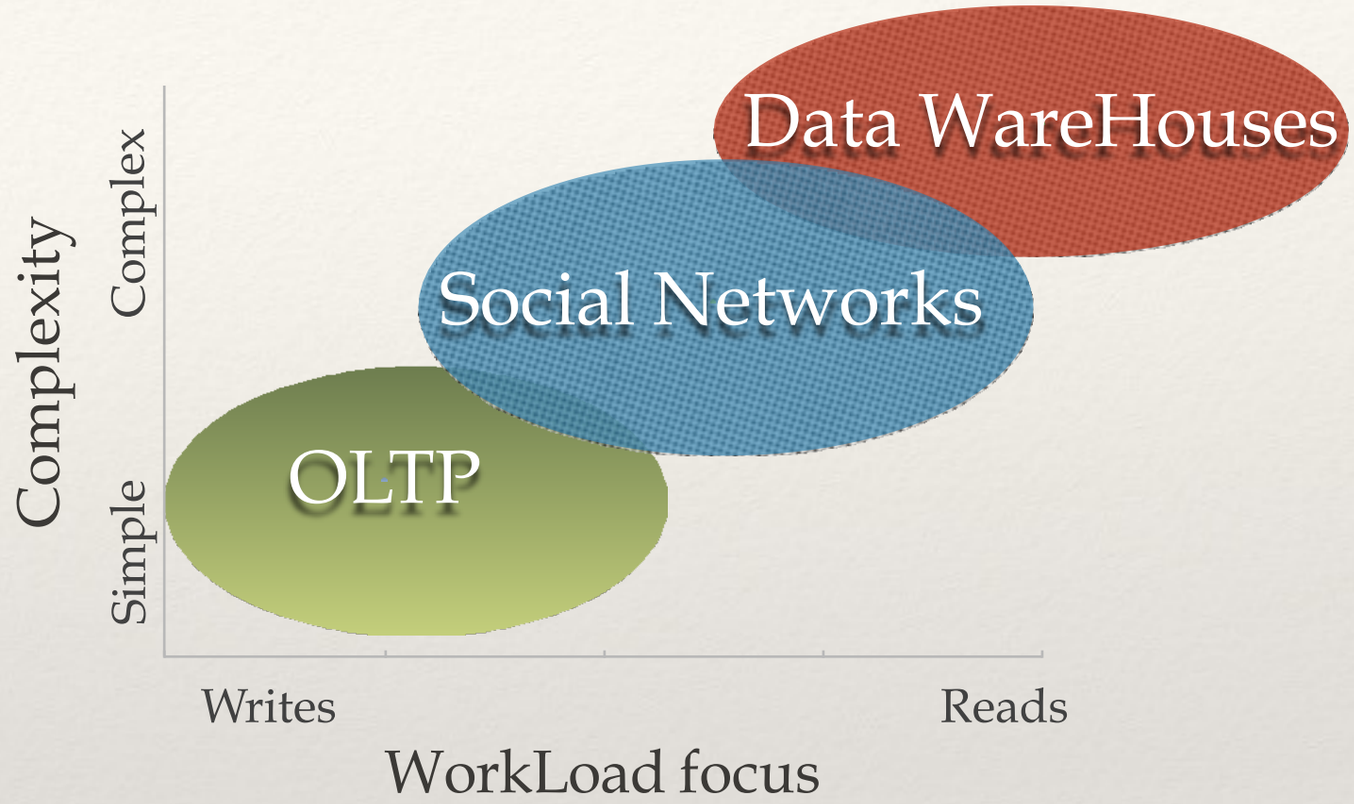
NewSQL Overview

History of SQL

- Relational Model in 1970
  - disk-oriented
  - rows
  - sql



- "One size fits all" doesn't work:
  - Column-oriented data warehouses for OLAP.
  - Key-Value storages, Document storages

Column-oriented DBMS

- Store content by column rather than by row

John	Smith	20
Joe	Smith	30
Alice	Adams	50

John:001; Joe:002; Alice:003.

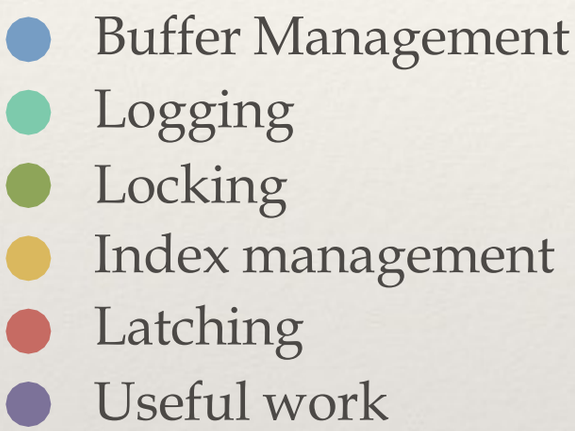
Smith:001,002; Adams:003.

