ArangoDB

The computer science behind a modern distributed data store

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Overview

Topics

- Resilience and Consensus
- Sorting
- Log-structured Merge Trees
- Hybrid Logical Clocks
- Distributed ACID Transactions

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Bottom line: You need CompSci to implement a modern data store

Resilience and Consensus

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(And we have not even talked about malicious attacks and enemy action.)

Paxos and Raft

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More recently, **Raft** (2013) has been proposed.

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But most importantly: **DO NOT TRY TO INVENT YOUR OWN!**

Raft in a slide

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- Very smart logic to ensure a unique leader and automatic recovery from failure.
- It is all a lot of fun to get right, but it is proven to work.
- One puts a key/value store on top, the log contains the changes.

Raft demo

`file:///Users/mchacki/talks/talks/compScience/raft/raft.github.io/raftscope/index.html`

`http://raft.github.io/raftscope/index.html`

(by Diego Ongaro)

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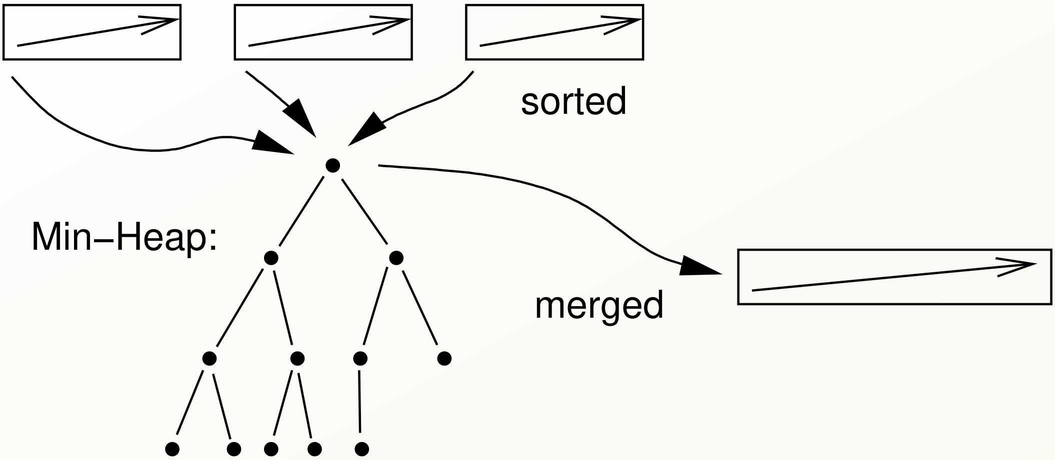
Since the time where an Apple IIe was blazing fast hardware,

- compute power in one core has increased by $\times$20000
- a single memory access by $\times$40
- and now we have 32 cores in a CPU
- this means **computation** has outpaced **memory access** by $\times$1280!

Idea for a parallel sorting algorithm: Merge Sort



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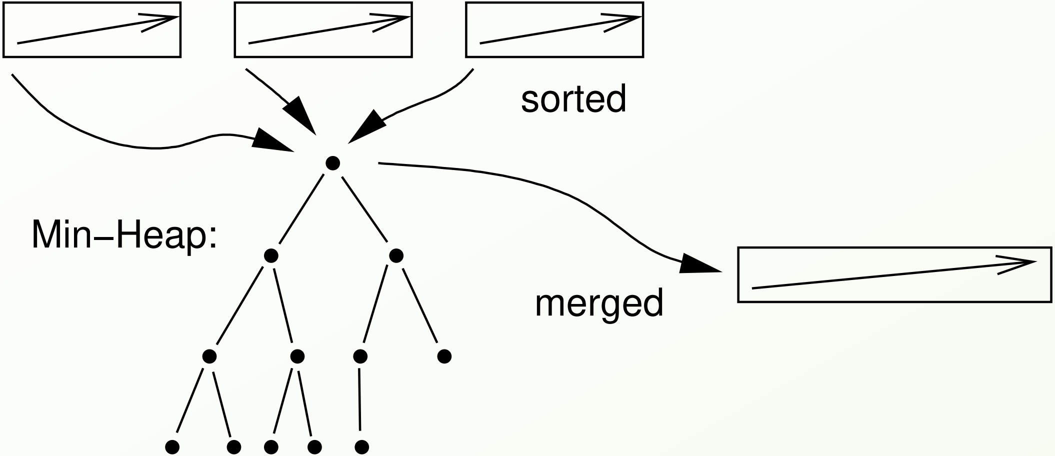

Nearly all comparisons hit the L2 cache!

