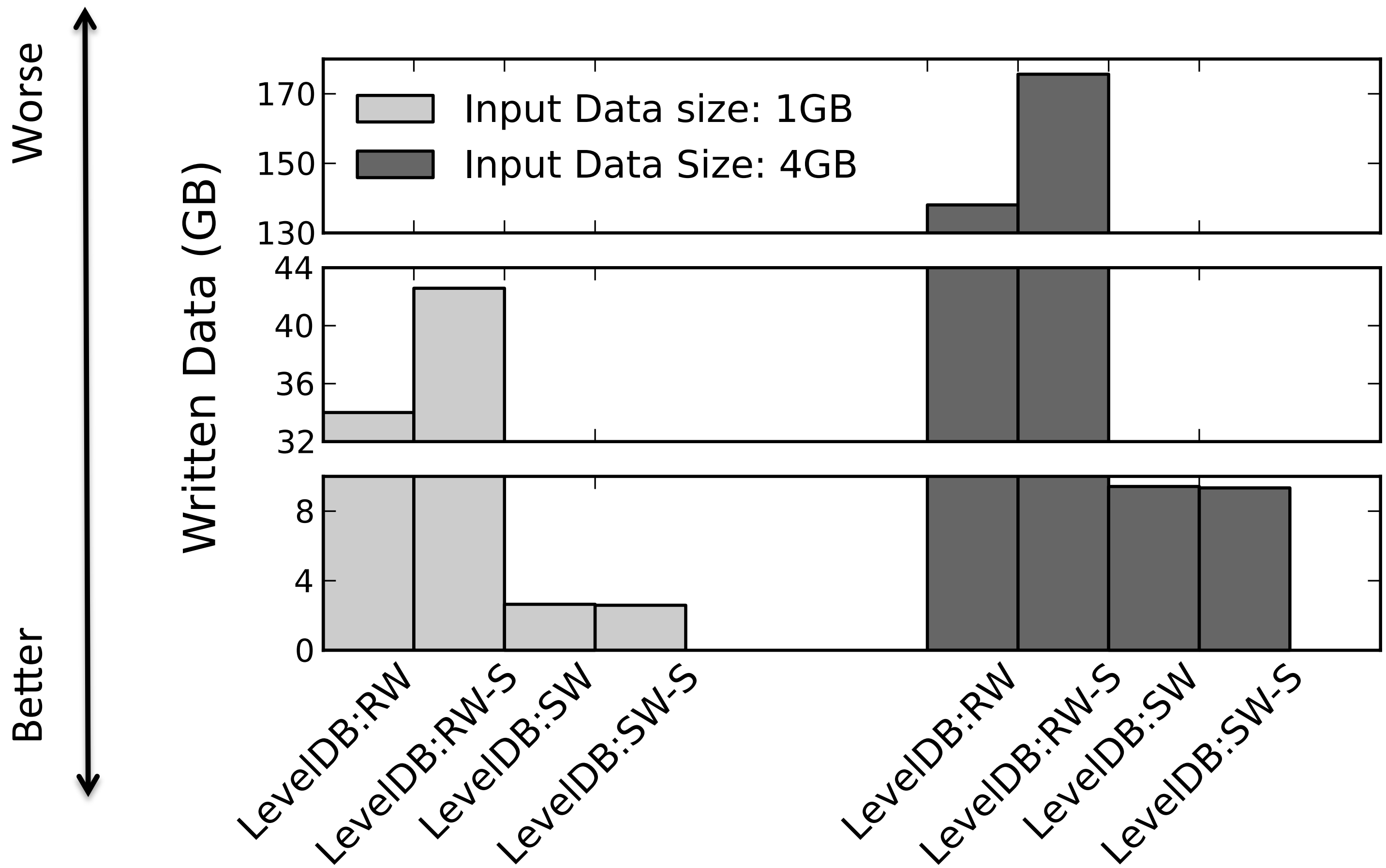
- Preferred data management solution for Internet services
- Provide simple interface
  - get, put, delete
- Provide weaker consistency model
  - Compared to RDMS
  - Tradeoff between performance and consistency

Limitations of existing solutions*

- Use log-structured/out-of-place updates
  - Better performance on hard-disk and older SSD's
- Require compaction/garbage collection
- Creates auxiliary write amplification
  - Performance penalty
  - Reduces the life of NAND flash

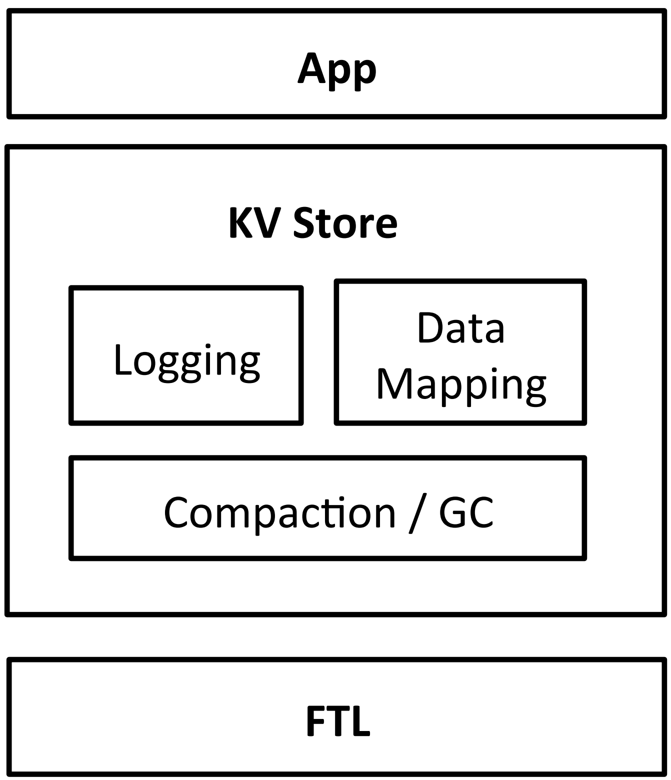
*Existing Key-Value Store optimized for FLASH storage

How bad is the situation?