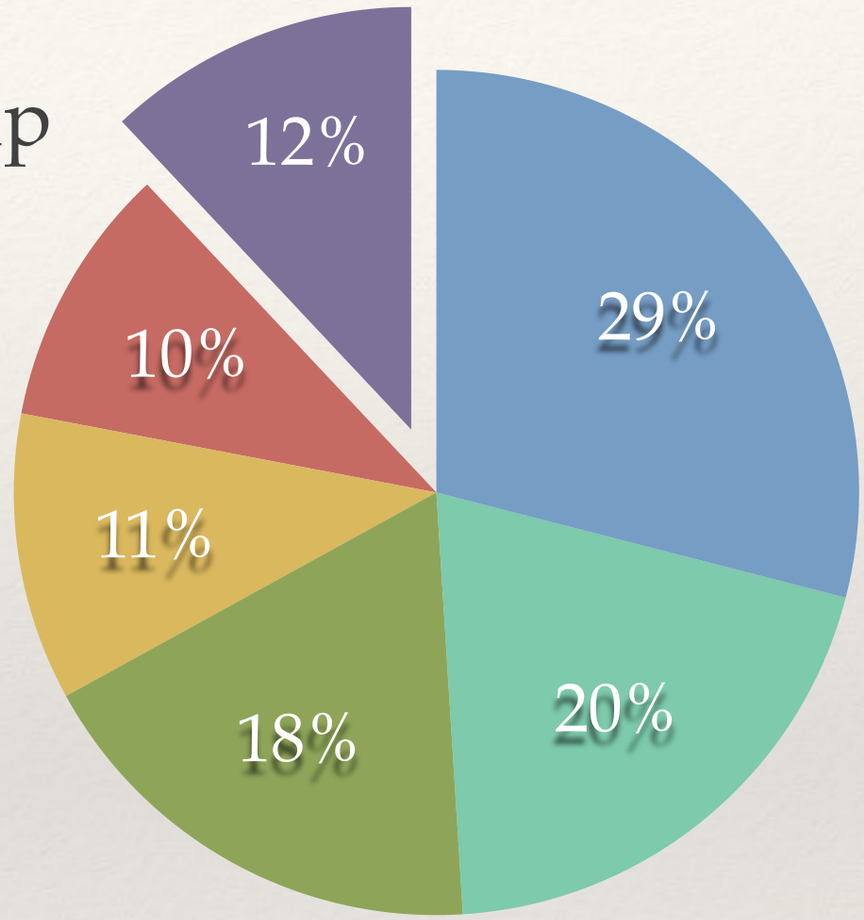
20:001; 30:002; 50:003.

- Efficient in hard disk access
- Good for sparse and repeated data
- Higher data compression
- More reads/writes for large records with a lot of fields
- Better for relatively infrequent writes, lots of data throughput on reads (OLAP, analytic requests).