Log structured merge trees (LSM-trees)

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People rightfully expect from a data store, that it

- can hold more data than the available RAM,
- works well with SSDs and spinning rust,
- allows fast bulk inserts into large data sets, and
- provides fast reads in a hot set that fits into RAM.

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Traditional B-tree based structures **often fail to deliver** with the last 2.

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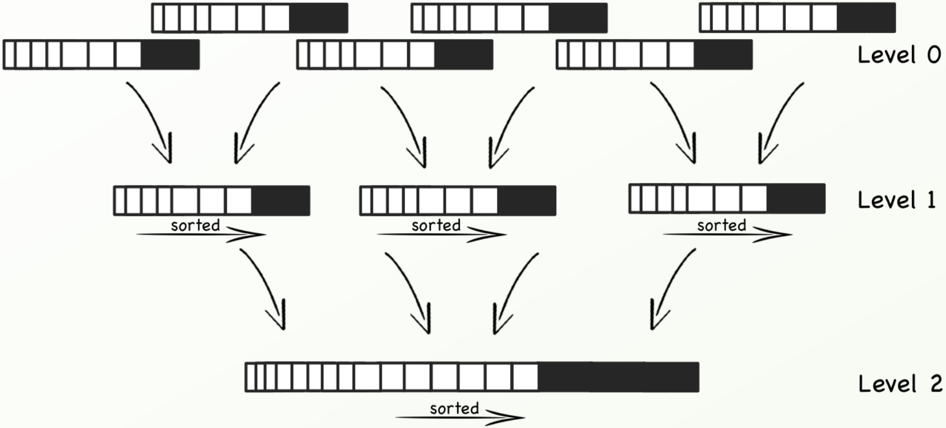

Compaction continues creating fewer, larger and larger files

(Source: `http://www.benstopford.com/2015/02/14/log-structured-merge-trees/`, Author: Ben Stopford, License: Creative Commons)

Log structured merge trees (LSM-trees)

LSM-trees — summary

- writes first go into memtables,
- all files are sorted and immutable,
- compaction happens in the background,
- merge sort can be used,
- all writes use sequential I/O,
- Bloom filters or Cuckoo filters for fast reads,
- $\Longrightarrow$ good write throughput and reasonable read performance,
- used in ArangoDB, BigTable, Cassandra, HBase, InfluxDB, LevelDB, MongoDB, RocksDB, SQLite4 and WiredTiger, etc.

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Why would this help?

- establish **“happened after”** relationship between events,
- e.g. for **conflict resolution**, **log sorting**, **detecting network delays**,
- **time to live** could be implemented easily.

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Send a time stamp with every message. The HLC always returns a value

$$> \max(\text{local clock, largest time stamp ever seen}).$$

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Causality is preserved, time can **"catch up"** with logical time eventually.

http://muratbuffalo.blogspot.com.es/2014/07/hybrid-logical-clocks.html

Distributed ACID Transactions

Atomic	either happens in its entirety or not at all
Consistent	reading sees a consistent state, writing preservers consistency
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(All relatively doable when transactions happen one after another!)

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We have to take **replication**, **resilience** and **failover** into account.

Distributed ACID Transactions

WITHOUT

Distributed databases without ACID transactions:
ArangoDB, BigTable, Couchbase, Datastax, Dynamo, Elastic, HBase, MongoDB, RethinkDB, Riak, and lots more . . .

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$\Longrightarrow$ Very few distributed engines promise ACID, **because this is hard!**

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- be **persisted** somewhere (durability),
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Transaction visibility needs to be implemented (MVCC), time stamps play a crucial role.

Links

http://the-paper-trail.org/blog/consensus-protocols-paxos

https://raft.github.io

https://en.wikipedia.org/wiki/Merge_sort

http://www.benstopford.com/2015/02/14/log-structured-merge-trees/

http://muratbuffalo.blogspot.com.es/2014/07/hybrid-logical-clocks.html

https://research.google.com/archive/spanner.html

https://www.cockroachlabs.com/docs/v1.1/architecture/overview.html

https://www.arangodb.com

http://mesos.apache.org