Exploiting Intel Optane Persistent Memory for Full Text Search

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Full text search is ubiquitous

Web search Google Bing

Retail

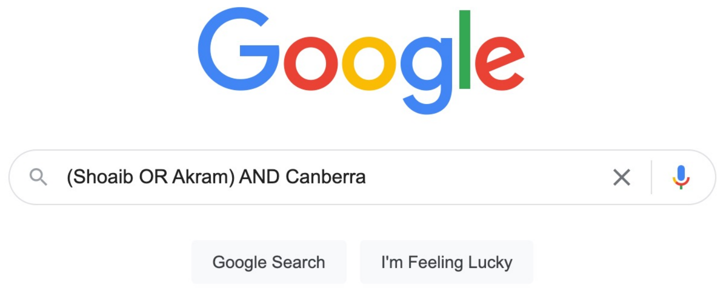
Social media

Search = Indexing + Query eval

Indexing builds an inverted index

word1 → document-list
word2 → document-list

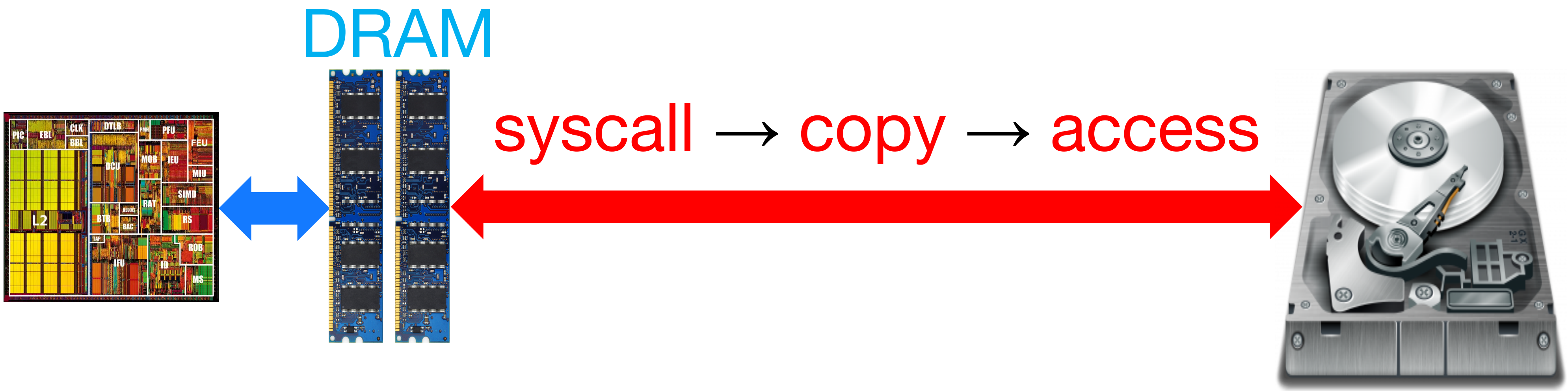
Query evaluation searches for words



Indexing speed increasingly **critical**

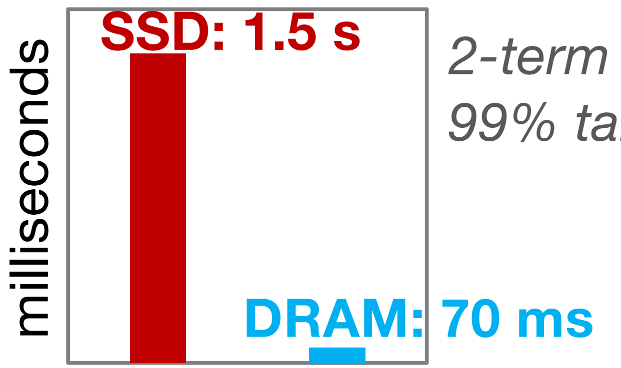
Challenge: I/O intensity

Writing & merging partial indices on storage takes up 40% of exec time



Challenge: DRAM capacity

NVMe SSD violates real time response constraint



2-term AND, 99% tail latency

🙁 Data growth outpaces DRAM scaling

Data volume → 2X

DRAM GB/$ → 20%

Today: Give up real time, or give up cost efficiency

Looking forward

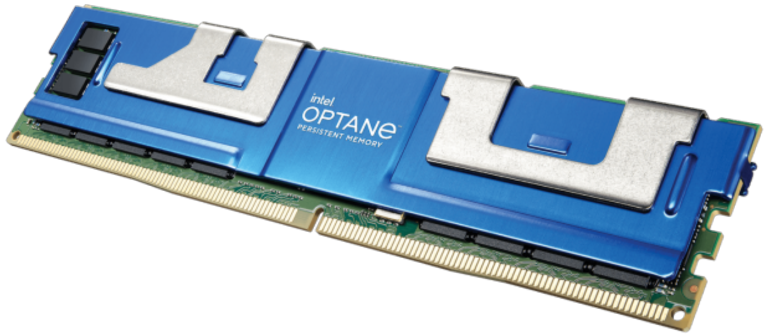
- Reduce I/O overhead
- Find a fresh memory scaling roadmap

Persistent memory (PM)