- Auxiliary write amplification varying from 2.5x to 43x
- “Don’t Stack your Log on my Log” by Yang et al. (INFLOW’14)

Existing KV Store Designs



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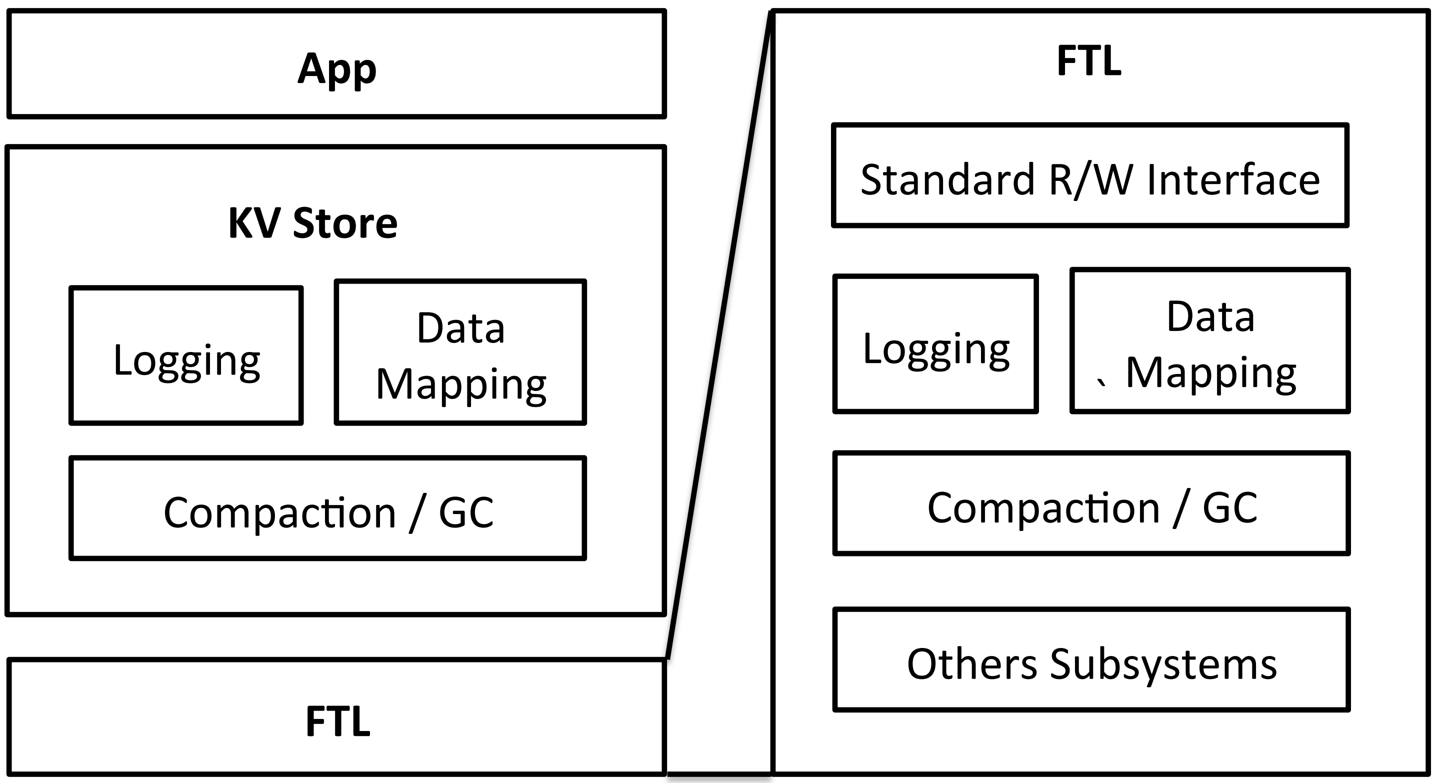
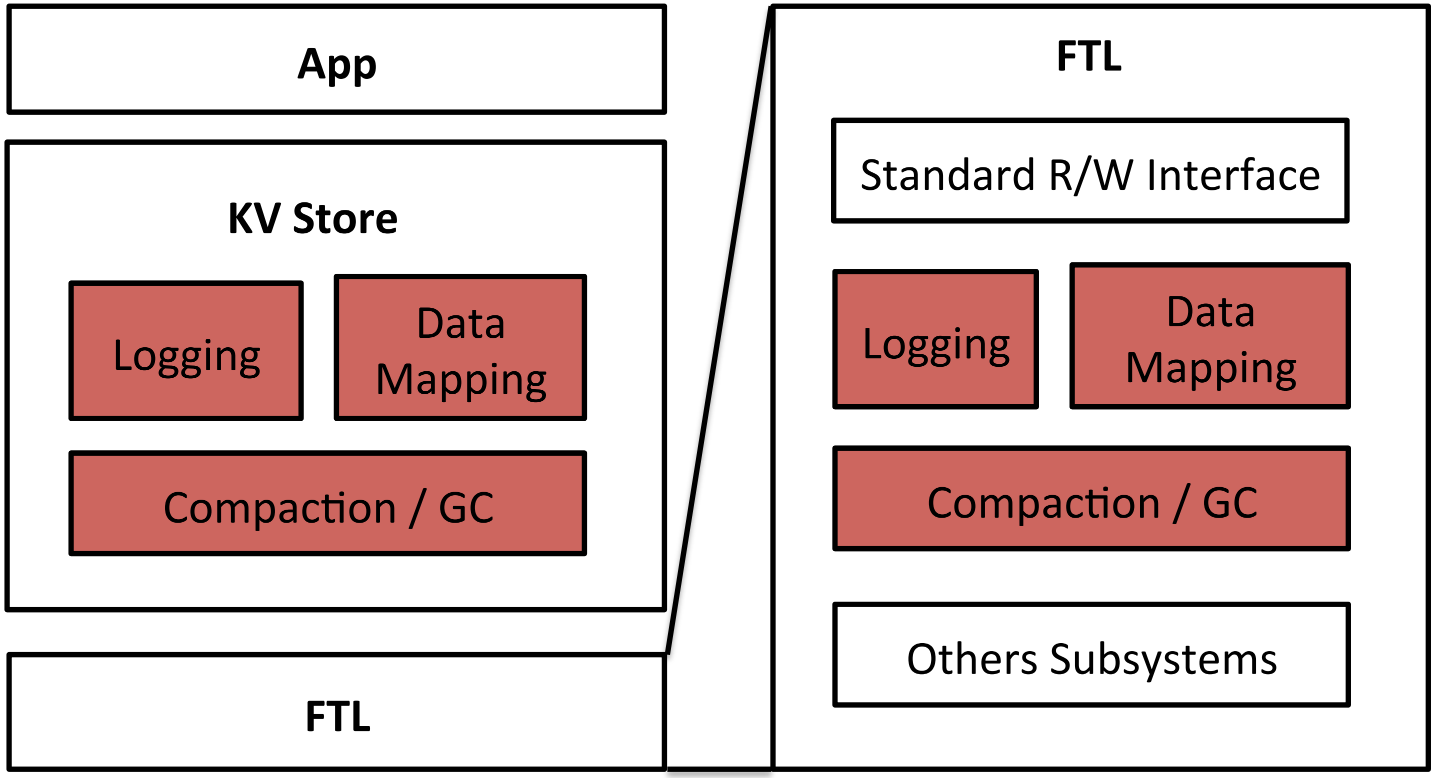
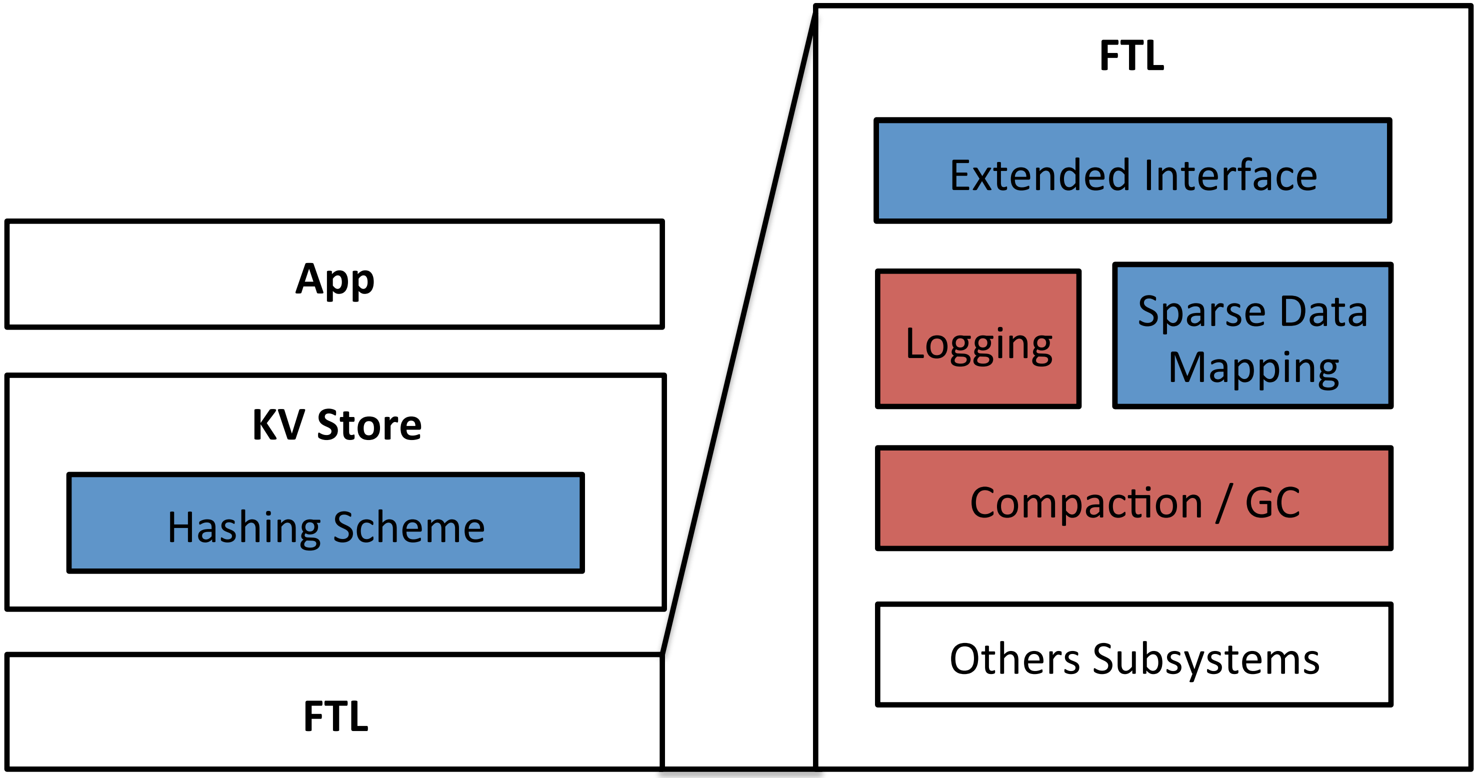


