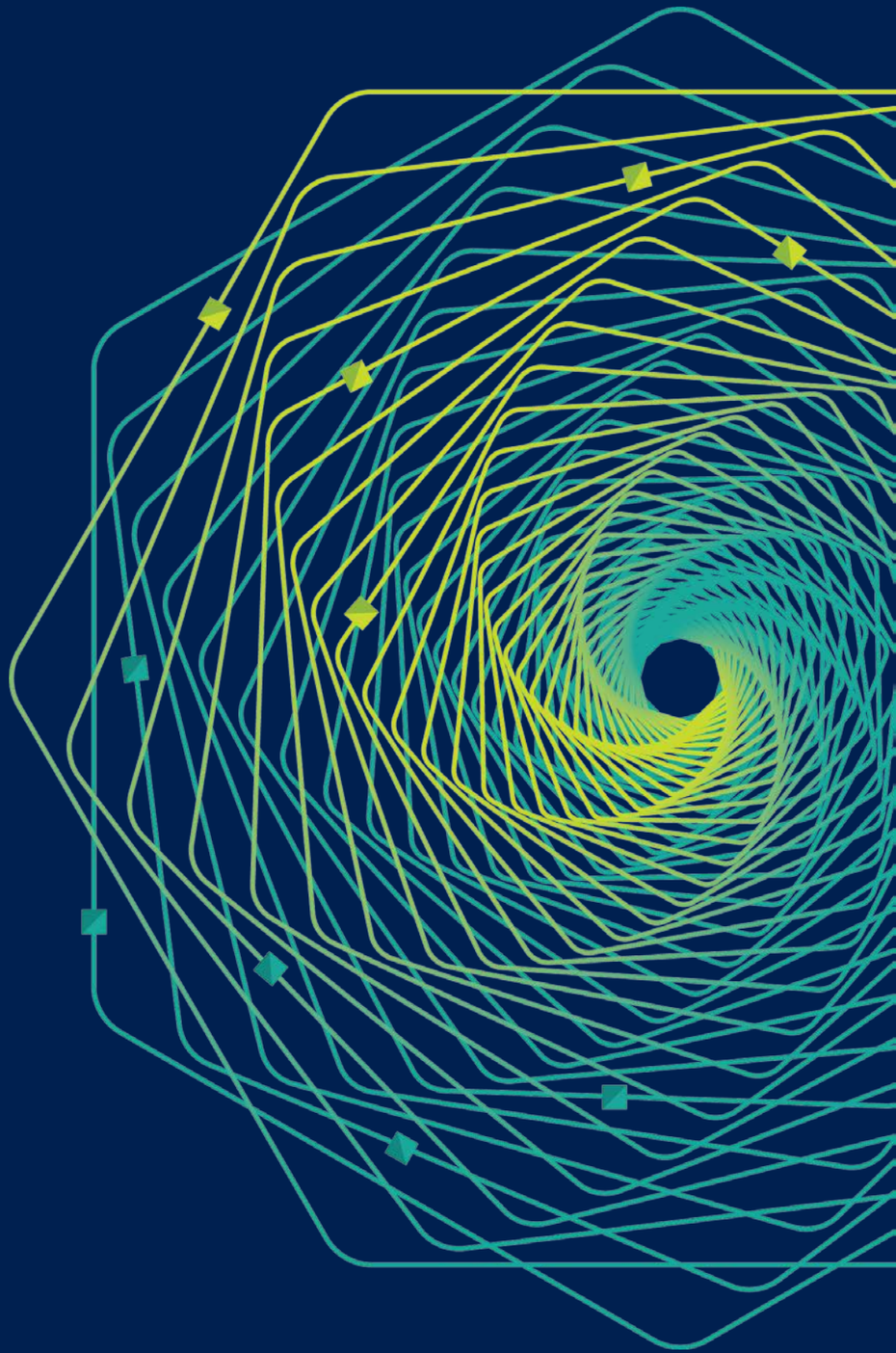
Microsoft

Research Faculty Summit 2018

Systems | Fueling future disruptions



What Should You Do With Persistent Memory?

Steven Swanson

Director, Non-Volatile Systems Lab

Computer Science and Engineering

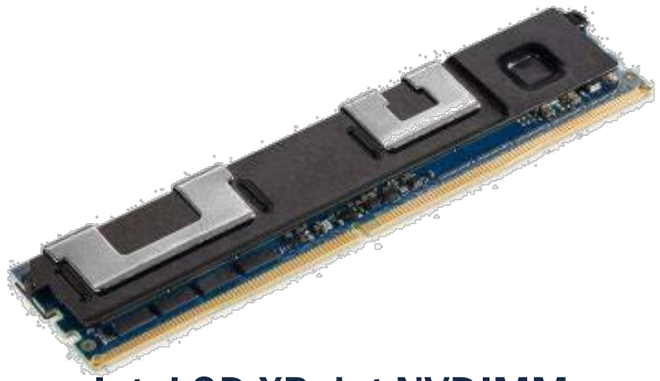
UC San Diego

NVSL

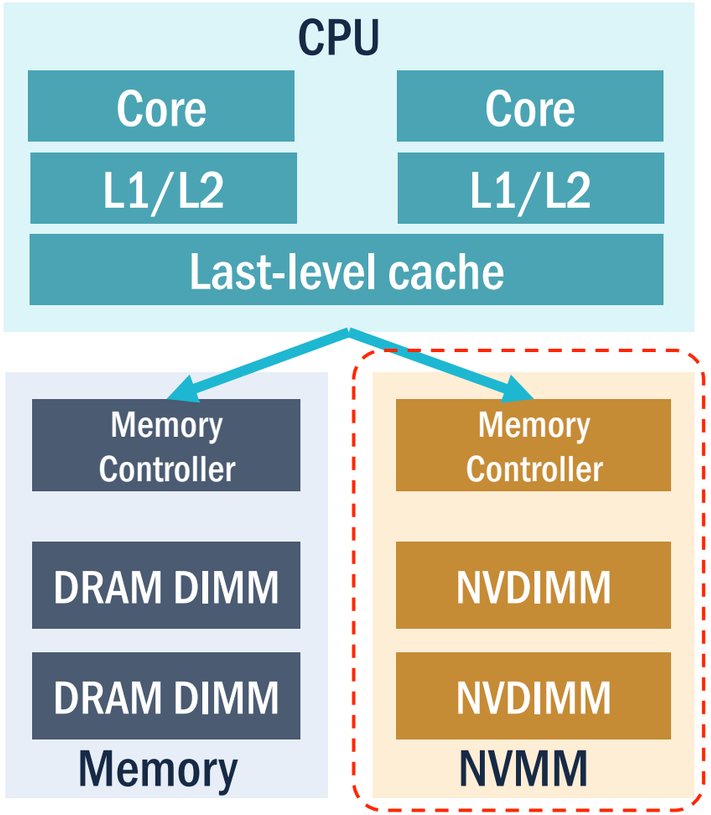
UCSDCSE Computer Science and Engineering