4X denser than DRAM

Load/store access

Non-volatile



Contribution: PM Search Engine

Exploiting PM for building/storing indices

→ Memory, storage, universal roles

→ Fine-grained crash consistent recovery

Extensive PM evaluation vs DRAM/SSD

→ Indexing perf, scalability, bottlenecks

→ Tail latency of query workloads

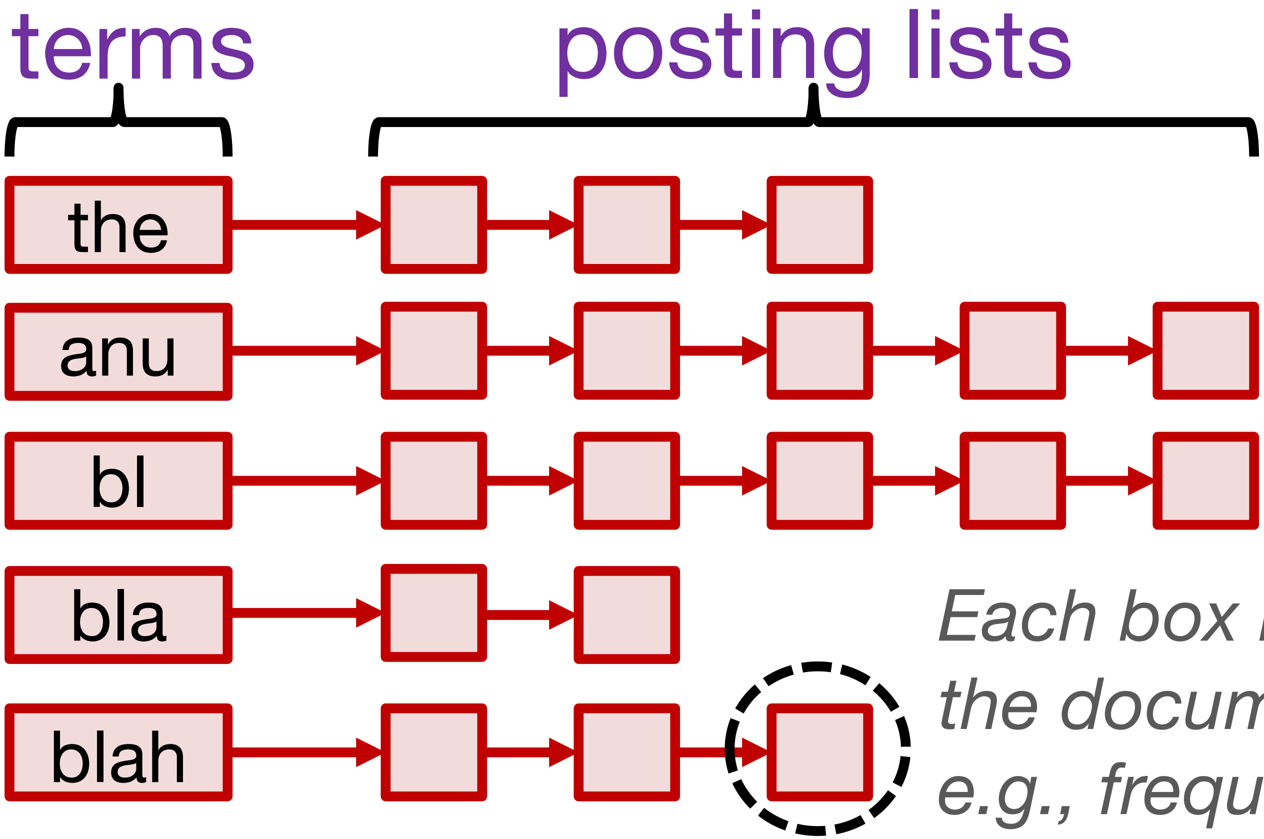
Rest of the talk

Building an index

Exploiting PM

Evaluation

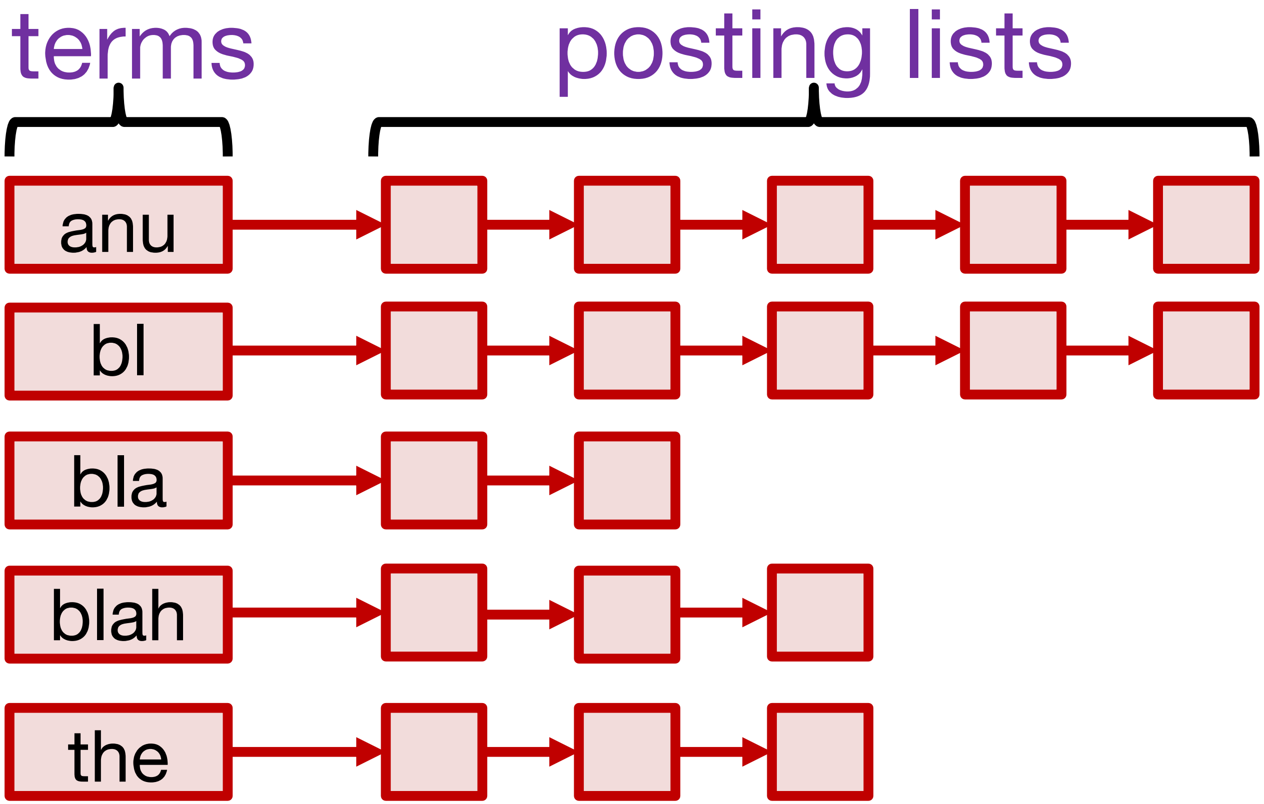
Step 1: Building the hash table



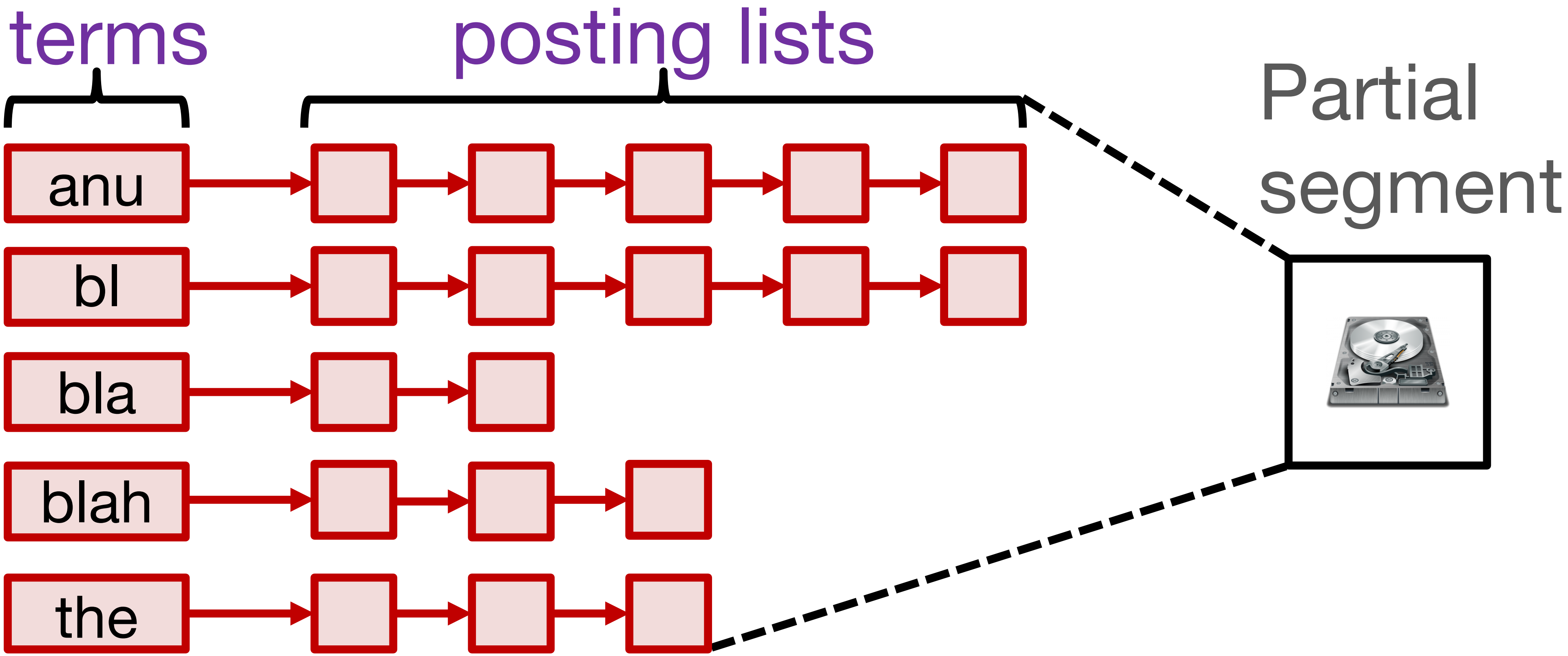
When the table is full → Step 2

Each box is a posting. It contains the document id plus meta-data, e.g., frequency and position of terms