Existing KV Store Designs

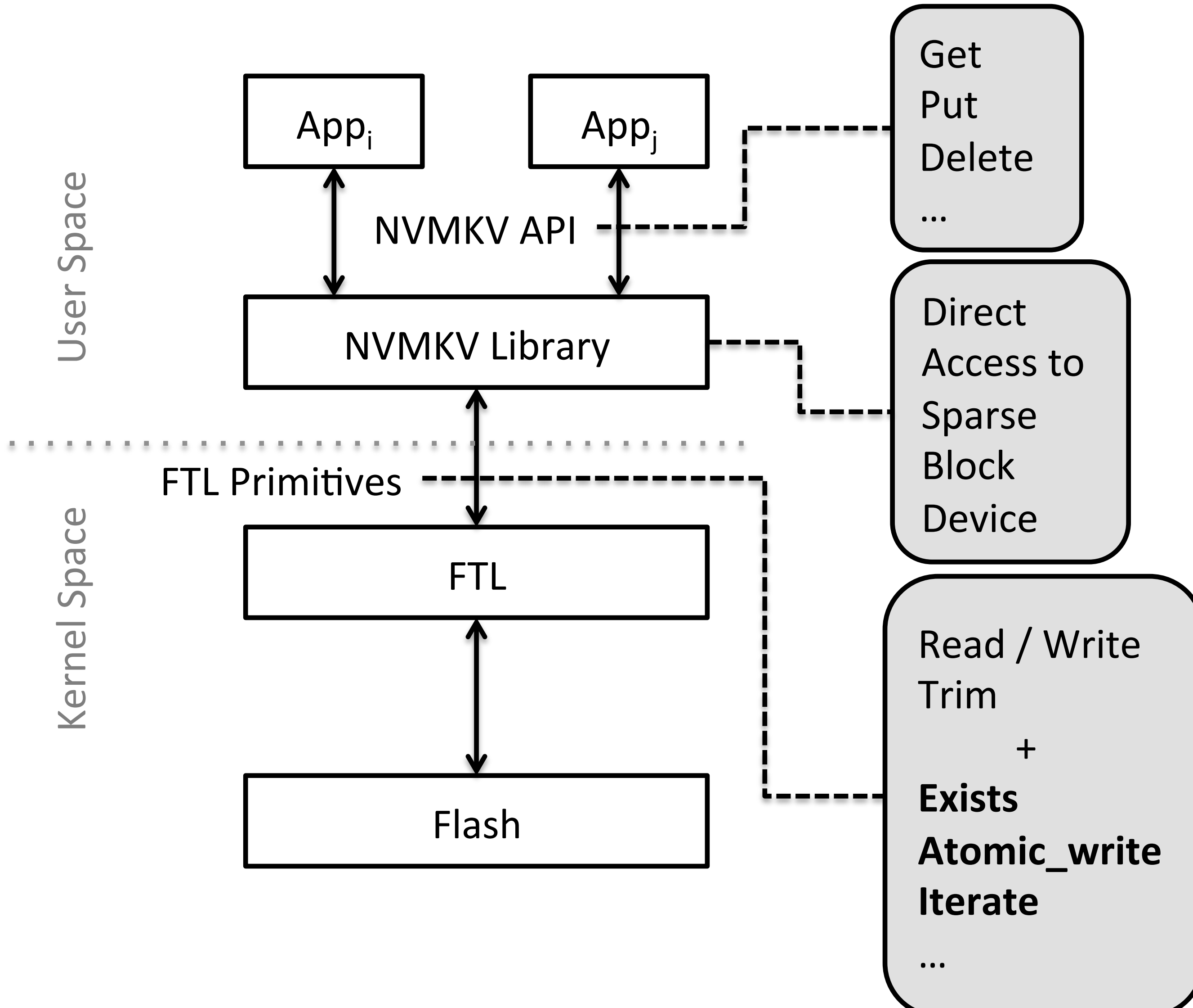


FTL Cooperative KV Store Design



Design

NVMKV System Architecture



NVMKV API

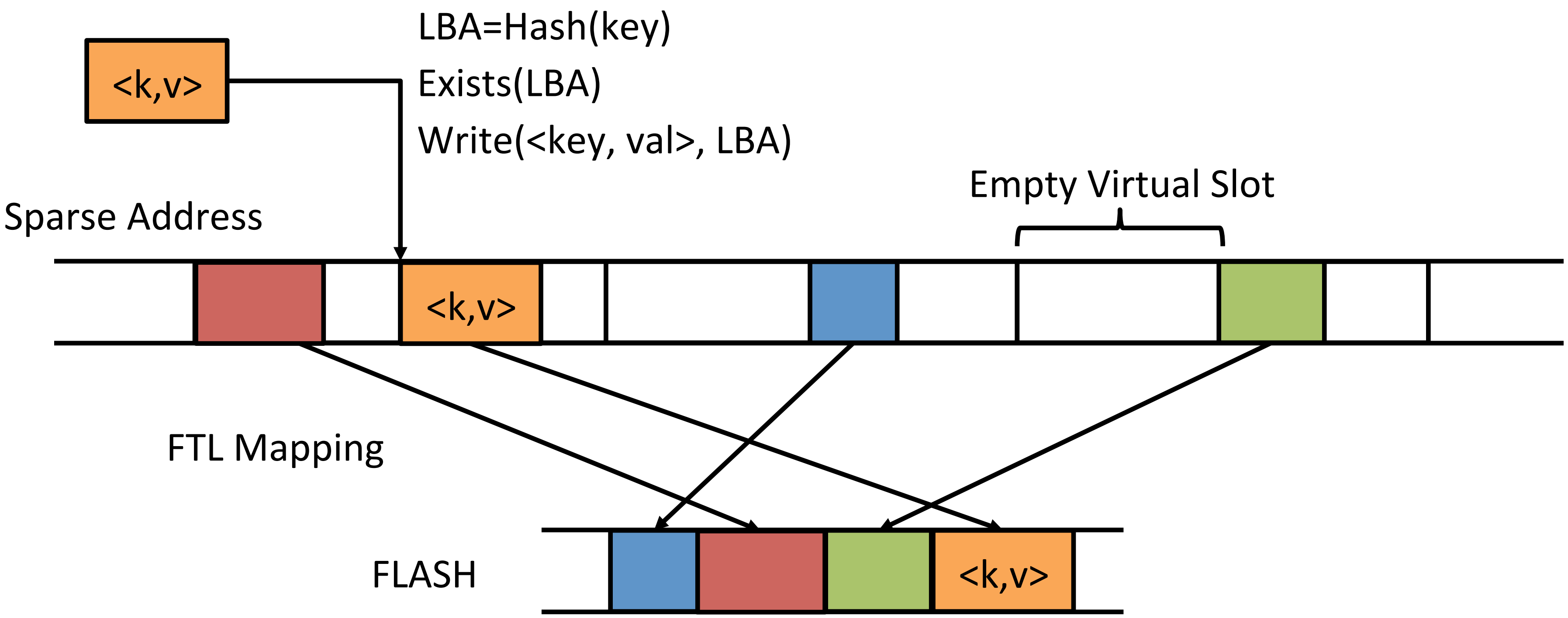
- Management
  - Open / Create
  - Close / Destroy
- Basic operations
  - Get, Put, Delete
- Batch operations
  - Batch-Get, Batch-Put
  - Batch-Delete
  - Delete-all

Code Fragment

```
fd = open(dev_name,…);
id = nvmkv_open(fd,…);
…
nvmkv_put(id,k1,v1,…);
…
nvmkv_exists(id,k2,…);
…
nvmkv_get(id,k2,…);
…
nvmkv_close(id);
close(fd)
```

- A full description of the API can be found in the paper
- “Beyond Block I/O: Rethinking Traditional Storage Primitives” by Ouyang et al.