Traditional DBMS overheads

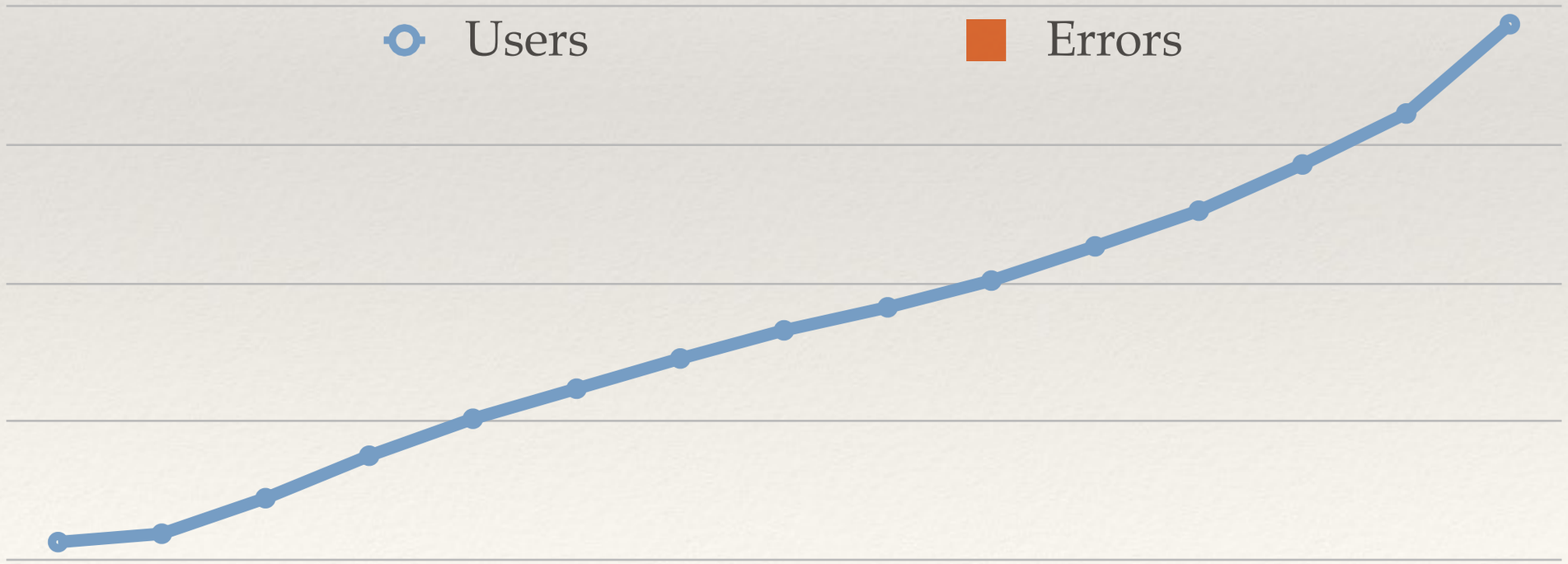
by Stonebraker & research group





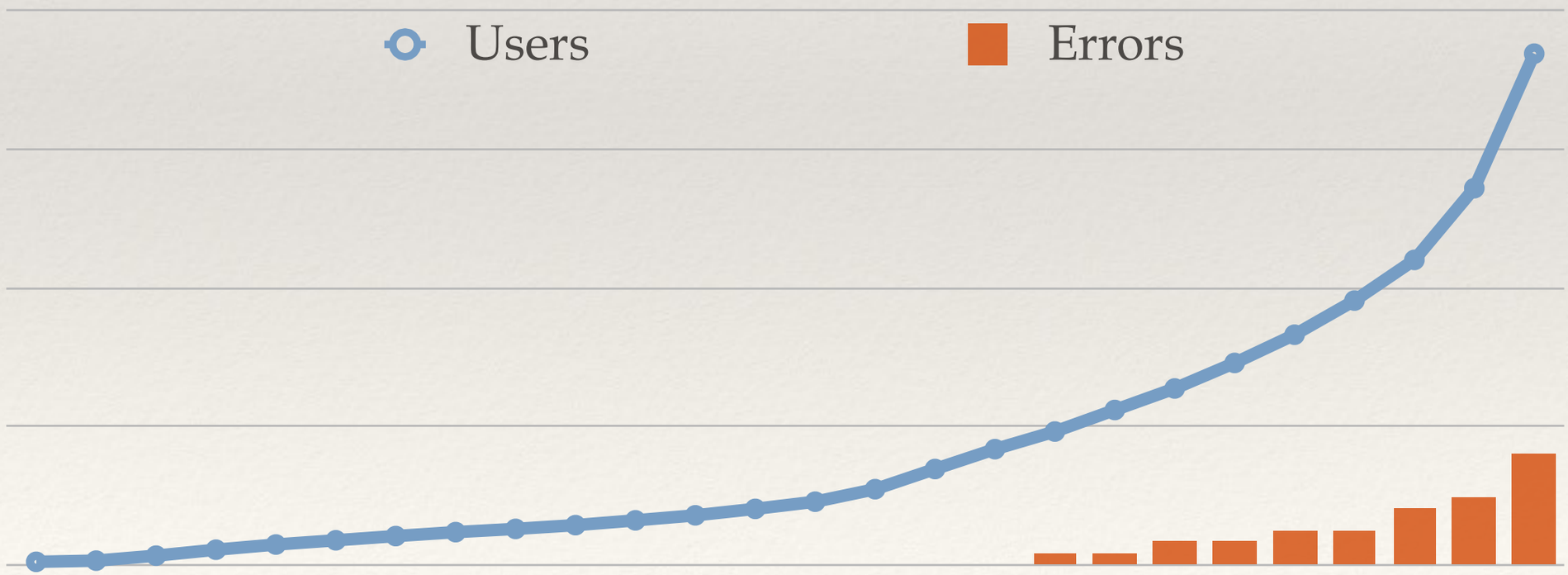
Startups lifecycle

- Start: no money, no users, open source



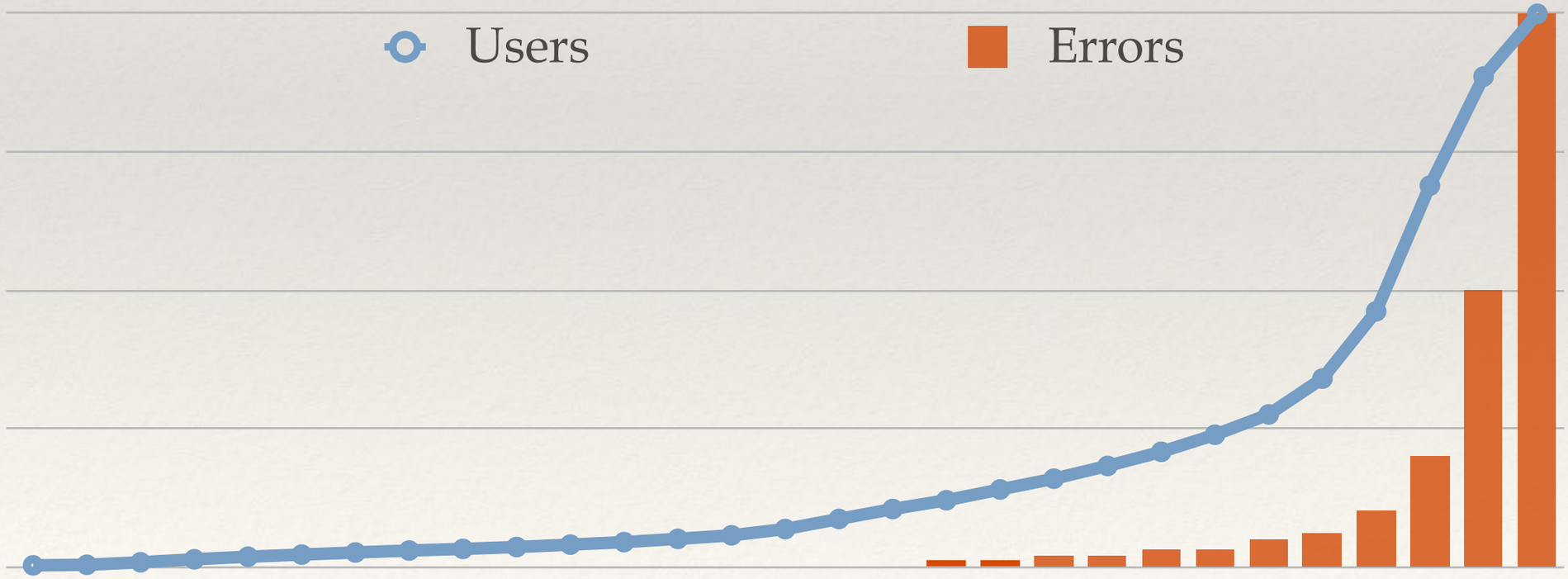
Startups lifecycle

- Start: no money, no users, open source
- Middle: more users, storage optimization



Startups lifecycle

- Start: no money, no users, open source
- Middle: more users, storage optimization
- Final: plenty of users, storage failure



Application-level sharding

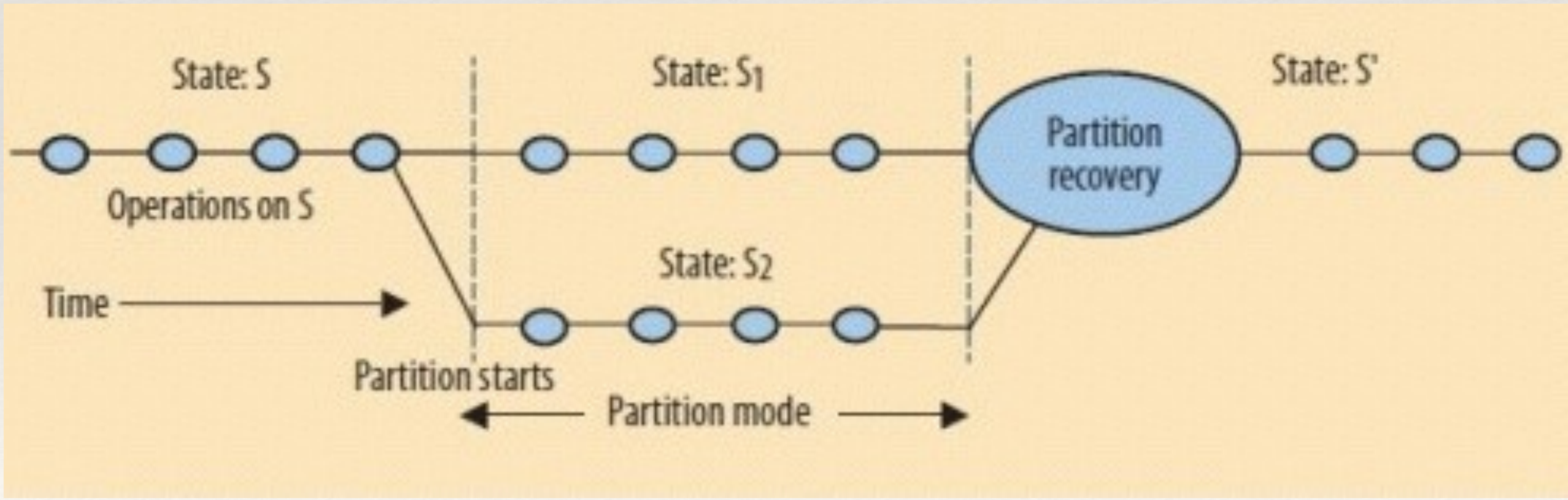
- Middleware + single-node DBMS
- Additional application-level logic
- Difficulties with cross-sharding transactions
- More servers to maintain and more components

NoSQL

- CAP: **c**onsistency, **a**vailability, **p**artitioning
- ACID: **a**tomicity, **c**onsistency, **i**solation, **d**urability

NoSQL

- ‘P’ in CAP is not discrete
- Managing partitions: detection, limitations in operations, recovery



NoSQL

- CAP: first ‘A’, then ‘C’: finer control over availability
- Horizontal scaling
- Not a “relational model”, custom API
- Schemaless
- Types: Key-Value, Document, Graph, …