Non-volatile main memory (NVMM)

- Byte-addressable
- Denser than DRAM
- DRAM-comparable latency
- Higher bandwidth than SSD
- Ready for DMA / RDMA



Intel 3D XPoint NVDIMM



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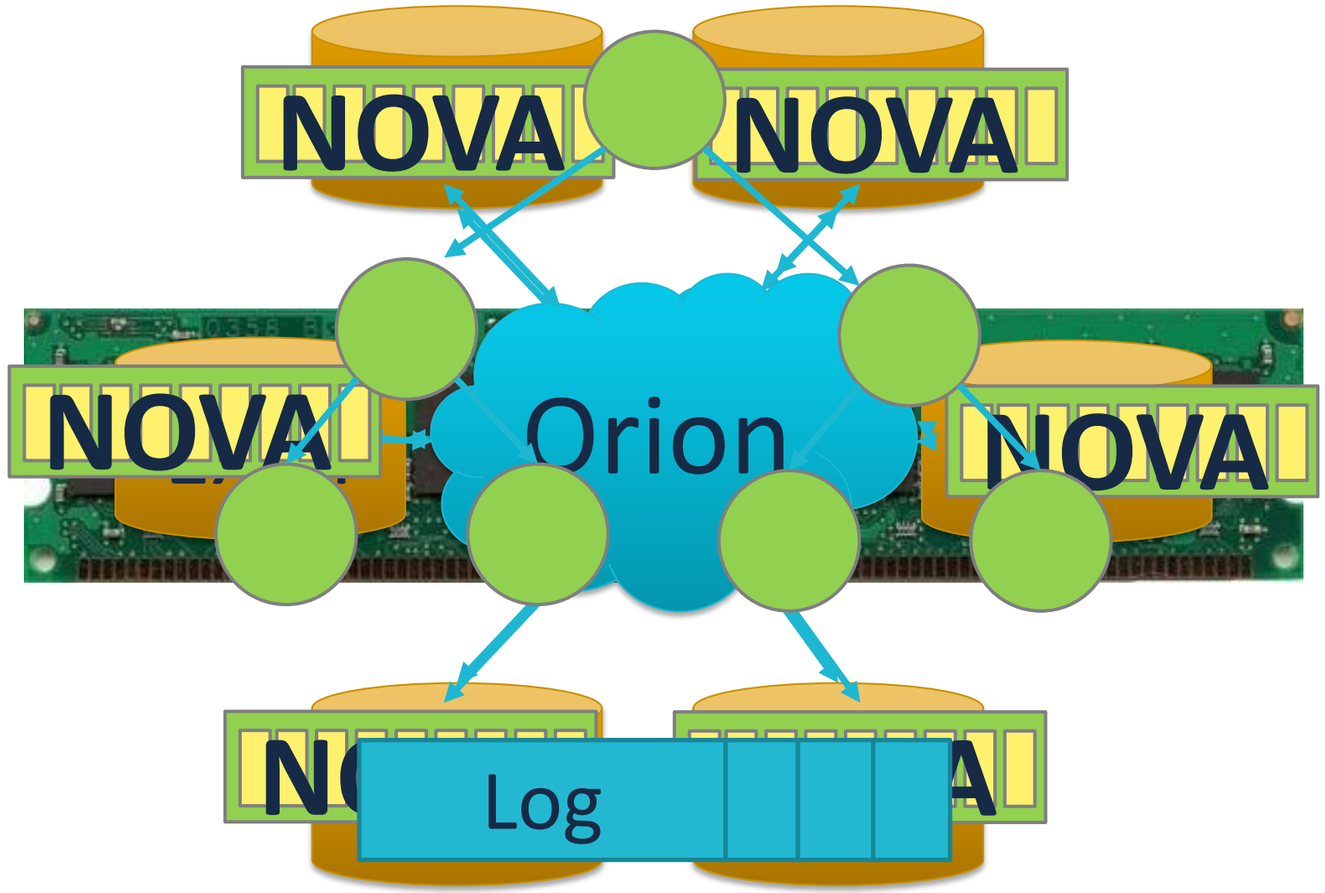
What Should You Do With NVMM?

1. Use files and a conventional (distributed) file system
2. Use files and better file (distributed) system
3. Build persistent data structures
4. Use it as slow DRAM



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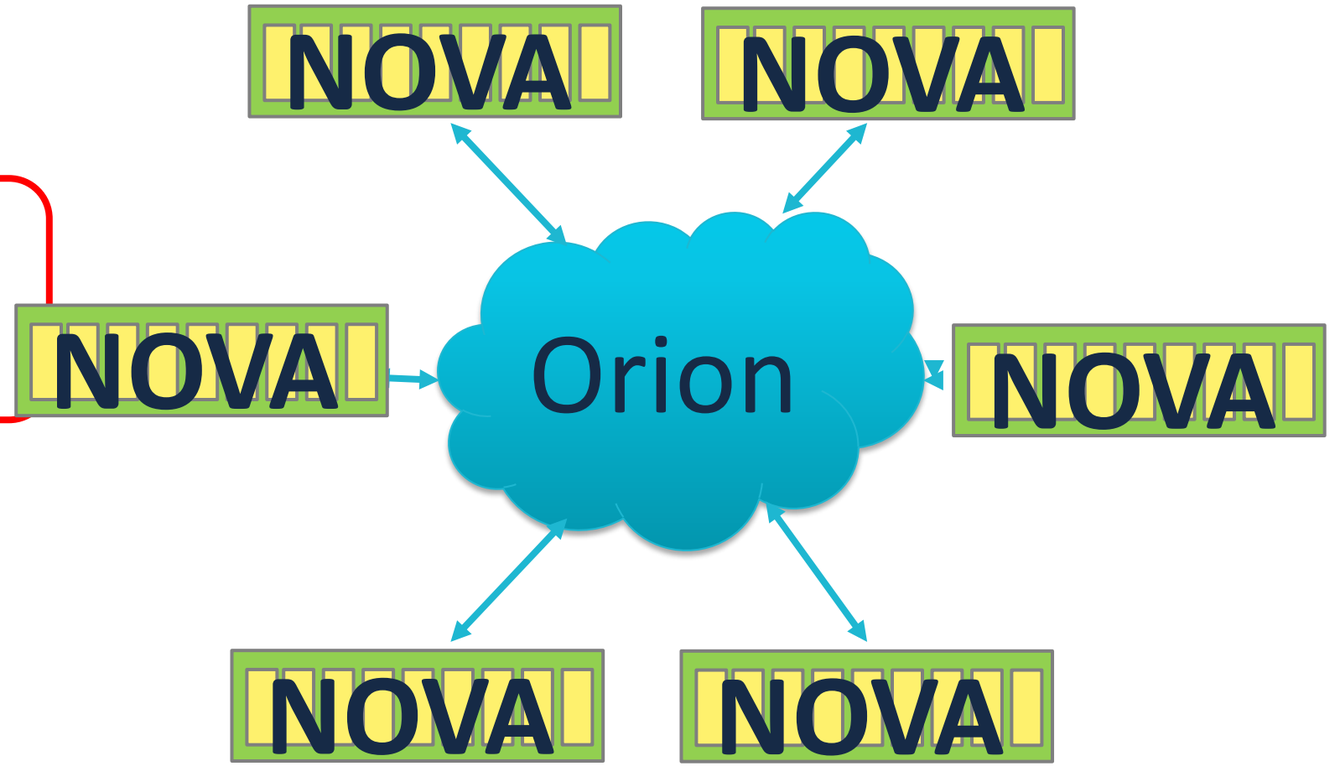

