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leanstore A Storage Engine for Modern Hardware

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Disk-Based Database Systems

[Harizopoulos et al., SIGMOD 2008]

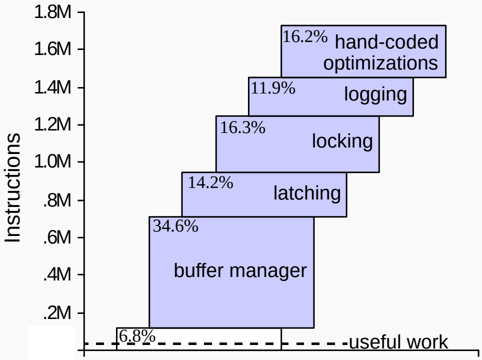
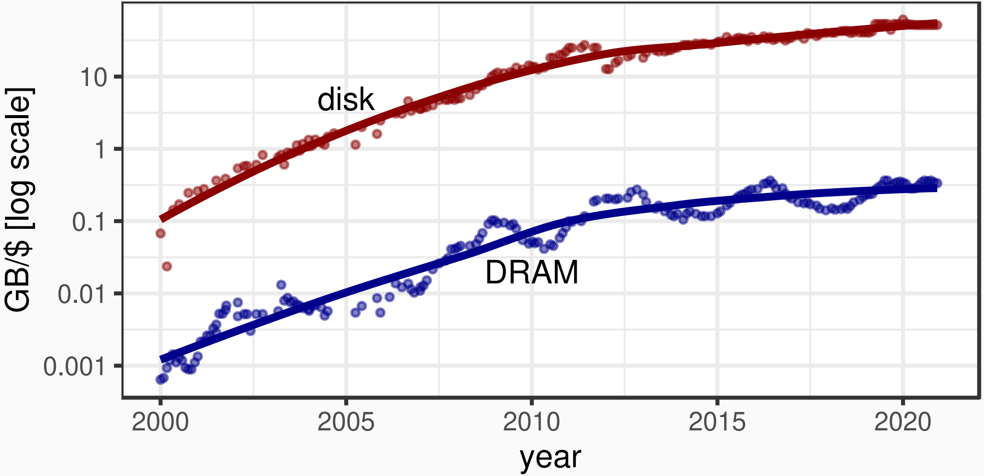


Figure 1. Breakdown of instruction count for various DBMS components for the New Order transaction from TPC-C. The top of the bar-graph is the original Shore performance with a main memory resident database and no thread contention. The bottom dashed line is the useful work, measured by executing the transaction on a no-overhead kernel.

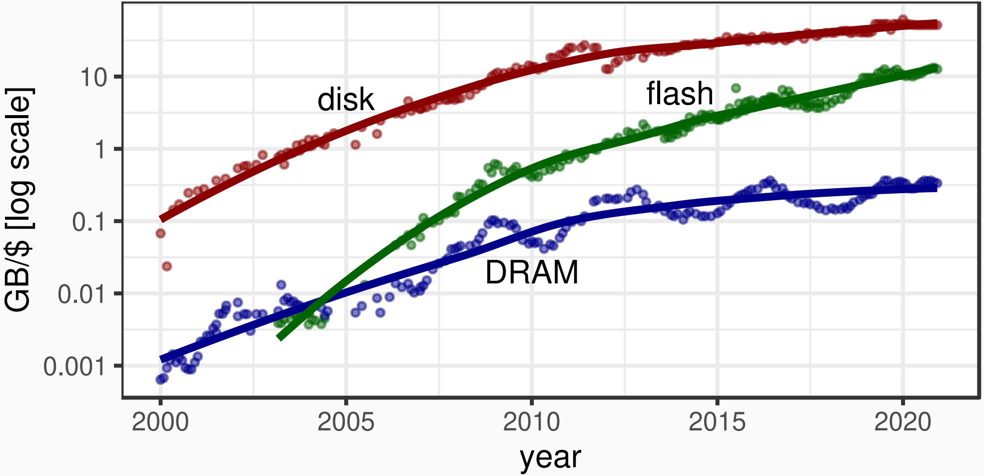
- disk-based systems are hopeless
- emergence of in-memory DBMS:
  - radically new architecture
  - <100K instructions/tx
  - no good support for large data sets

Storage Trends

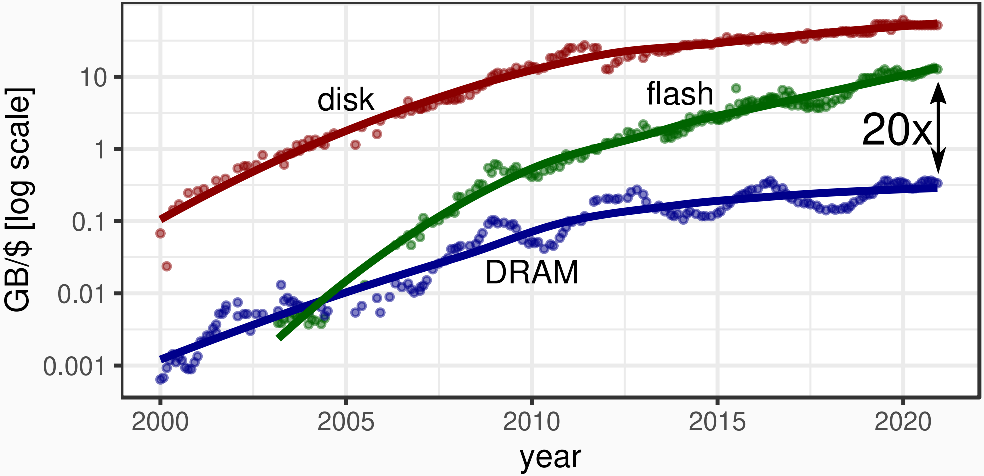


Storage Trends

[CIDR 2020]