NoSQL

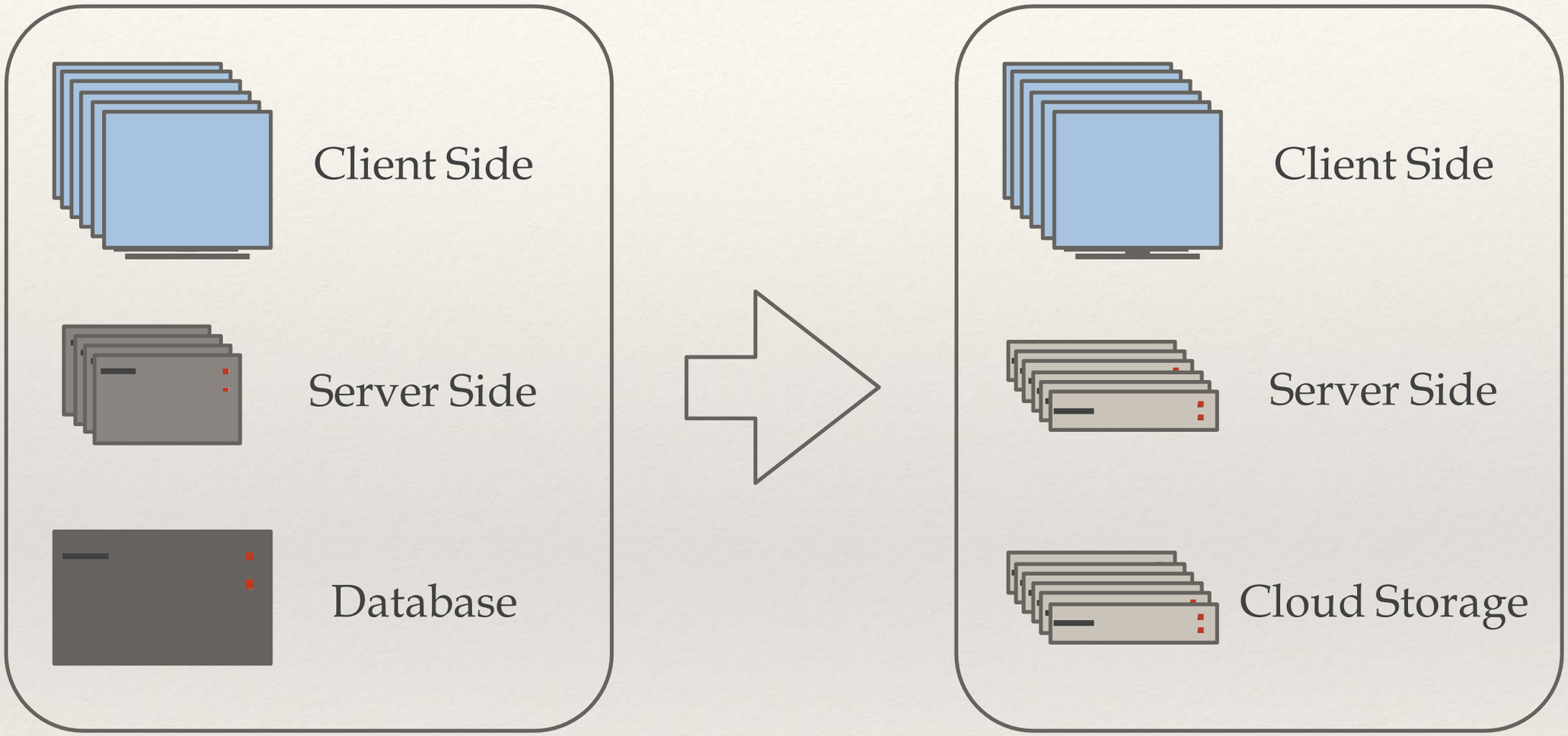
"NoSQL DBMSs cause their developers to spend too much time writing code to handle inconsistent data and that transactions provide a useful abstraction that is easier for humans to reason about."

Google

New requirements

- Large scale systems, with huge and growing data sets
- Information is frequently generated by devices
- High concurrency requirements
- Usually, data model with some relations
- Often, transactional integrity

Trends: architecture change



Consistency, transactions: Database

Storage optimization: Database

Scalability: Client Side

Consistency, transactions: Cloud

Storage optimization: Cloud

Scalability: All levels

NewSQL: definition

"A DBMS that provide the same scalable performance of NoSQL for online transaction processing (OLTP) read- write workloads while still maintaining ACID guarantees for transactions."

Andrew Pavlo & Matthew Aslett

NewSQL: definition

- *SQL as the primary interface*
- *ACID support for transactions*
- *Non-locking concurrency control*
- *High per-node performance*
- *Scalable, shared nothing architecture*