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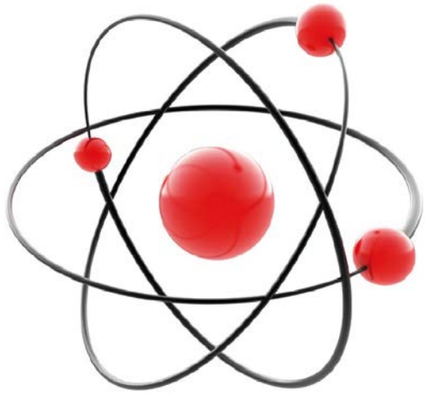
File IO



Atomicity

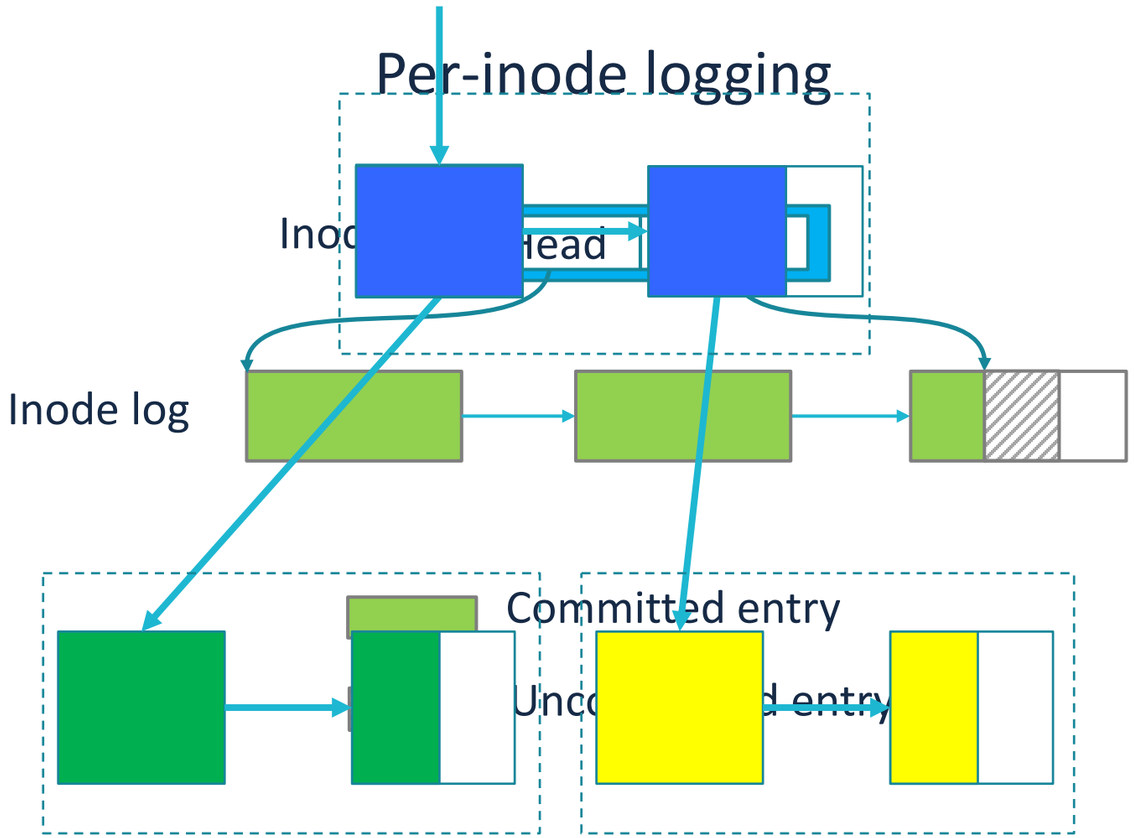
Fault Tolerance

Direct Access

Speed

NOVA: A File System for NVMM

- A NOVA FS is a tree of logs
- One log per inode
  - Inode points to head and tail
  - Logs are not contiguous
- Many Logs -> high concurrency
- Strong consistency guarantees
- Log-structured + journals + copy-on-write



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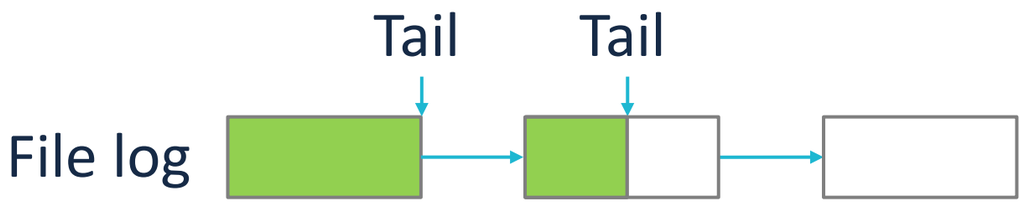
Atomicity: Logging for Simple Metadata Operations

- Combines log-structuring, journaling and copy-on-write
- Log-structuring for single log update
  - Write, msync, chmod, etc
  - Lower overhead than journaling and shadow paging