Step 2: Sorting the hash table



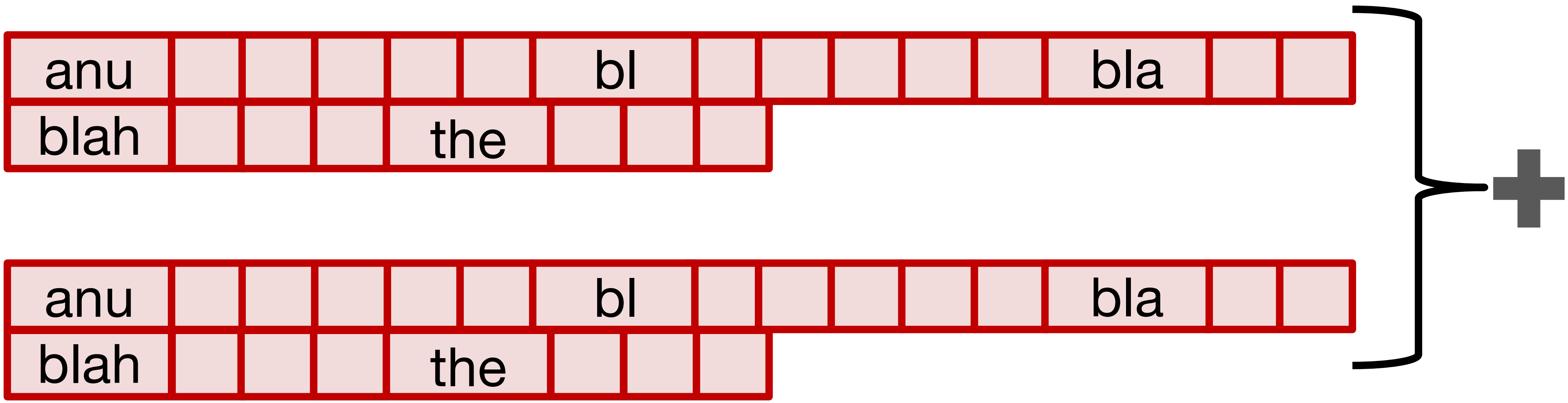
Step 3: Flushing the hash table



Flushing results in large amounts of sequentail I/O

Step 4: Merging segments

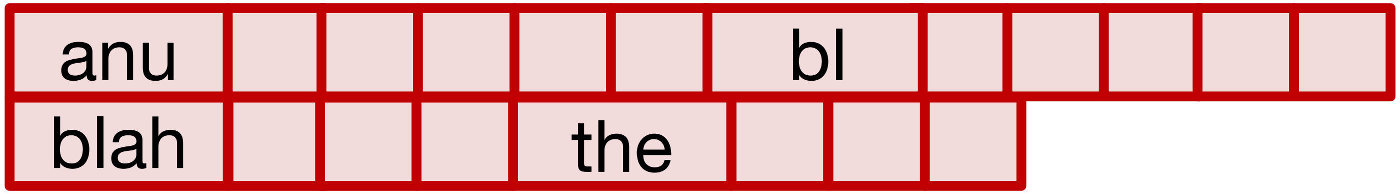
Merging segments is crucial for fast query evaluation



Merging results in large amounts of read/write I/O

Index = Segment + Dictionary

term	offset
anu	0
bl	6



Segment: Sequentially sorted postings on storage

Dictionary: To find posting lists in segments, indexers use a key-value store, such as, Berkeley DB

Different ways to exploit PM

Hash table, DRAM → PM

Partial segments, SSD → PM

Merged segments, SSD → PM

Dictionary, SSD → PM

PM configurations for indexing

Name of Configuration	Placement of Table, Postings, and Dictionary				Role of Optane PM
	H Table	Partial St	Merged St	Dict	
stock	DRAM	SSD	SSD	SSD	none
table-pm	PM	SSD	SSD	SSD	main memory
pm-only	PM	PM	PM	PM	universal
hybrid	DRAM	PM	PM	PM	storage
hybrid+	DRAM	PM	PM	SSD	storage

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Crash consistent indexing

Crash consistent segment flushing

→ Use pmem_persist(segment)

→ Track progress (docIds)

Crash consistent merging

→ Tracking progress is tricky

→ Details of “logging” in the paper

Baseline Engine

Psearchy

MOSBENCH

Silas Boyd-Wickizer, Austin T. Clements, Yandong Mao, Aleksey Pesterev, M. Frans Kaashoek, Robert Morris, Nickolai Zeldovich mosbench@pdos

MOSBENCH is a set of application benchmarks designed to measure scalability of operating systems. It consists of applications that previous work has shown not to scale well on Linux and applications that are designed for parallel execution and are kernel intensive. The applications and workloads are chosen to stress important parts of many kernel components.

Native, fast, and flexible

Easily integrated with Intel PMDK

Indexing Methodology

Dataset and measurement

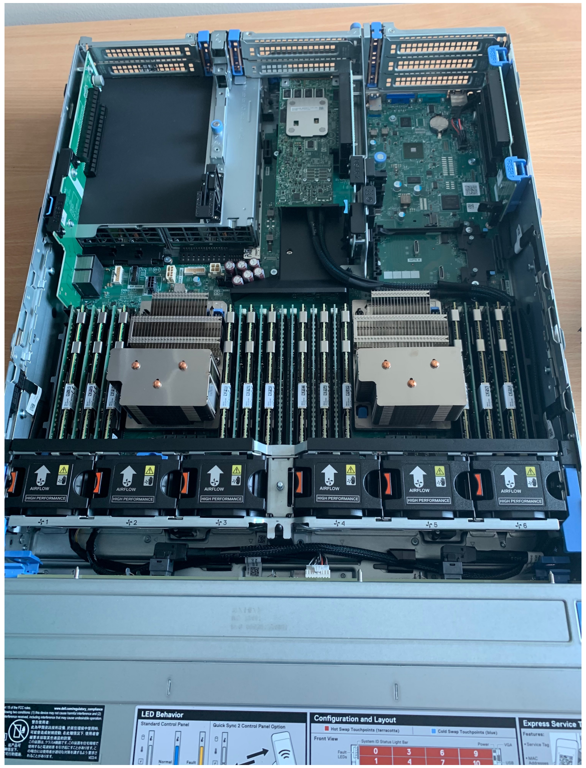
- → Wikipedia English (DRAM)
- → Execution time
- → 1 GB HT per core, up to 32 cores

PM setup

- → Interleaved, local, EXT4+**DAX**
- → pmemkv dictionary github.com/pmem/pmemkv