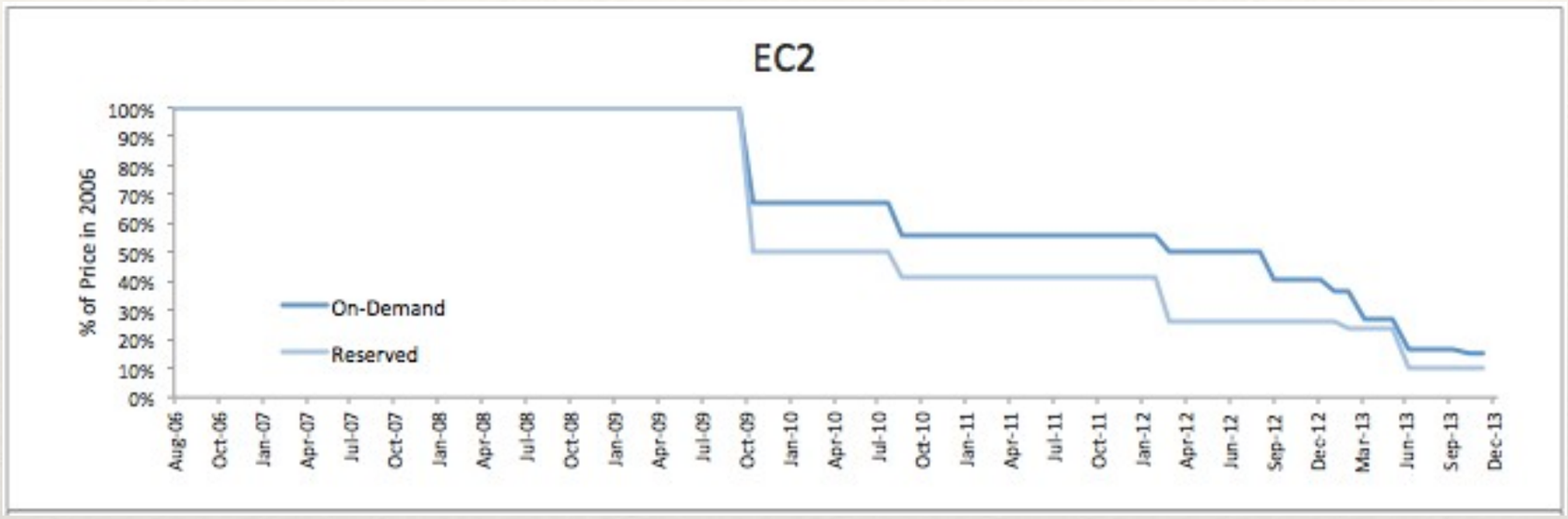
Michael Stonebraker

Shared nothing architecture

- No single point of failure
- Each node is independent and self-sufficient
- No shared memory or disk
- Scale infinitely
- Data partitioning
- Slow multi-shards requests

In-memory storage: price

Amazon price reduction

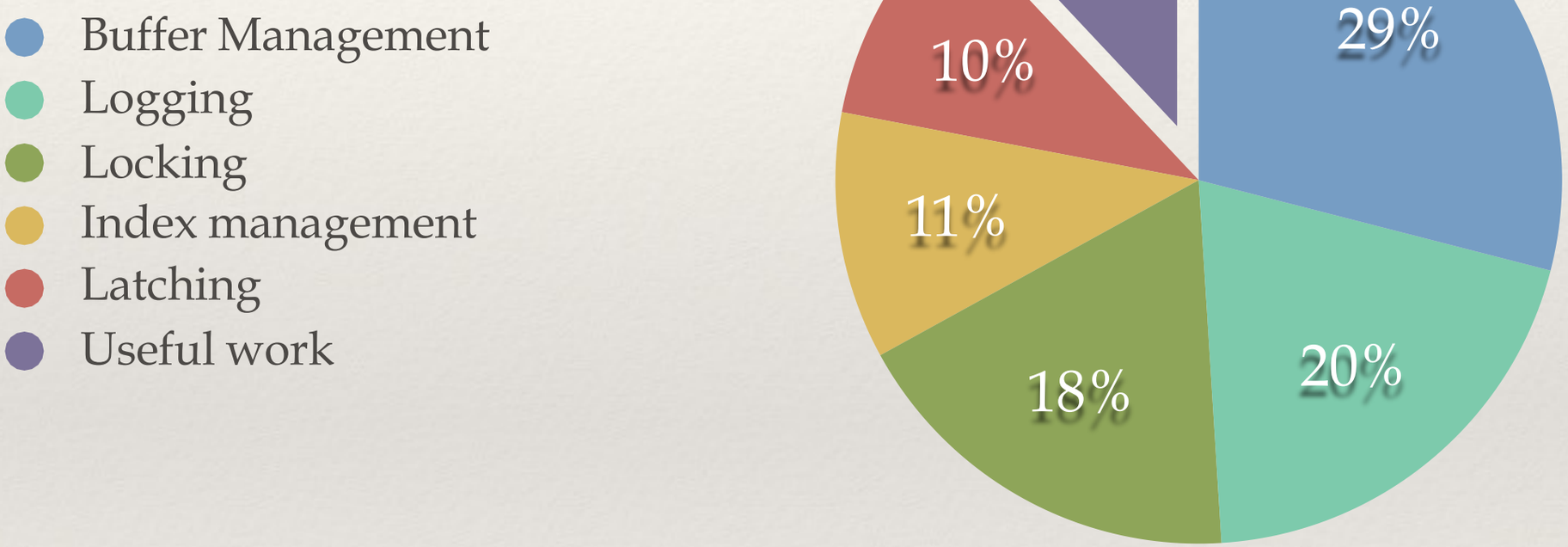


Current price for 1TB (~4 instances of 'r3.8xlarge' type)

	on-demand	3Y-reserved plan
per hour	11.2 $	3.9 $
per month	8.1K $	2.8K $
per year	97K $	33,7K $

Traditional DBMS overheads

by Stonebraker & research group



"Removing those overheads and running the database in main memory would yield orders of magnitude improvements in database performance"

In-memory storage

- High throughput
- Low latency
- No Buffer Management
- If serialized, no Locking or Latching