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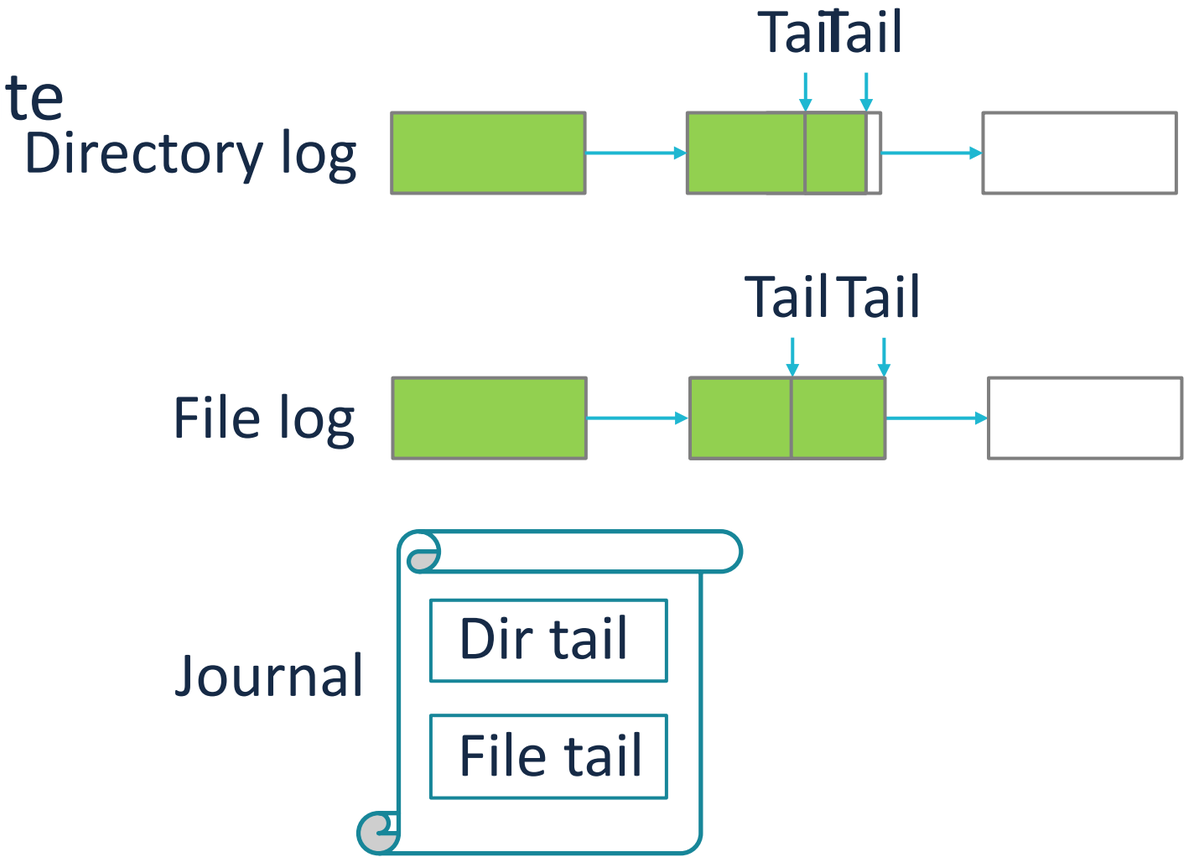
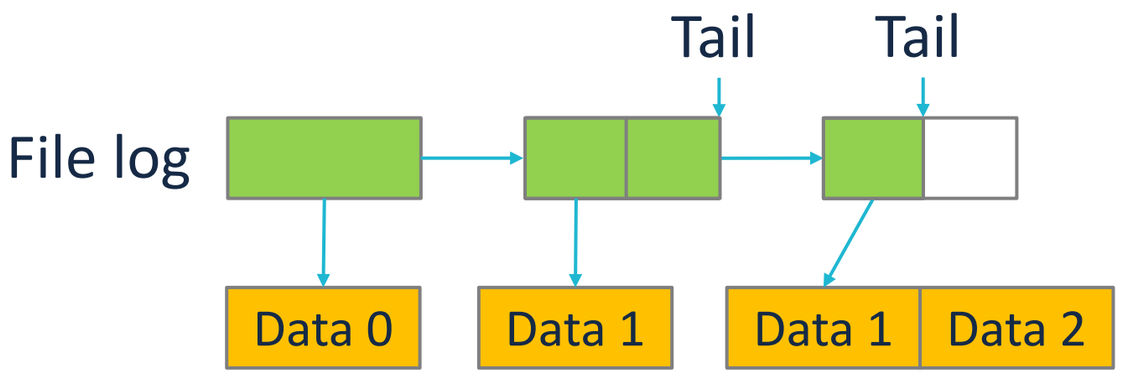
Atomicity: Lightweight Journaling for Complex Metadata Operations

- Lightweight journaling for update across logs
  - Unlink, rename, etc
  - Journal log tails instead of metadata or data



Atomicity: Copy-on-write for file data

- Copy-on-write for file data
  - Log only contains metadata
  - Log is short
  - Instant data GC



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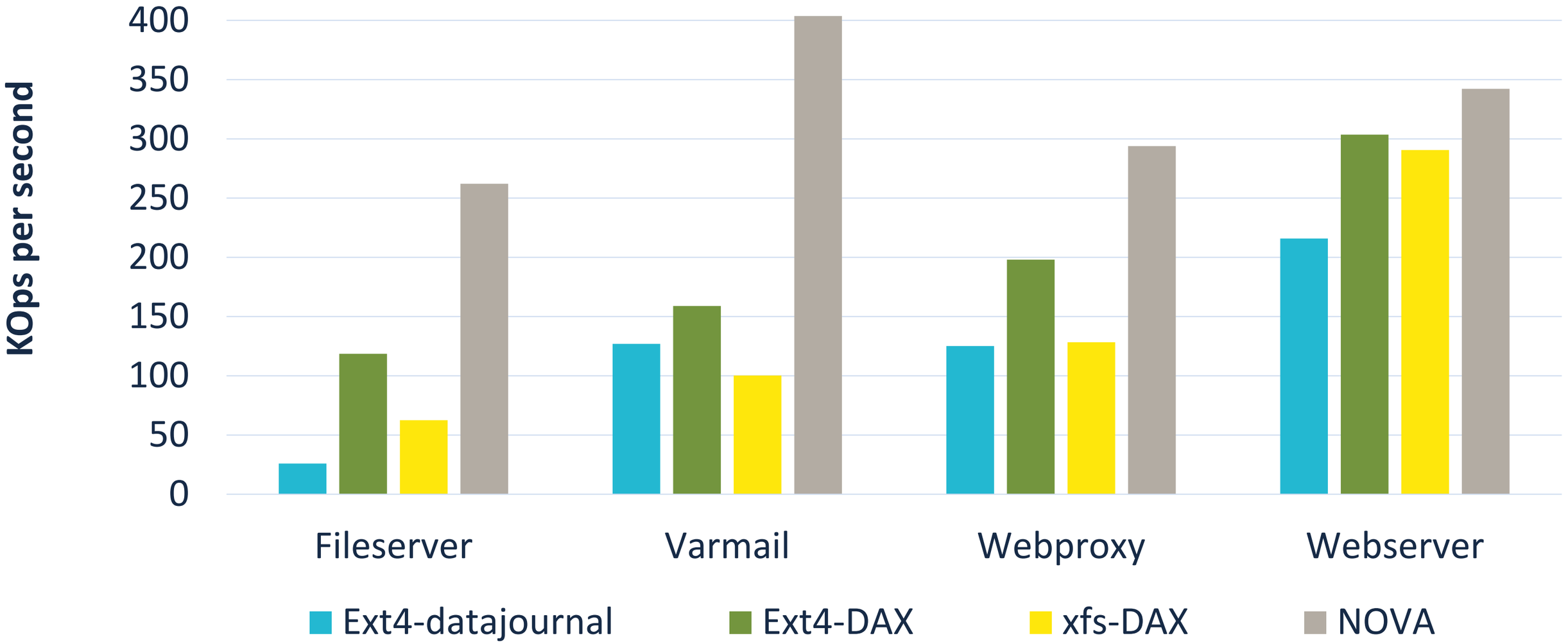
Filebench throughput