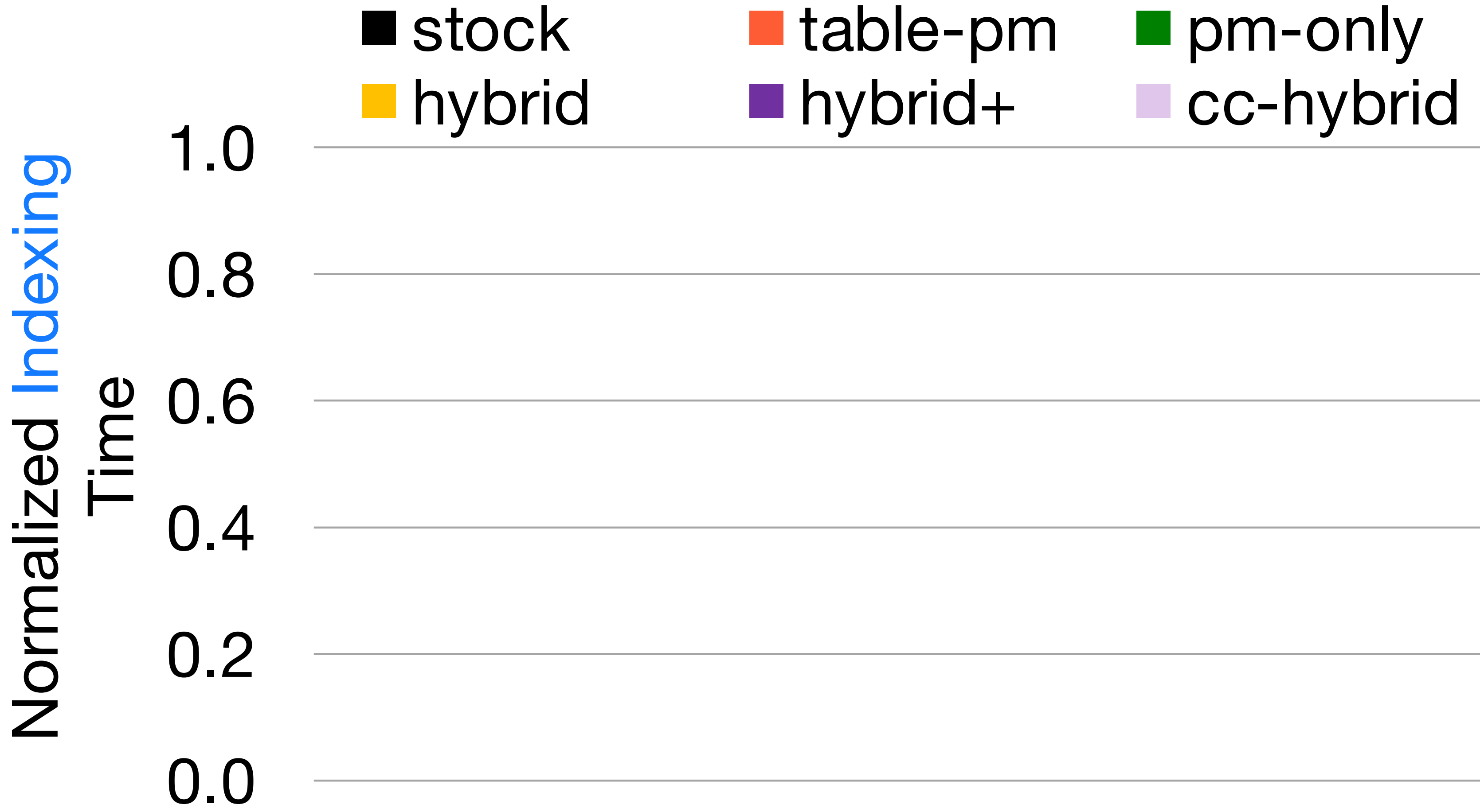
Experimental Platform

Our in-house server with DRAM, PM, & SSD

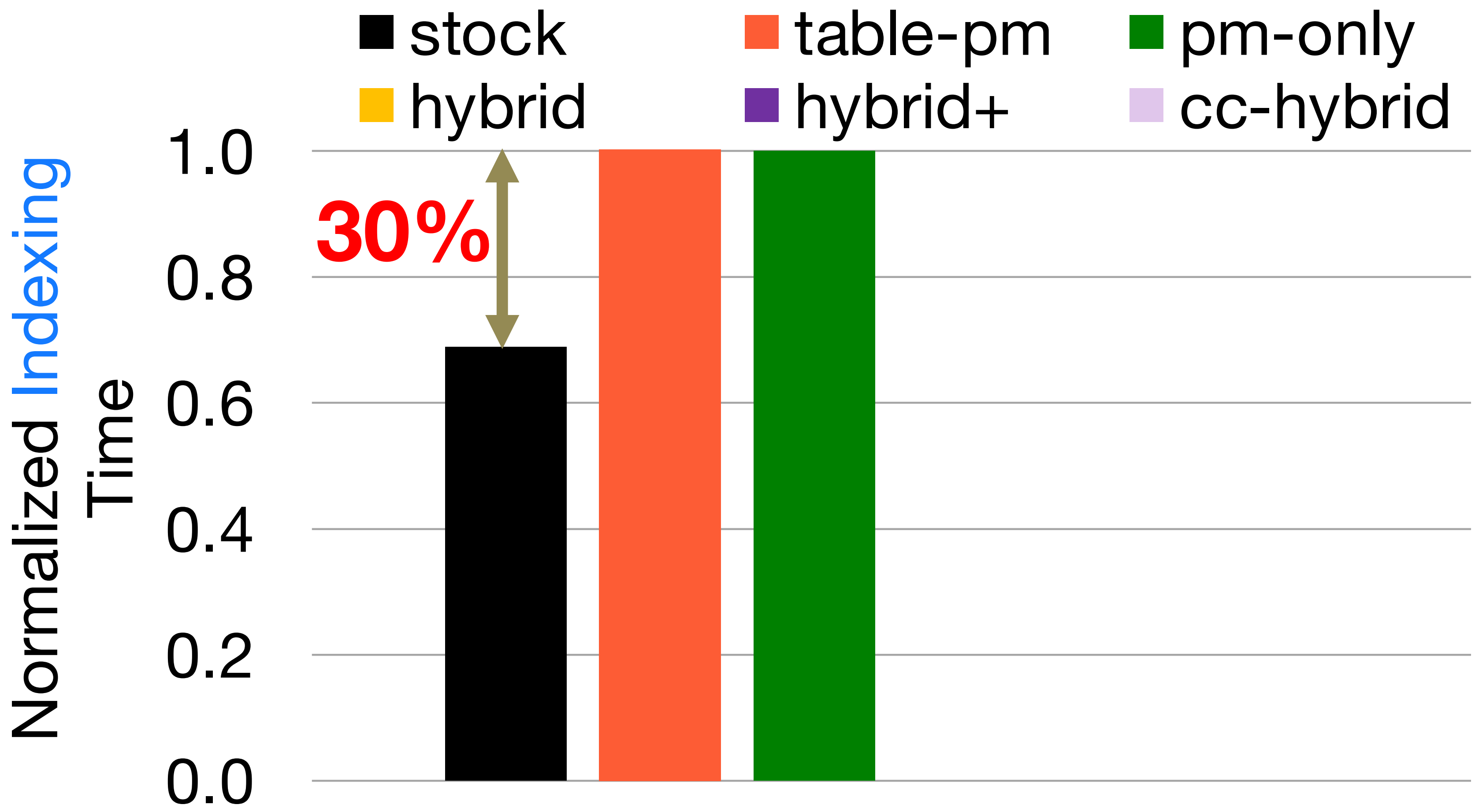


2 TB PM
0.5 TB DRAM
1.5 TB NVMe Optane SSD

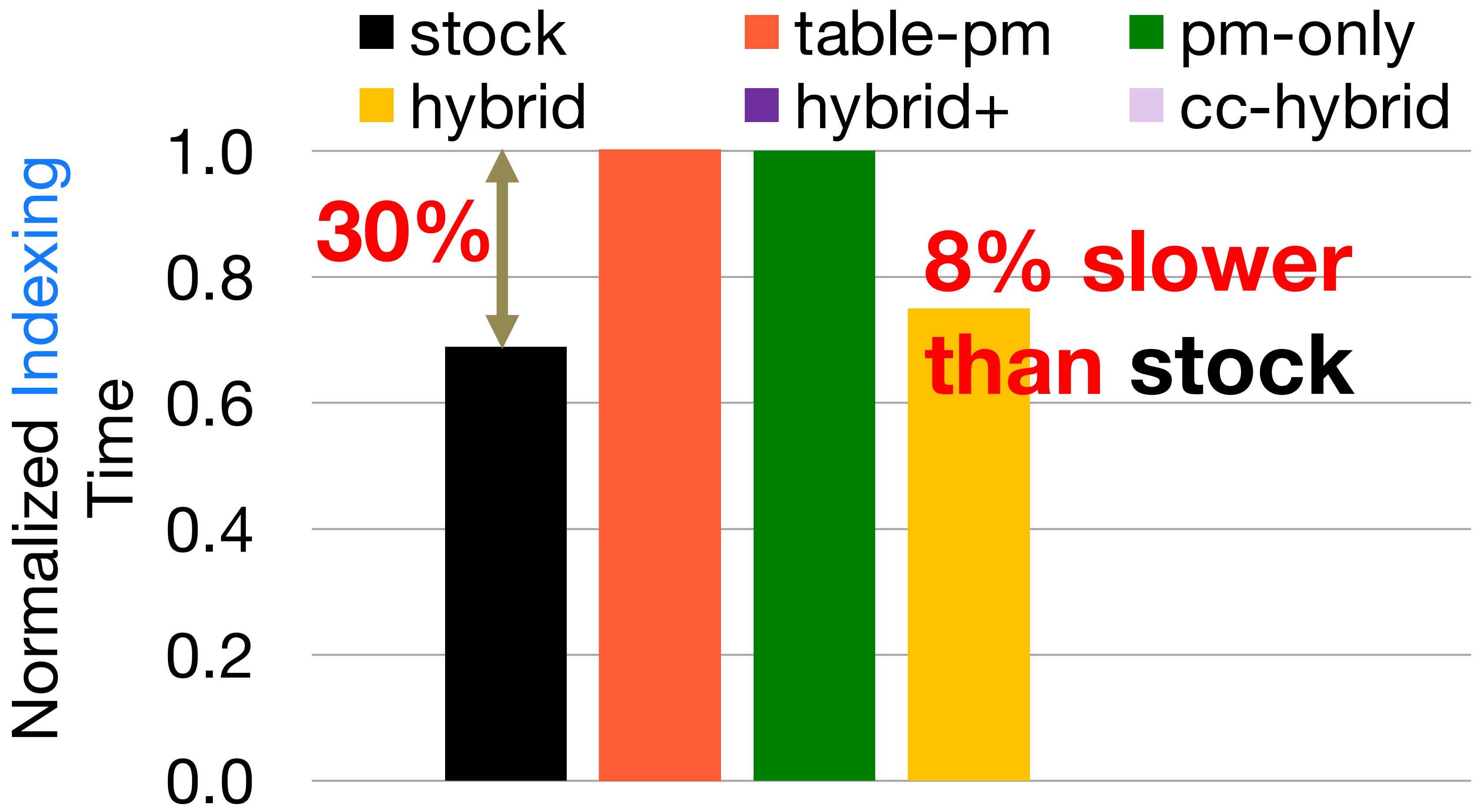
Indexing perf with one core



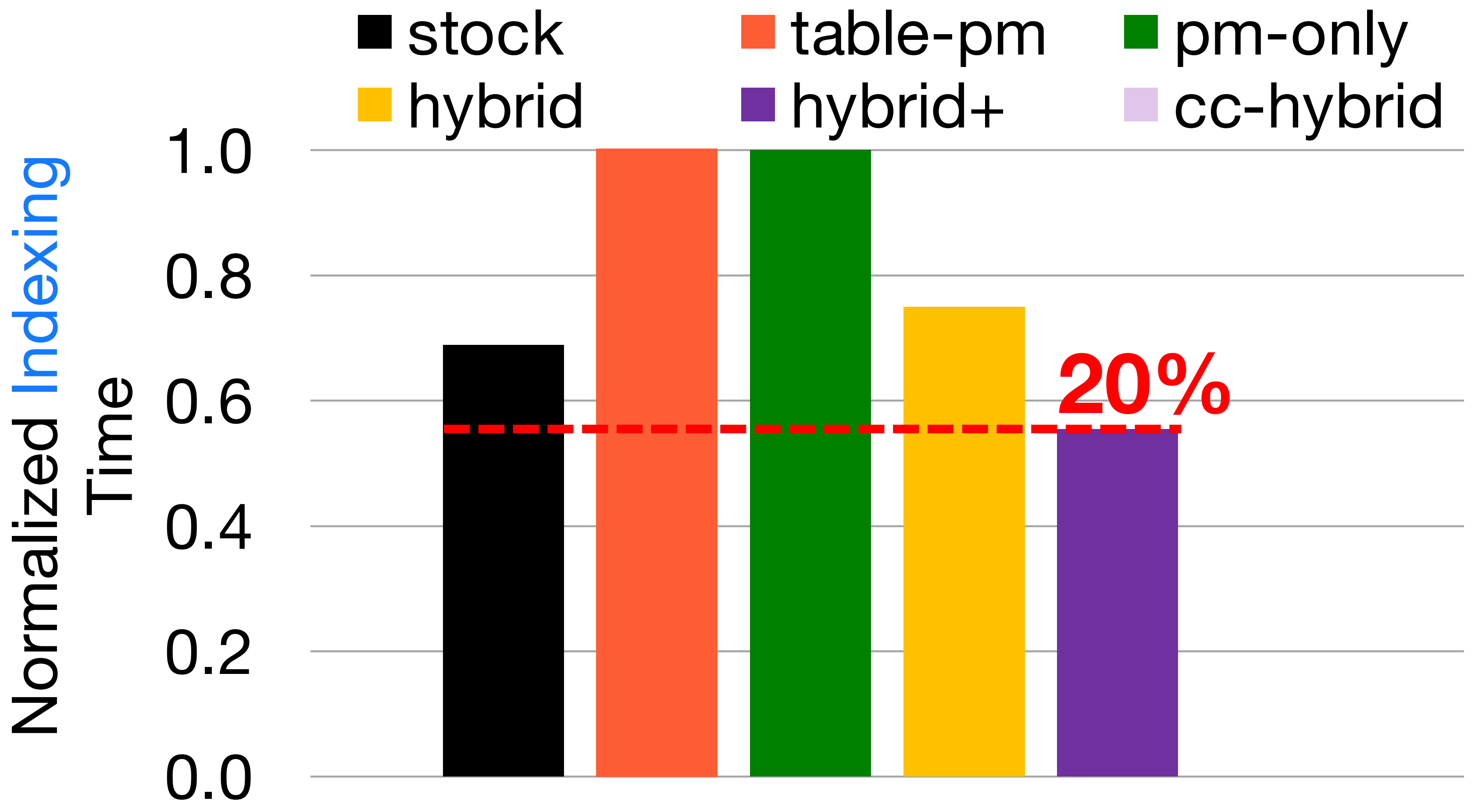