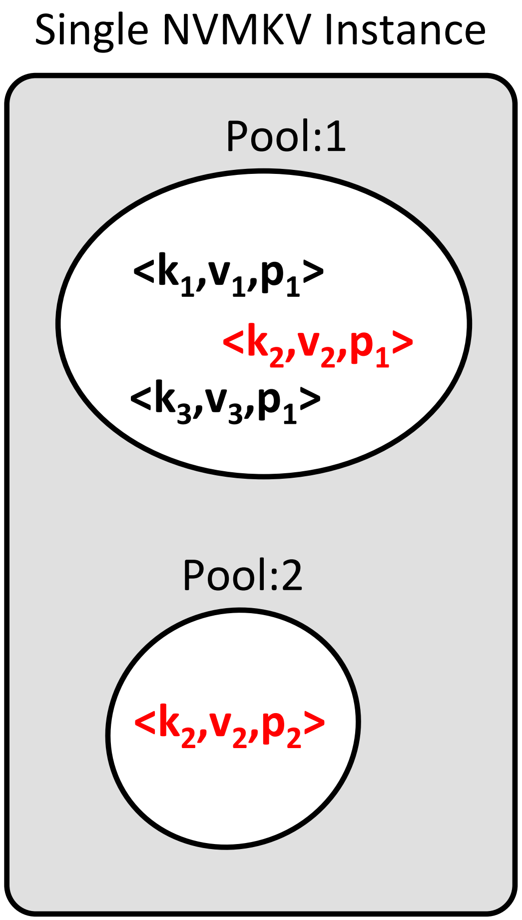
I/O on a Sparse Block Device



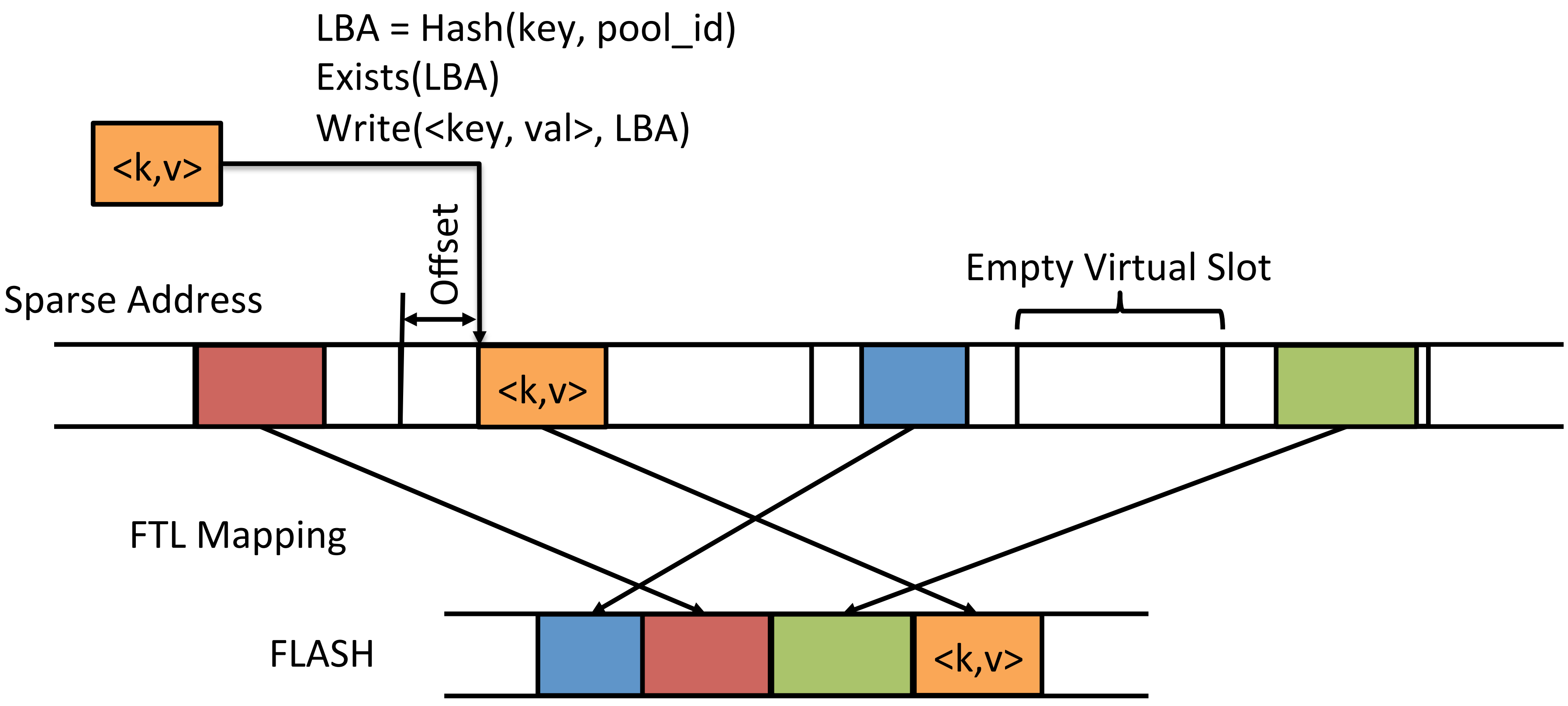
- Exists(LBA) does not perform I/O
- New LBA(s) are computed using polynomial probing
- The size of the virtual slots can be configured

Multiple NVMKV On Single Device

- Pool: Set of unique key-value pairs that shared the same pool id.
  - Part of hashing scheme
    - LBA = Hash(key, pool_id)
  - No in-memory metadata
  - No extra I/O operations
  - Now operations required pool_id, in addition to key & value