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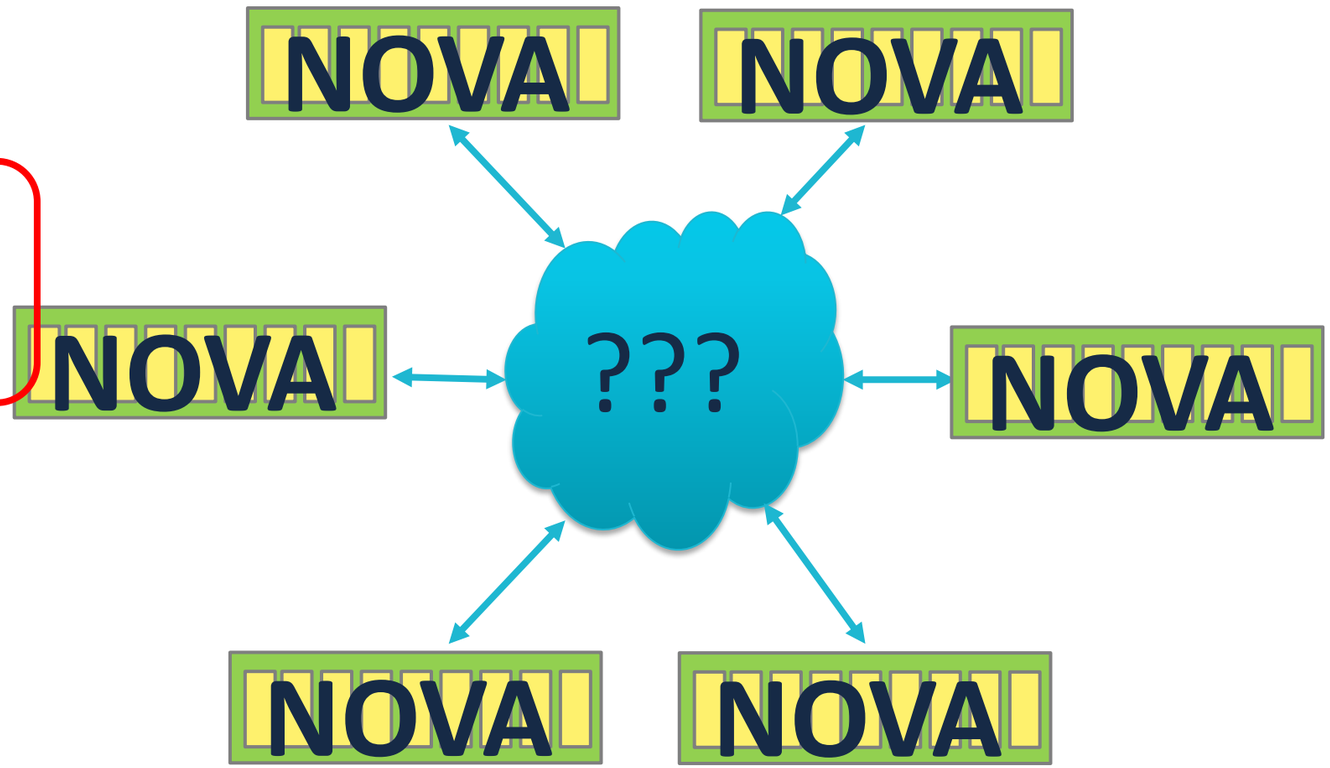
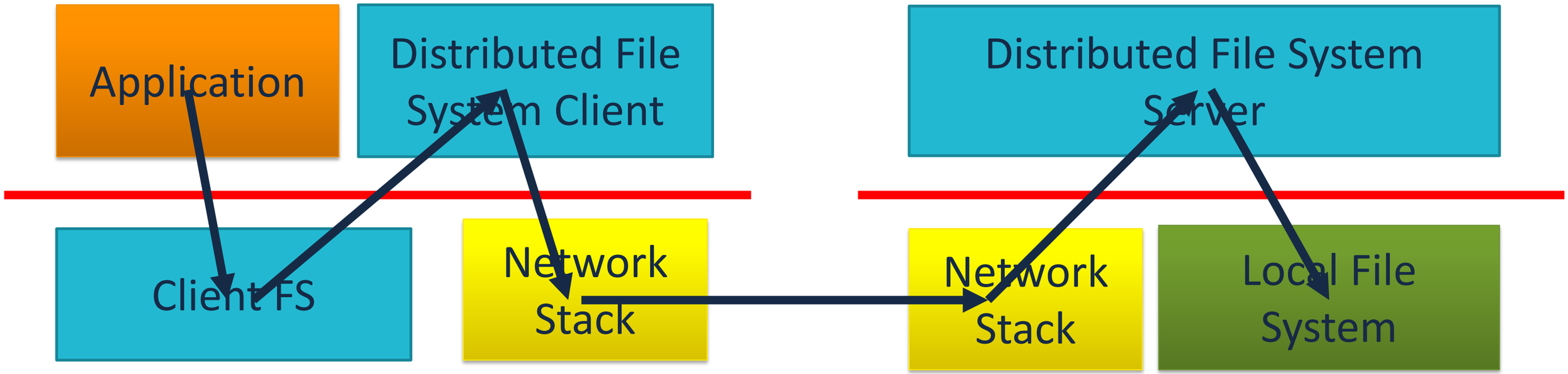
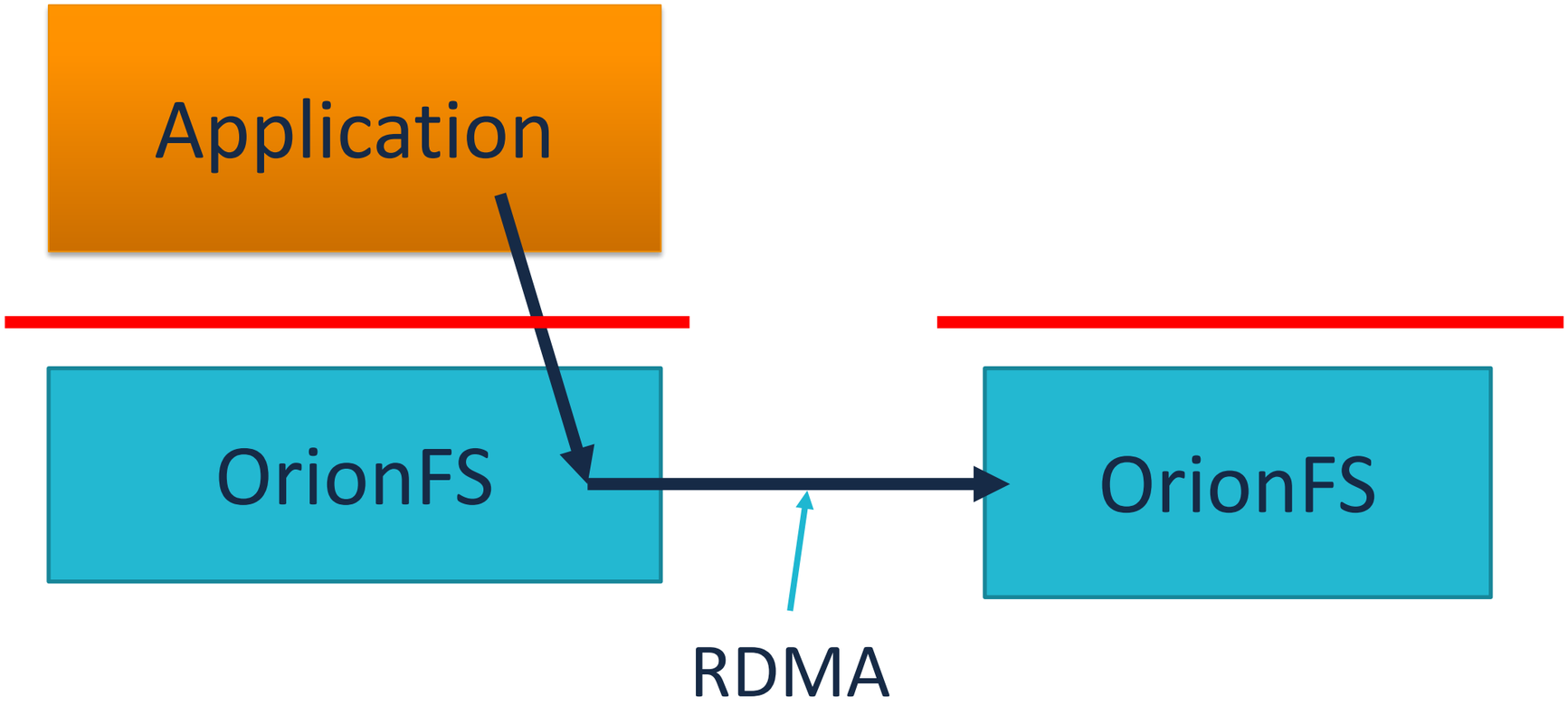