PM as main/only is 30% slower



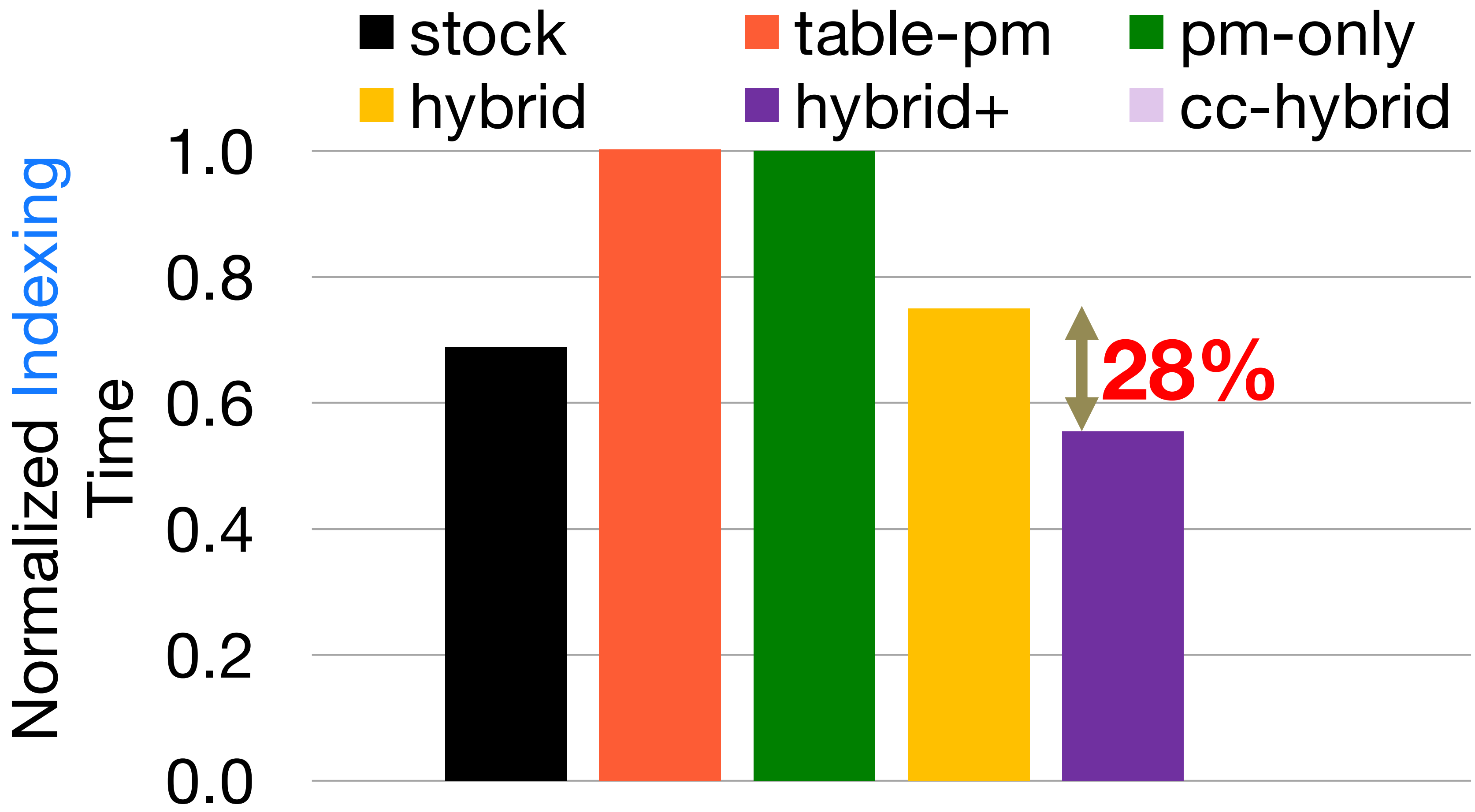
Hybrid is 8% slower than stock



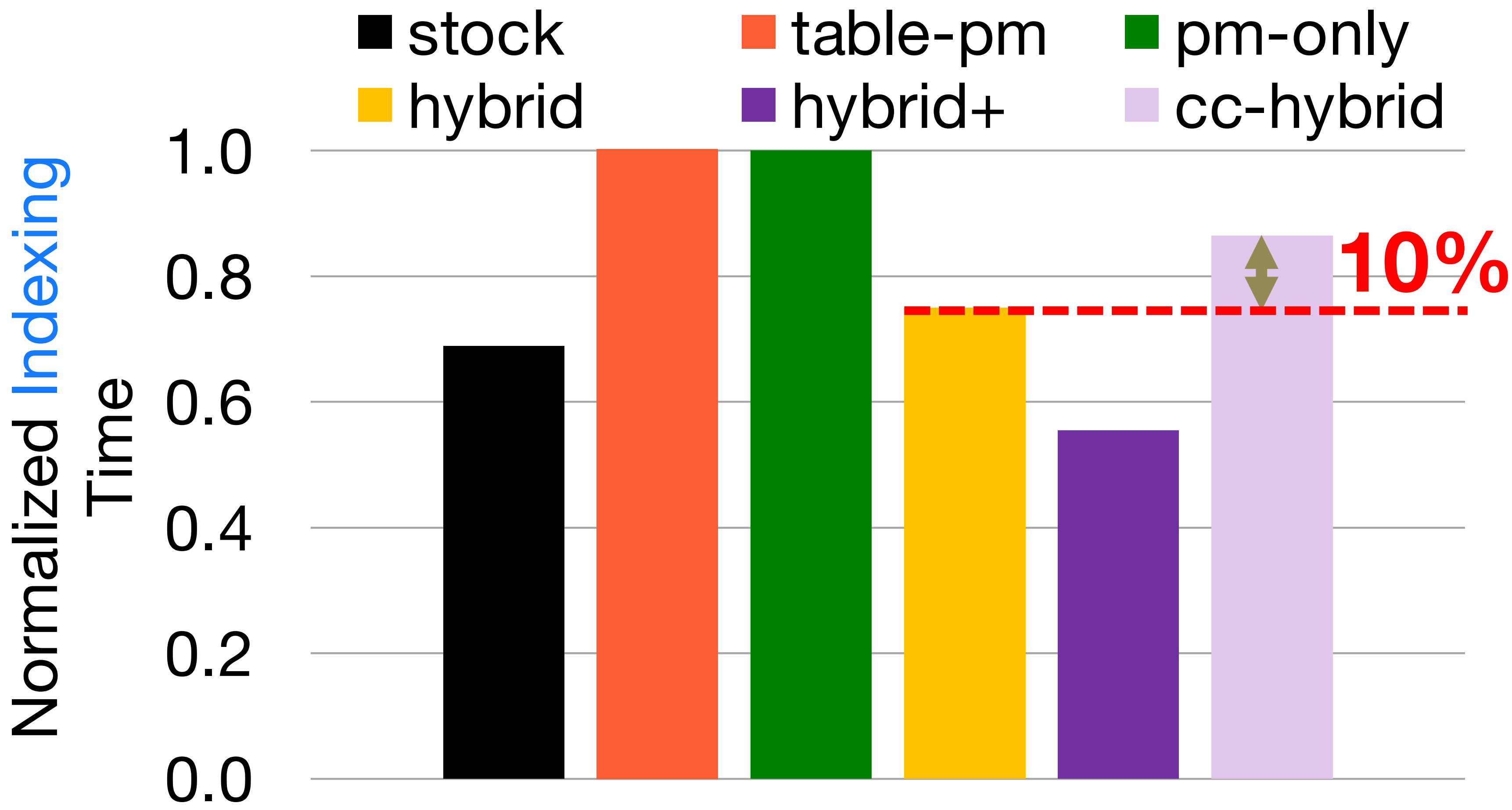
Hybrid+ is best, 20% over stock



Hybrid+ is best, pmkv costs 28%

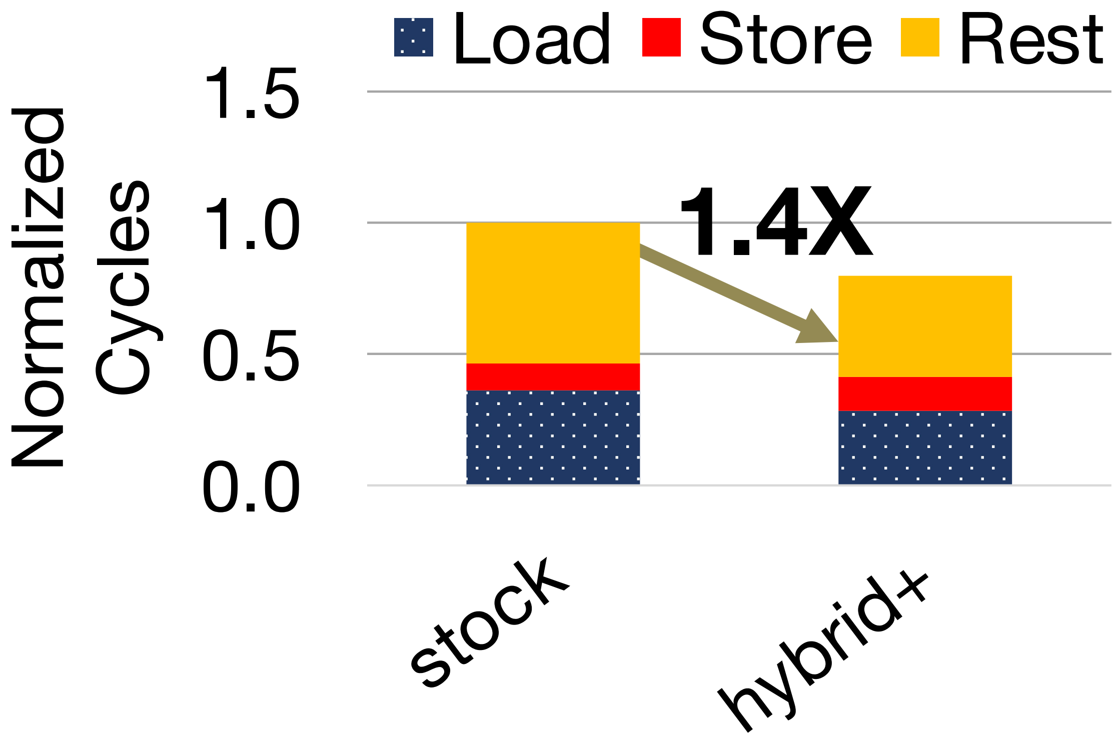


Crash consistency costs 10%