Inserting KV-Pairs into Pools



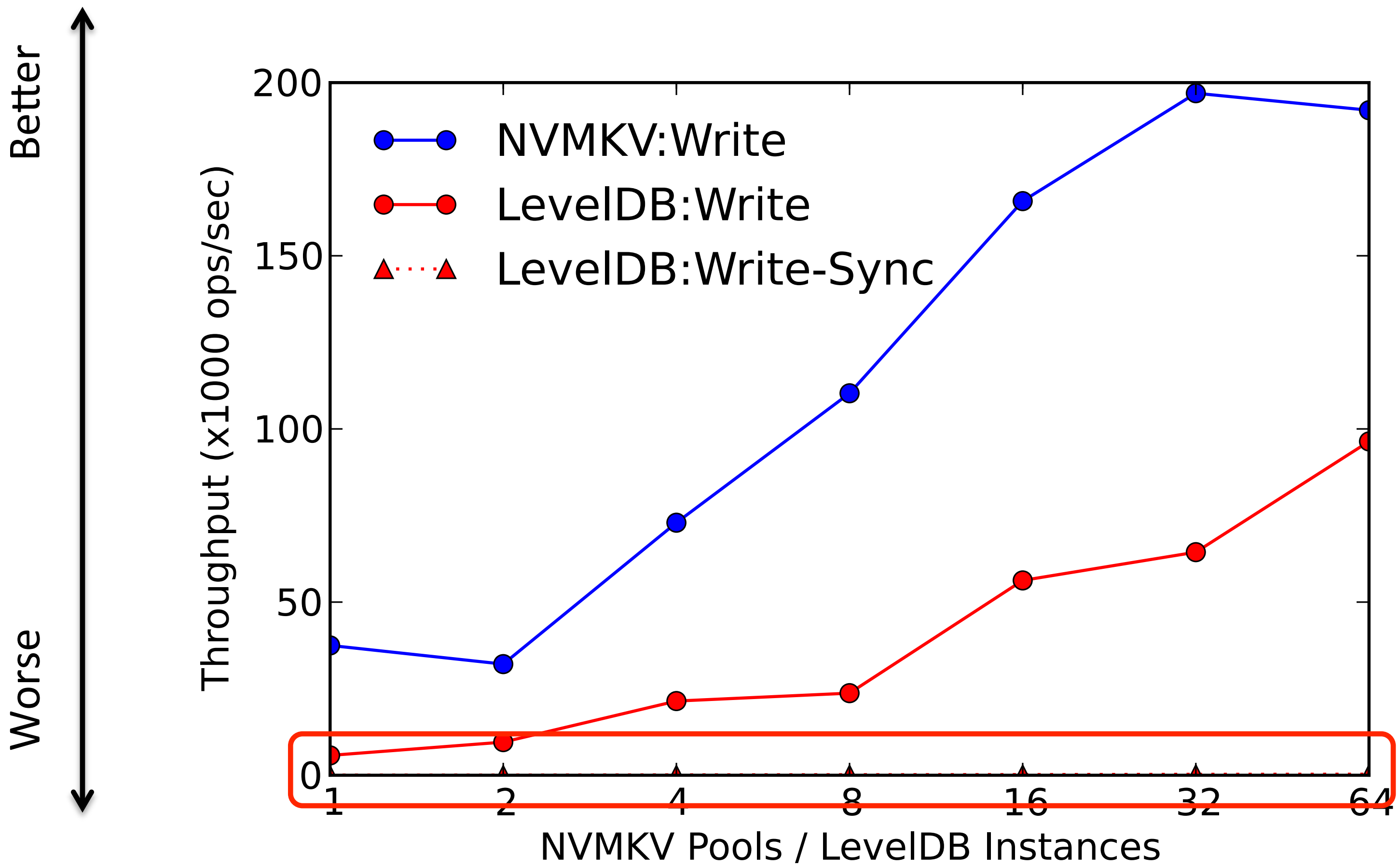
- Only one <key,val> per virtual slot
- Offset within the virtual slot determines the pool_id
- Offsets in virtual address does not creates wasted space in flash

Improving Performance by Caching

- **Read-only Cache**: Improves read performance.
- **Collision Cache**: Prevents multiple I/Os when cache collision occurs.
- For more details, please consult the paper.