Existing Distributed File Systems are Slow



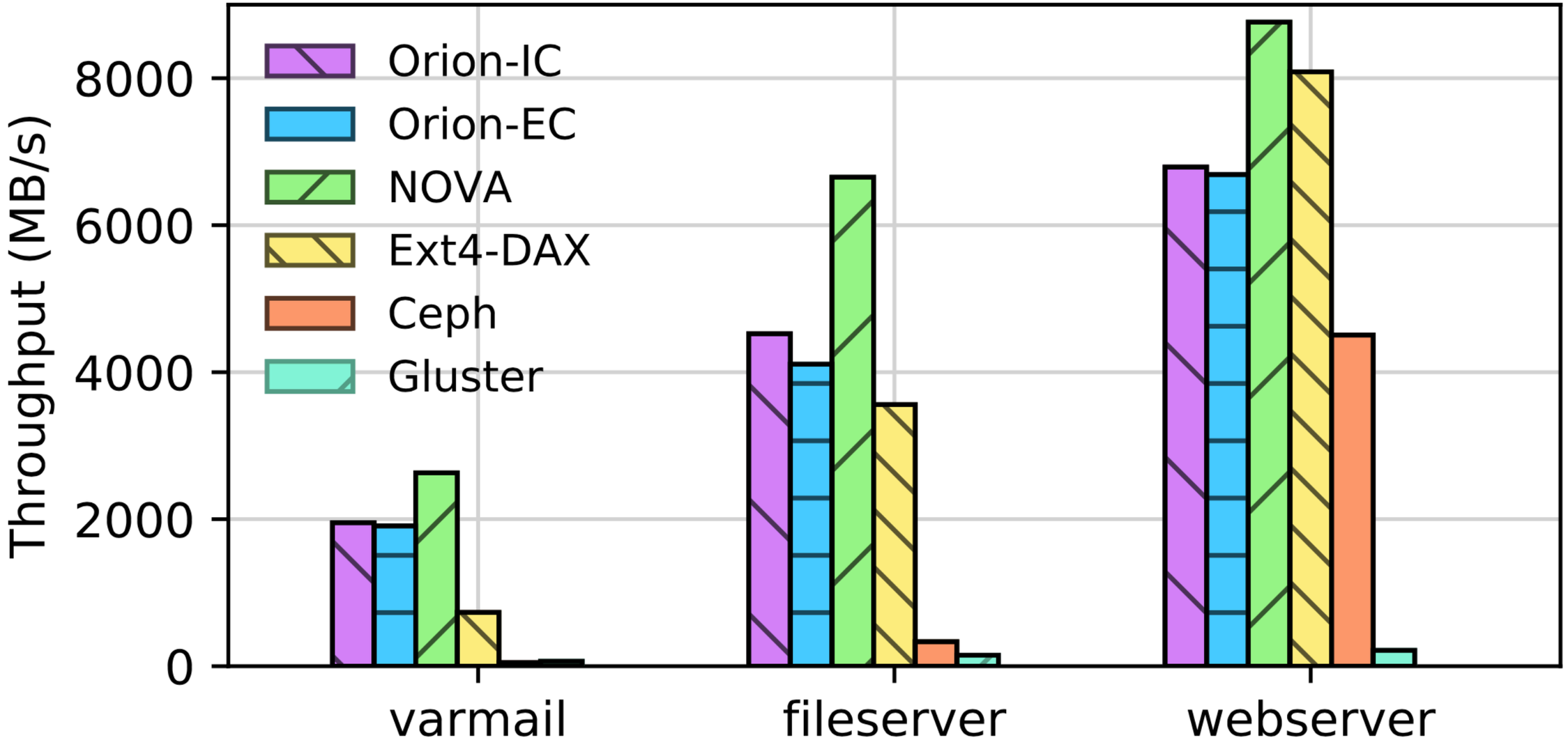
Orion: A Distributed Persistent Memory File System



Orion: Key Features

- Based on NOVA
- Mirrored metadata on client
  - Client keep local, NVMM copy of inode's log
  - Leases + simple arbitration for concurrent updates
- Mostly-local operation
  - Local read cache
  - CoW creates new, local copy
- Pervasive RDMA
  - All addresses/pointers are RDMA-friendly
  - Zero-copy IO for most transfers (NOVA data structures are RDMA targets)
  - Single-ended remote data access