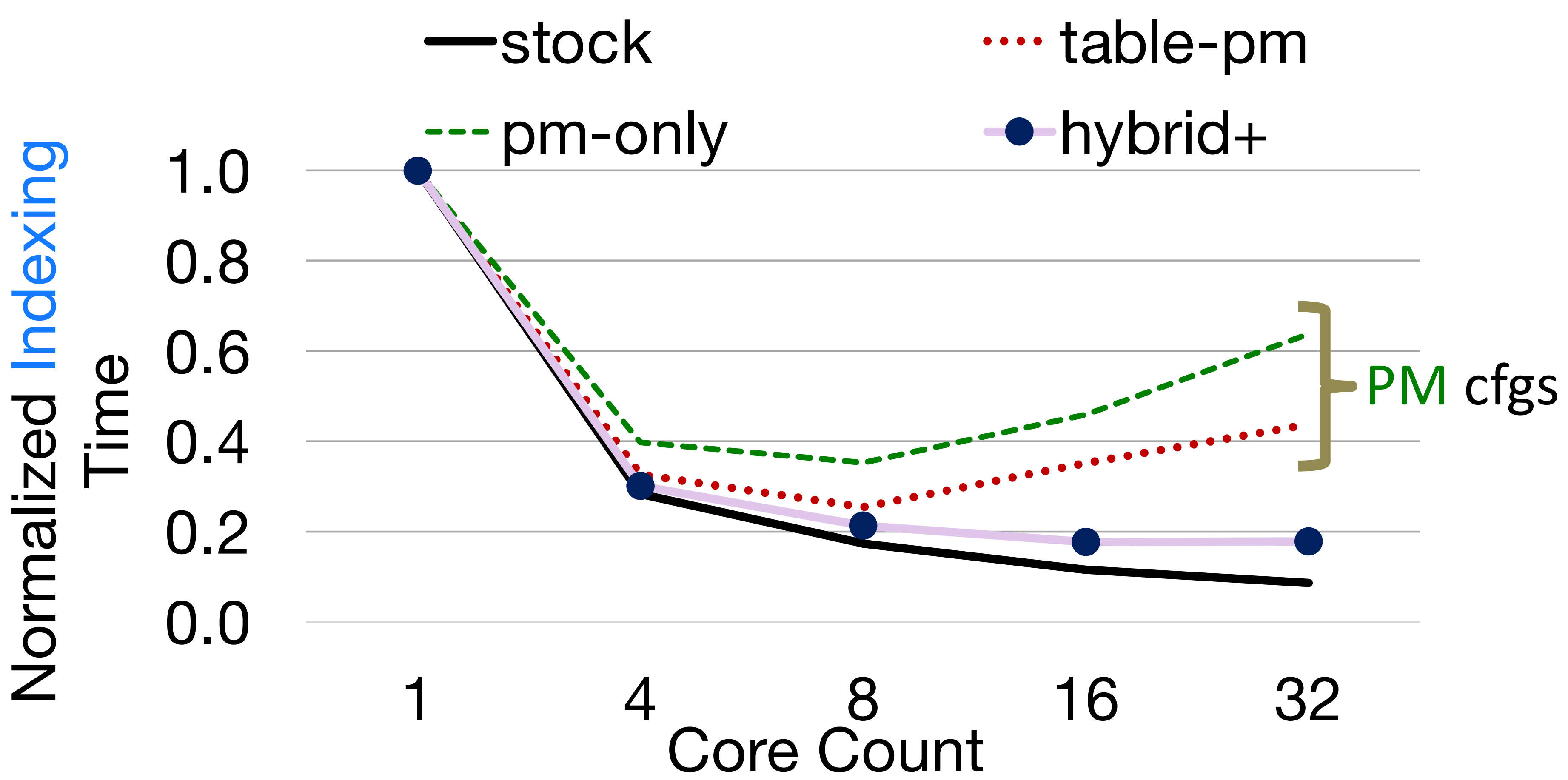


syscall → mmap is mainly why **hybrid+** beats stock

Use perf counters to observe Load/Store stalls the multicore incurs

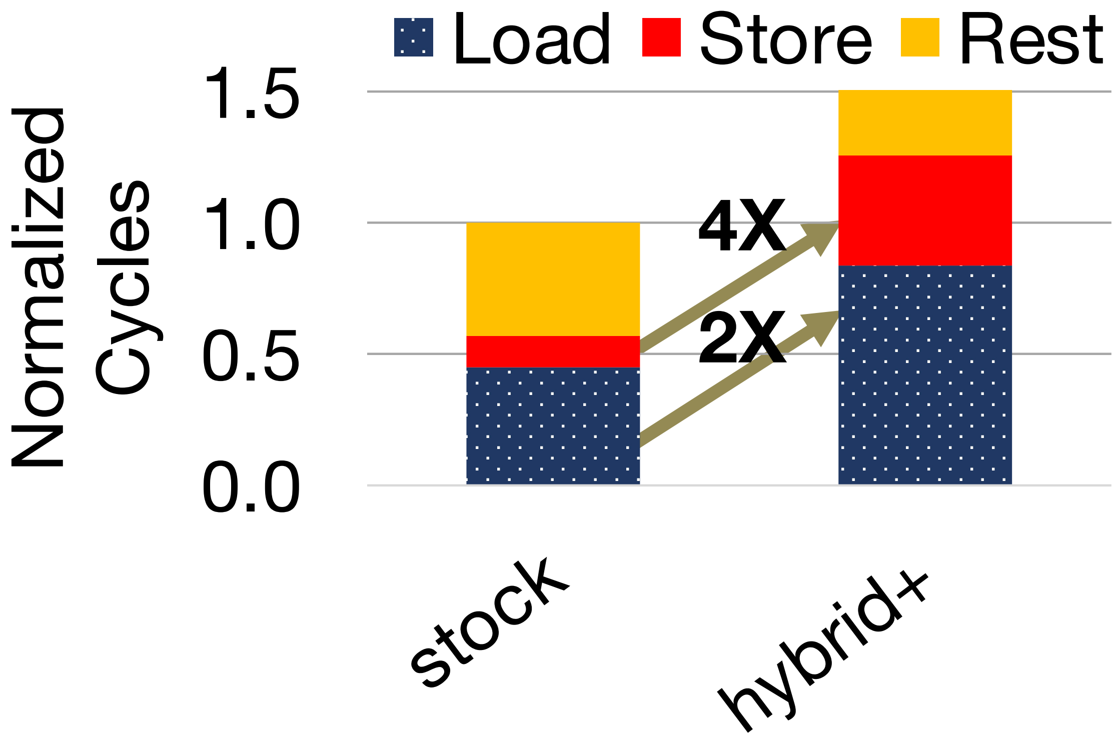


Indexing scalability



Hybrid+ incurs an increase in memory stalls (32 cores)