NewSQL: categories

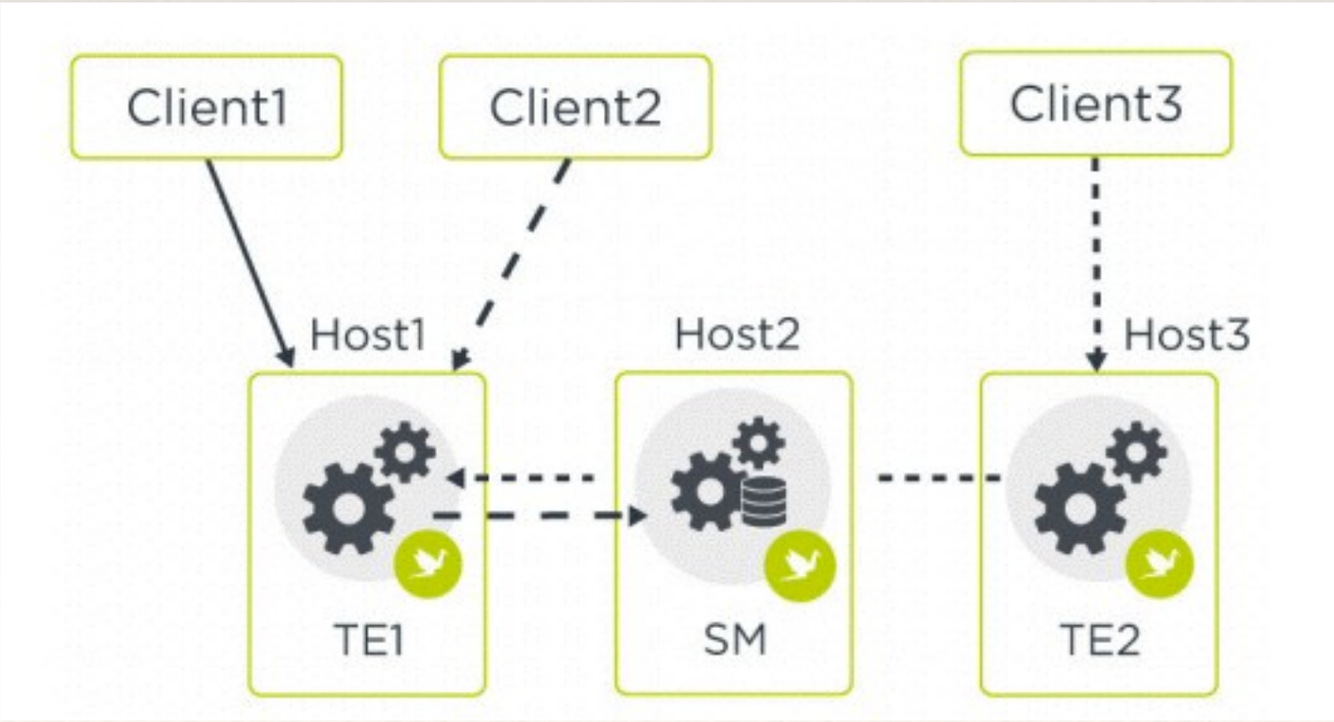
- **Novel new systems**: Spanner, NuoDB, VoltDB, Clustrix, MemSQL , SAP HANA, Hyper
- **Sharding Middleware**: dbShards, ScaleBase
- **Database-as-a-service**: Amazon Aurora, ClearDB

NuoDB

- Multi-tier architecture:
- Administrative: managing, stats, cli, web-ui
- Transactional: ACID except ‘D’, cache
- Storage: key-value store (‘D’ from ACID)

NuoDB

- Everything is an ‘Atom’
- Peer-to-peer communication, encrypted sessions
- MVCC + Append-only storage