Application performance on Orion



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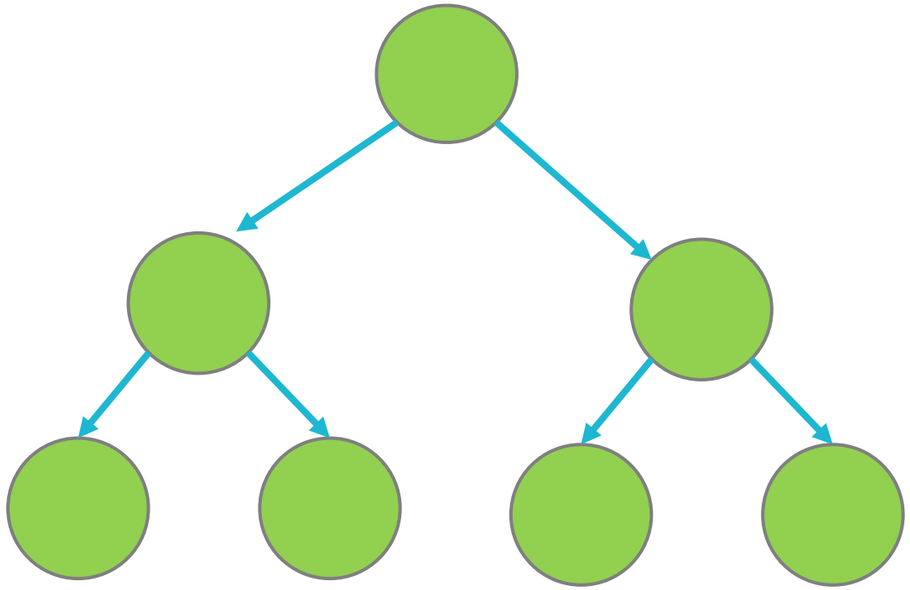

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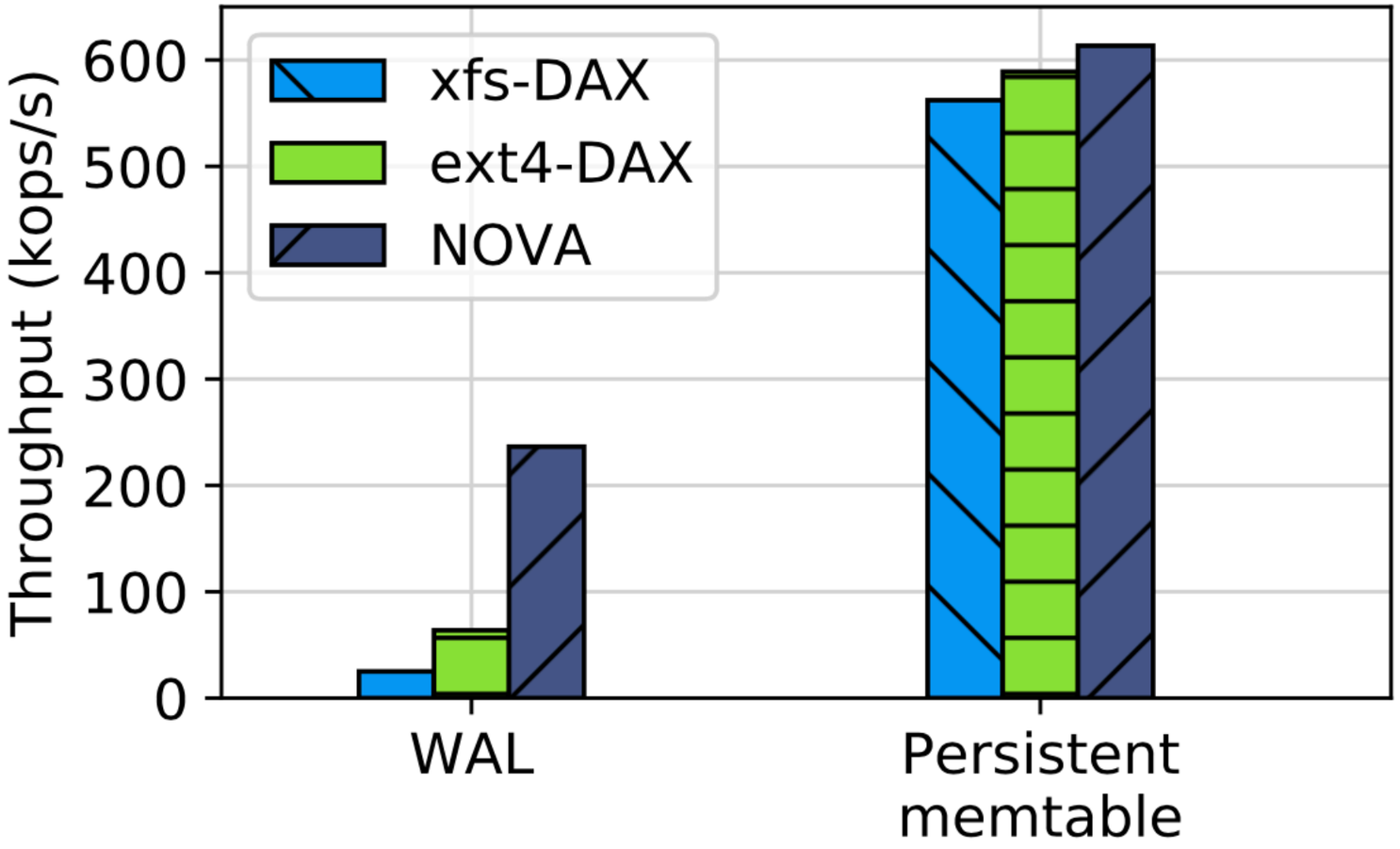
Build NVMM Data Structures Is Hard

- All existing programming errors are still possible
  - Memory leaks
  - Multiple frees
  - Locking errors
- There are new kinds of errors
  - Pointers between NV memory pools
  - Pointers from NVMM to DRAM
- Programmers get this stuff wrong
- Rebooting/restarting won't help!
- Language + Compiler support will come, but slowly

Optimizing RocksDB



What Should You Do With NVMM?

1. Use files and a conventional (distributed) file system → Easy; ~5x gains
2. Use files and better file (distributed) system → Pretty easy; ~10x gains