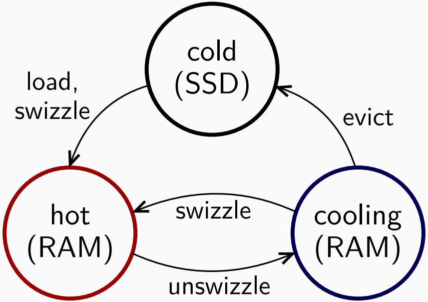
Storage Trends



LeanStore Features

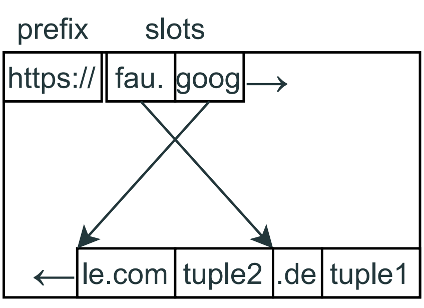
- high-performance storage engine for OLTP
- RocksDB-like C++ interface
- highly scalable on multi-cores CPUs
- optimized for directly-attached NVMe arrays
- B-tree indexes with row-wise storage
- logging, checkpointing, and recovery
- concurrency control implmentation in progress

- page-based storage (4 KB)
- pointer swizzling: page reference can be pointer or page id
- lightweight two-stage page replacement algorithm (random + FIFO)



Indexing

- almost textbook B^+trees
- keys and values have variable size
- keys are prefix-compressed
- cache optimization: first four key bytes are in slot
- not quite as fast as the best in-memory structures but robust



(Optimistic) Latching

[DEBULL 2019, Damon 2020]

- each page has
  - version: `atomic<u64>`
  - mutex: `pthread_rwlock`
- page access modes:
  - optimistic
  - shared
  - exclusive
- B-tree is synchronized using Optimistic Lock Coupling
- buffer managers don't need memory reclamation (!)

Contention and Space Management in B-trees

[CIDR 2021]

- Optimistic Lock Coupling solves read contention
- B-trees can have unnecessary write contention, solved by Contention Split:
  - use probabilistic per-page access counters to detect contention
  - split if contention is detected
- B-trees have can low space utilization, solved by XMerge:
  - before page is evicted from buffer pool, check its and its neighboring fill factors
  - merge to save space

Logging, Checkpoints, and Recovery with ARIES

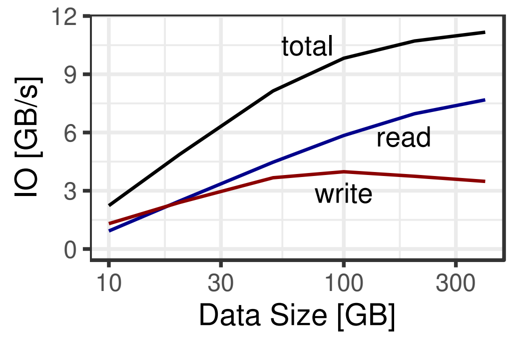
- lightweight in-memory logging approaches are not really feasible for out-of-memory workloads
- ARIES has many nice features:
    - arbitrarily large transactions
    - fuzzy and cheap checkpoints
    - fast recovery
- but standard ARIES is inefficient and not scalable on multi-core CPUs

Logging, Checkpoints, and Recovery in LeanStore [SIGMOD 2020]

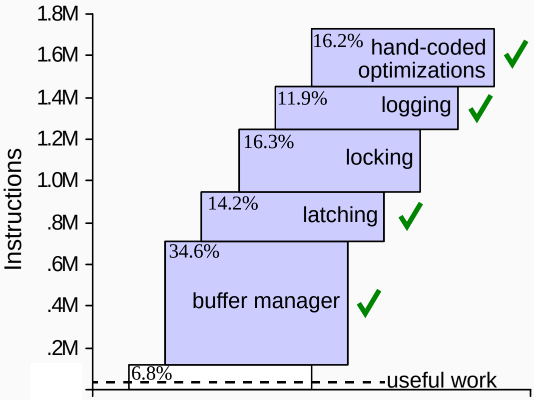
- physiological WAL with read+undo info
- scalable distributed per-thread logging
  - WAL on PMem: low-latency commits with remote flush avoidance
  - WAL on SSD: high throughput with group commit
- continuous fuzzy checkpoints
- multi-threaded recovery

In-Memory TPC-C Performance (64 Core AMD Rome)

Out-Of-Memory TPC-C Performance (10 GB Buffer Pool, 7 × PCIe 3 SSDs)



Conclusions



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- old techniques optimized for modern hardware
- made lots of progress
- currently a research prototype
- still many interesting technical challenges ahead (stay tuned)

`http://leanstore.io`

References

- [SIGMOD 2008]: OLTP through the looking glass, and what we found there, Harizopoulos et al.
- [ICDE 2018]: LeanStore: In-Memory Data Management Beyond Main Memory, Leis et al.
- [DEBULL 2019]: Optimistic Lock Coupling: A Scalable and Efficient General-Purpose Synchronization Method, Leis et al.
- [Damon 2020]: Scalable and robust latches for database systems, Böttcher et al.
- [SIGMOD 2020]: Rethinking Logging, Checkpoints, and Recovery for High-Performance Storage Engines, Haubenschild et al.
- [CIDR 2020]: Exploiting Directly-Attached NVMe Arrays in DBMS, Haas at al.
- [CIDR 2021]: Contention and Space Management for B-Trees, Alhomssi at al.