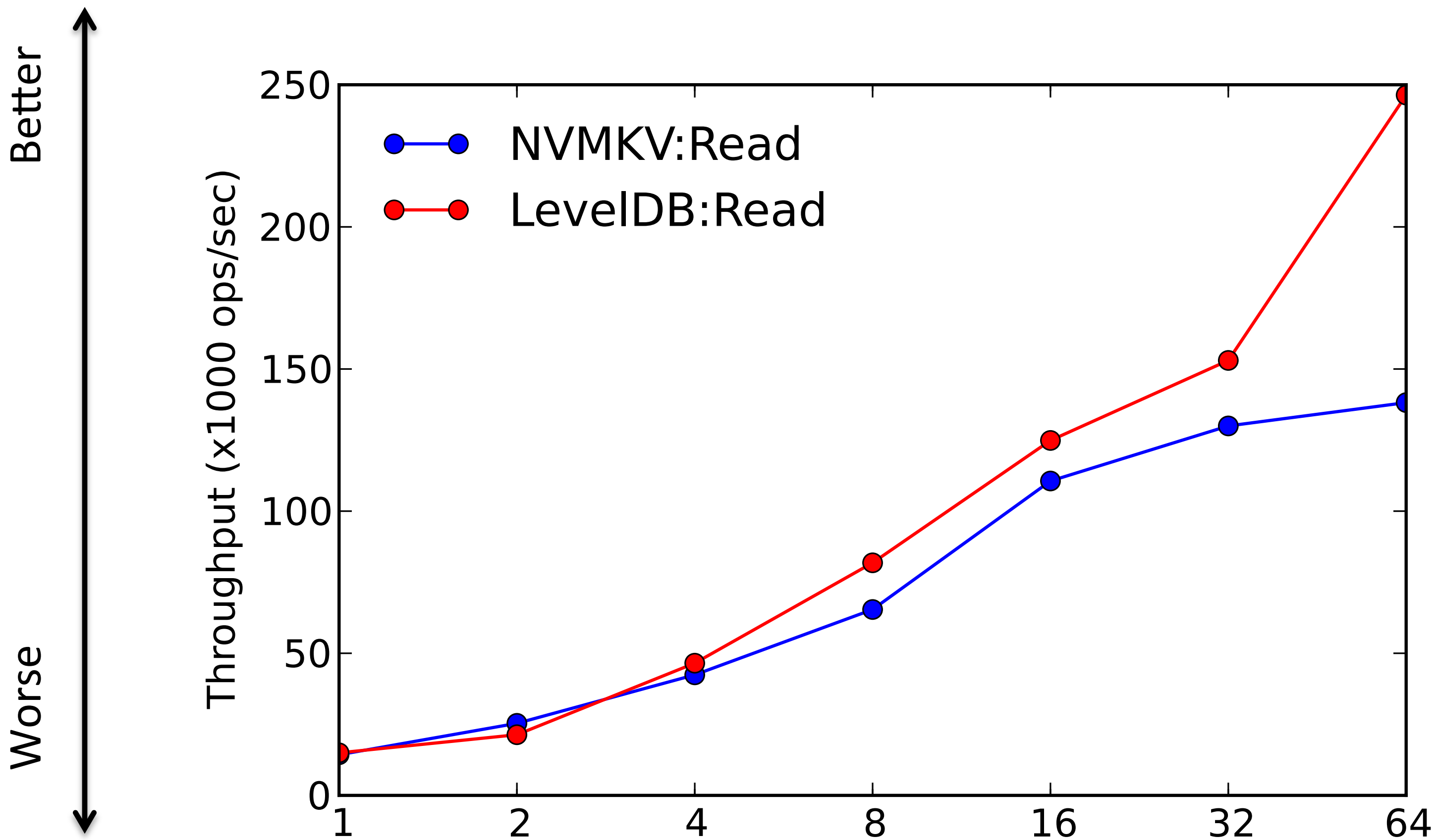
Evaluation Results

NVMKV Performance



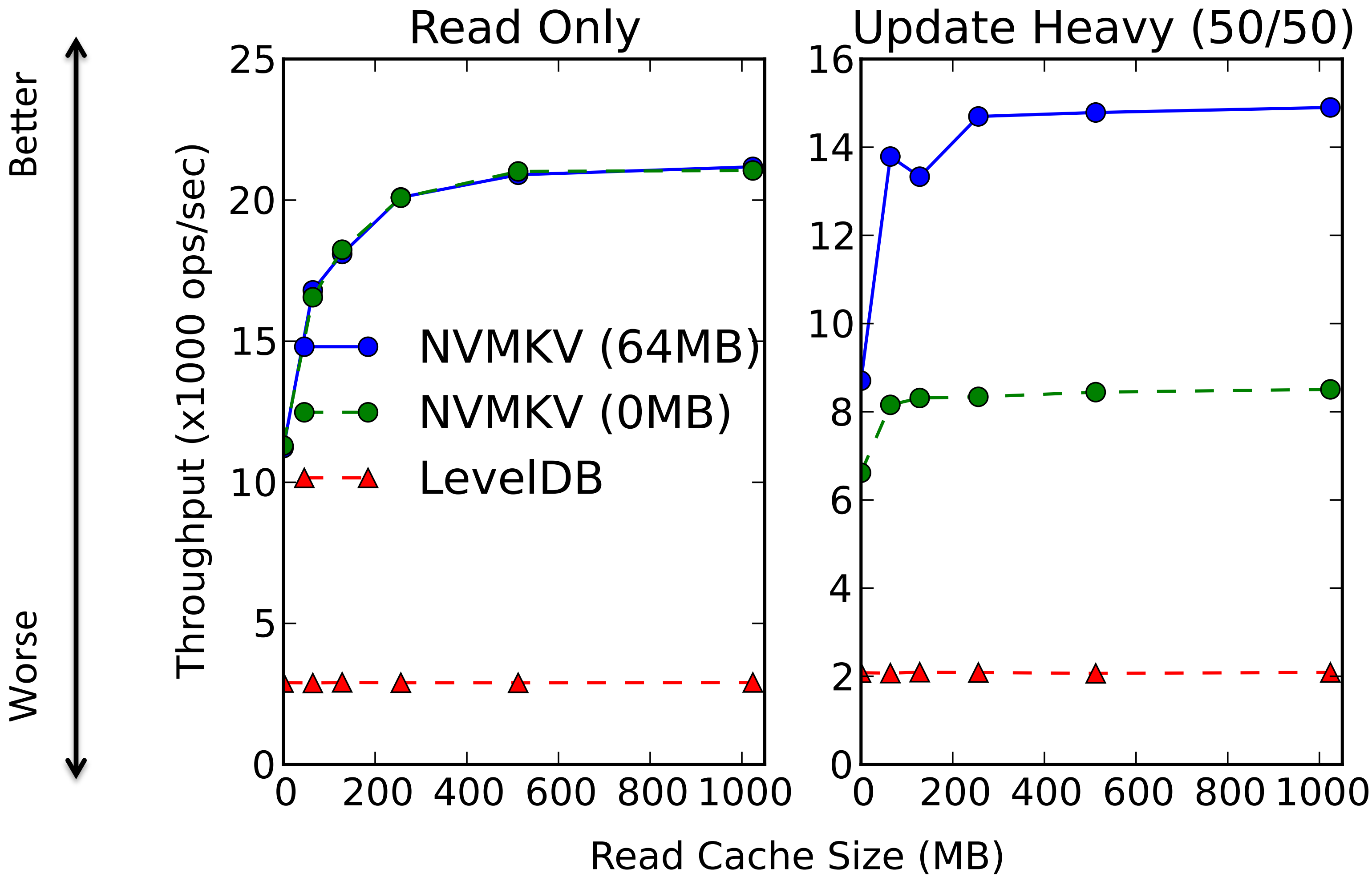
- NVMKV outperform LevelDB even when LevelDB uses async writes
- NVMKV writes are always synchronous (no buffering)

NVMKV Performance



- LevelDB benefits from both its own cache and the file system cache (warmed)
- NVMKV perform competitively up to 32 pools even without any caching

YCSB Benchmark



Summary

- We propose a FTL cooperative design that allows for:
  - Simple KV-Store design and implementation
  - Constant amount of metadata
  - Multiple KV-Stores sharing the same FLASH
  - High performance / parallelism
  - Atomicity and durability of KV operations
  - Low write amplification
    - Reduced write amplification by up to 29x compared to LevelDB

Fork me on GitHub

Thank you!

opennvm.github.io

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