The NVMM Programmability Gap

3. Build persistent data structures → Really hard; ~30x gains
4. Use it as slow DRAM

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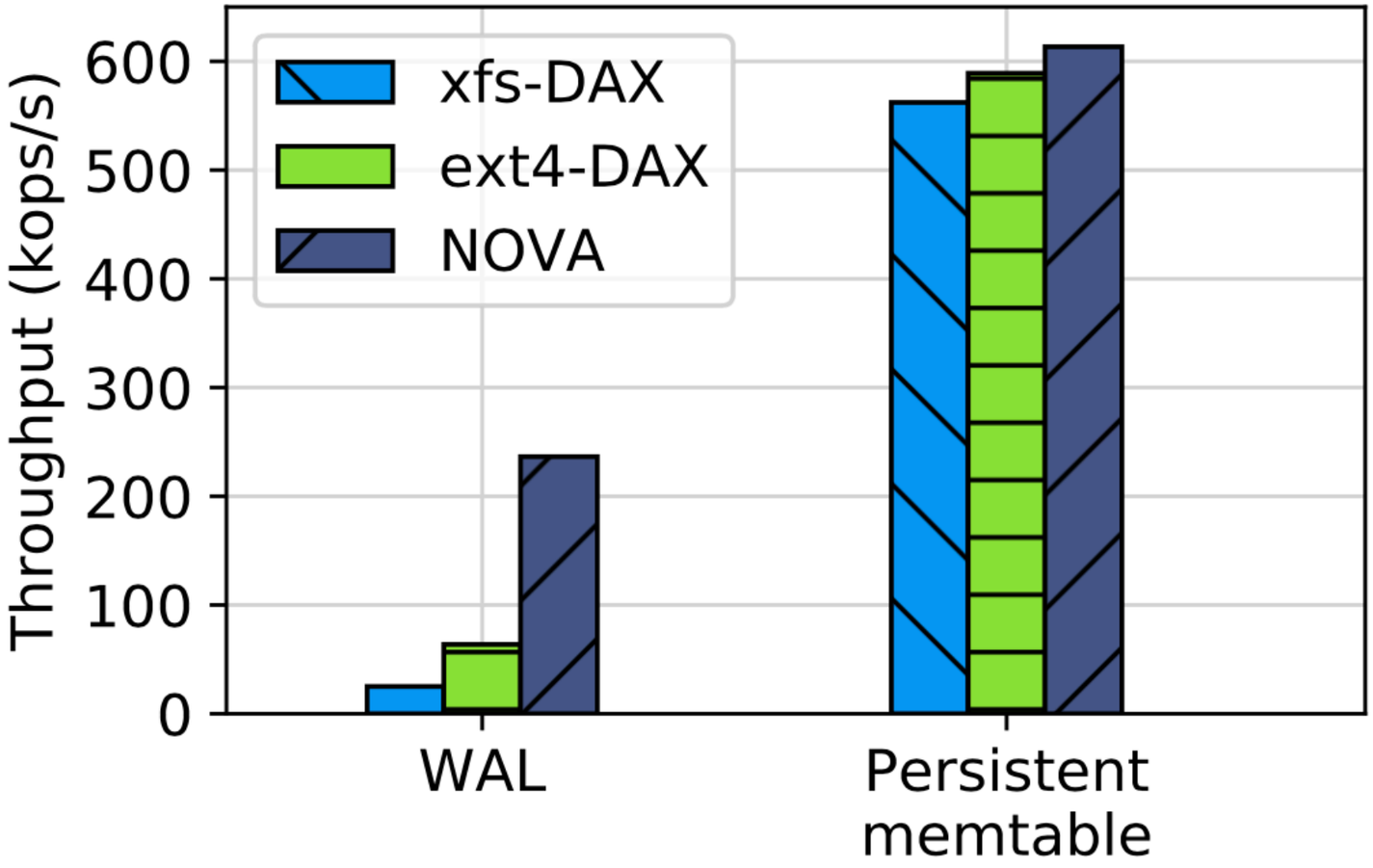
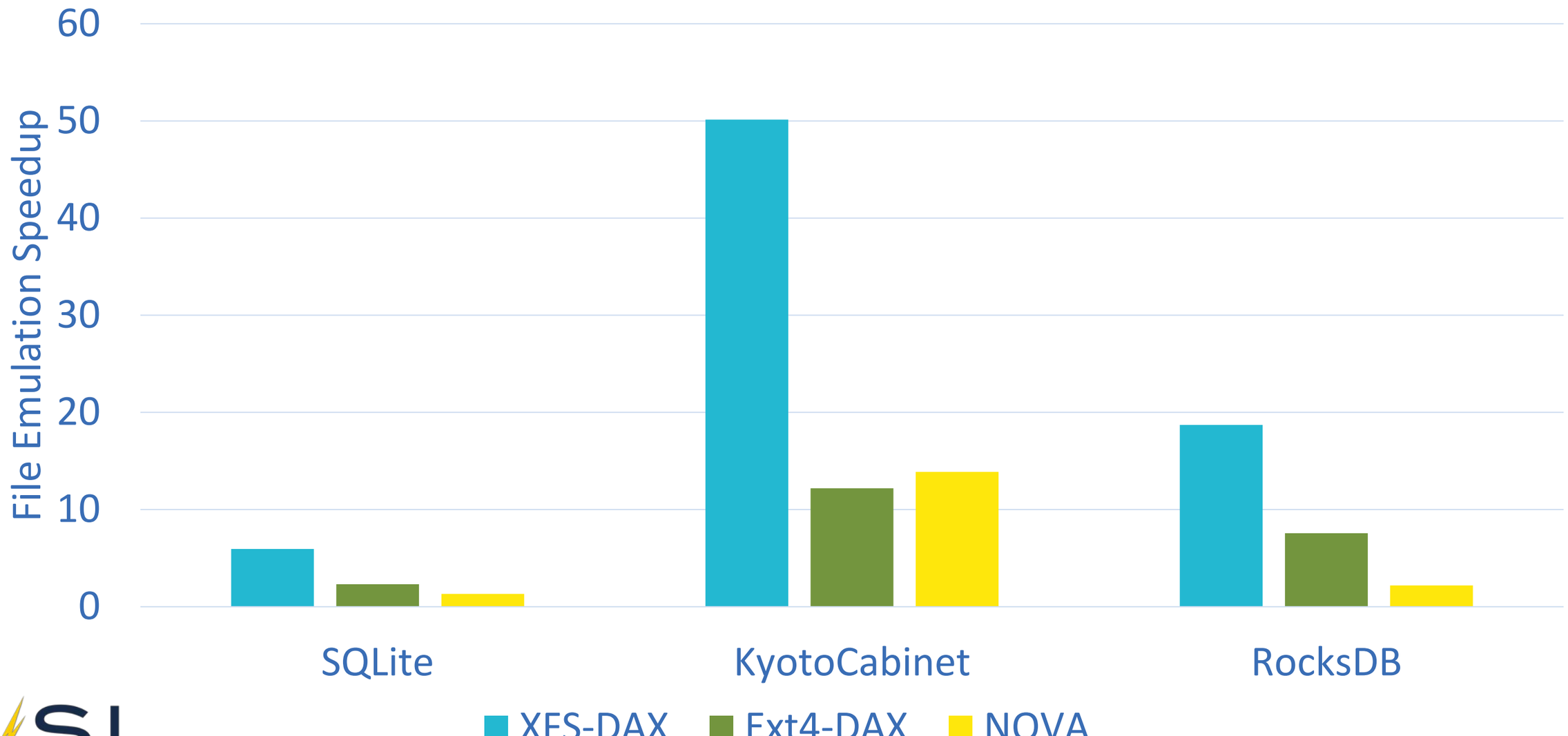
Optimizing RocksDB



File Emulation

- Normal write-ahead logging
  - open();
  - write(); sync();
- Emulate read/write in user space
  - open(); mmap();
  - memcpy() + clwb + fence
- Almost POSIX semantics
  - Minimal changes to app logic
  - No complex logging, allocation, or locking
- Almost persistent data structure performance
  - Just 10% slower.

File Emulation Speedups



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What Should You Do With NVMM?

- You should study it!
  - Many interesting, open problems remain
  - Lots of PhDs to come
- You should use it!
  - Use a file system!
  - Want more performance? Use file emulation!
  - Want more performance? Build persistent data structures.

NOVA is open source.
We are preparing it for “upstreaming” in to Linux.

To help or try it out:
https://github.com/NVSL/linux-nova

Thanks!

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Thank you!

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