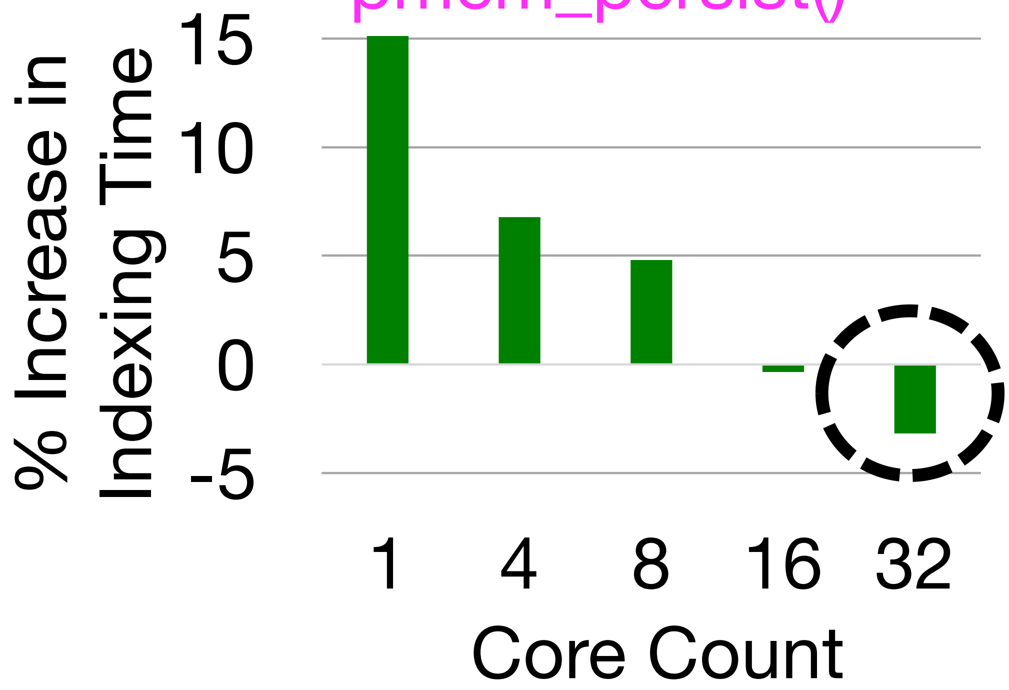
Use perf counters to observe Load/Store stalls the multicore incurs



Crash consistent indexing with 32 cores improves perf

32 cores: Invalidated cache lines become replacement candidates, improving LLC hit rate

Baseline: No pmem_persist()



Query Evaluation Methodology

Tail latency of 100K concurrent queries

→ 1 term

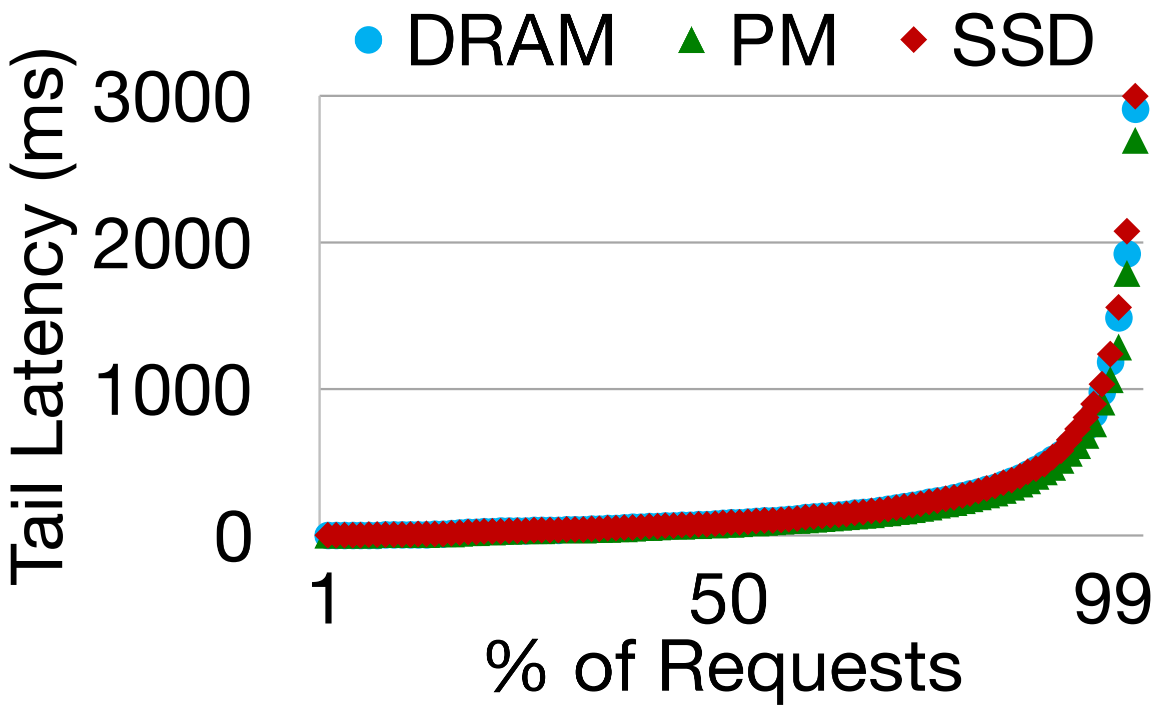
→ AND 2 terms

See paper for details

→ Term selection, variation, ranking

Tail latency of single-term queries
DRAM = PM = SSD

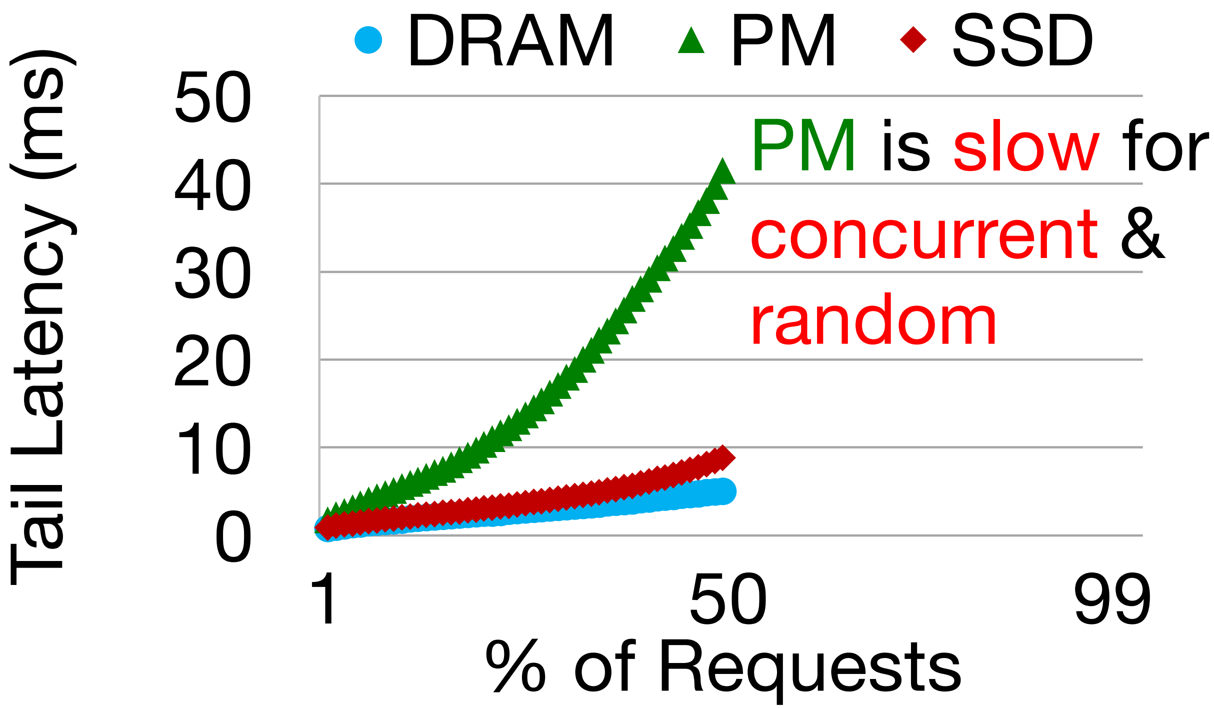
Accessing a single posting list results in a sequential access pattern



Tail latency of 2-term AND Region 1: DRAM < SSD < PM

50% Shortest queries

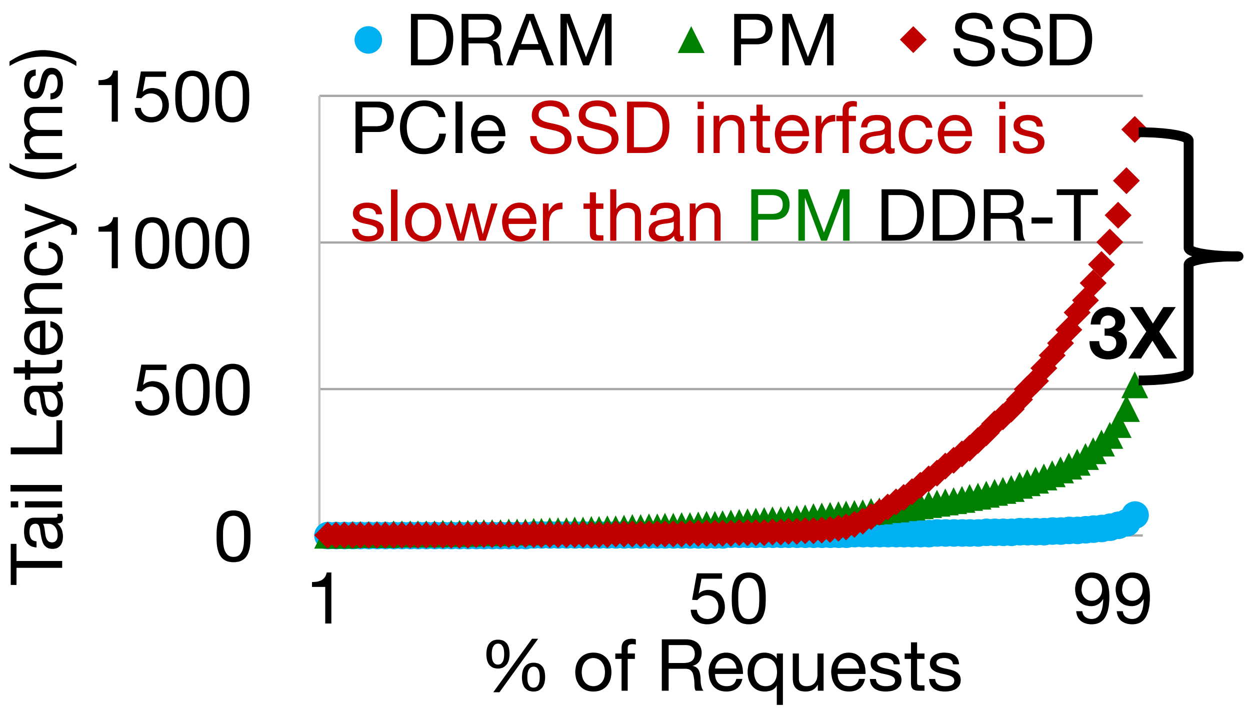
Advancing two lists leads to random accesses



Tail latency of 2-term AND Region 2: DRAM < PM < SSD

50% Longest queries

These queries access the SSD media



More analysis in the paper

Indexing: updates

Query eval: access patterns

Breakdowns: sort vs merge, load vs store

pmemkv: volatile map, binding

Other: OS caching impacts

Key Takeaways

PM does not scale well for write I/O bound indexing

PM shines for the latency-critical query evaluation

Contribution: PM Search Engine

Exploiting PM for building/storing indices

→ Memory, storage, universal roles

→ Fine-grained crash consistent recovery

Extensive PM evaluation vs DRAM/SSD

→ Indexing perf, scalability, bottlenecks

→ Tail latency of query workloads