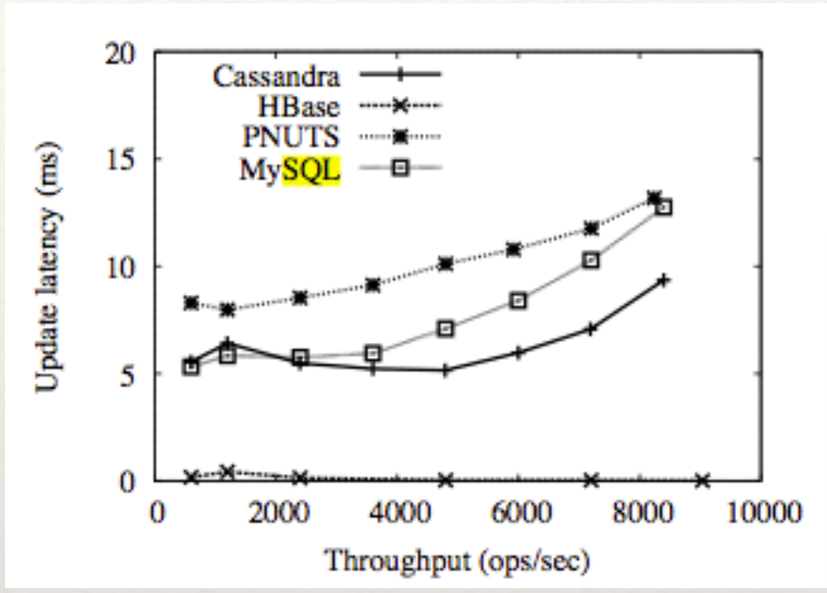


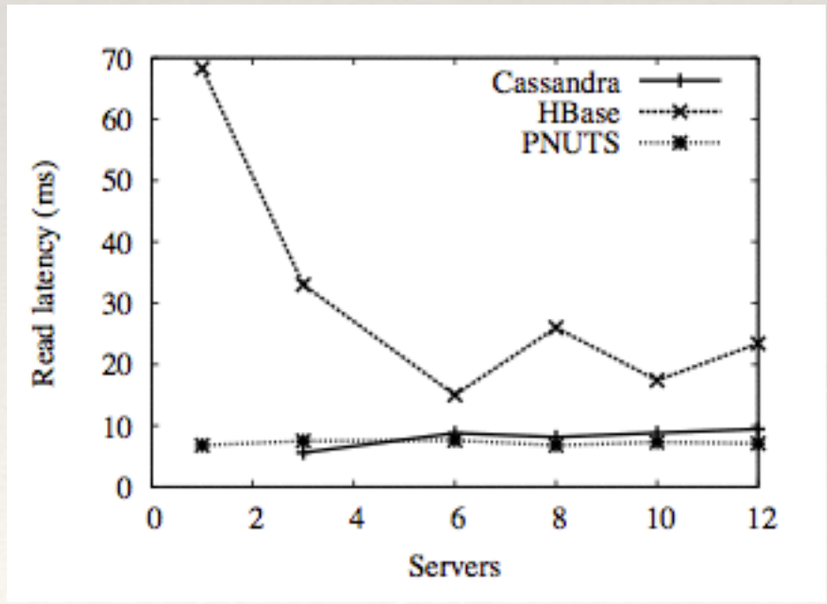
NuoDB: Partitioning

- Dynamic Partitioning
- Retrieve all of the atoms and broadcast changes
- Heuristics “Pin”

YCSB

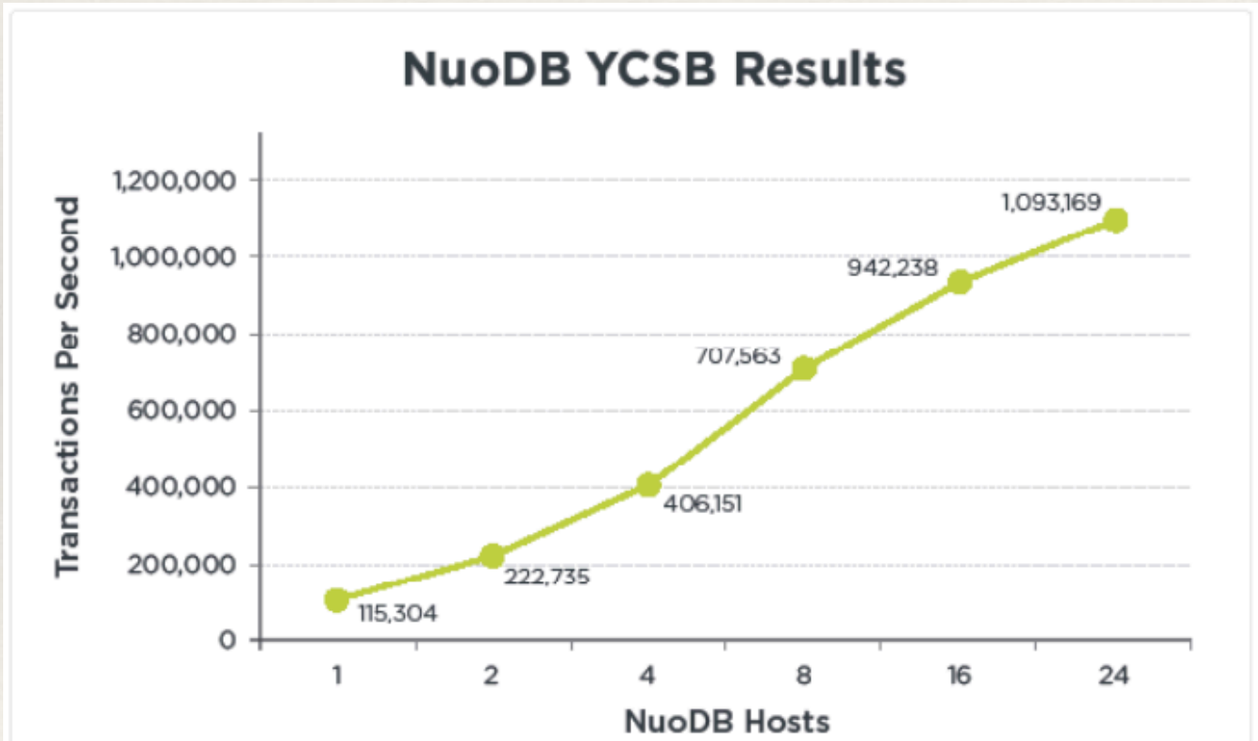
- Yahoo Cloud Serving Benchmark
- Key-value: insert/read/update/scan
- Measures:
  - Performance: latency/throughput
  - Scaling: elastic speedup

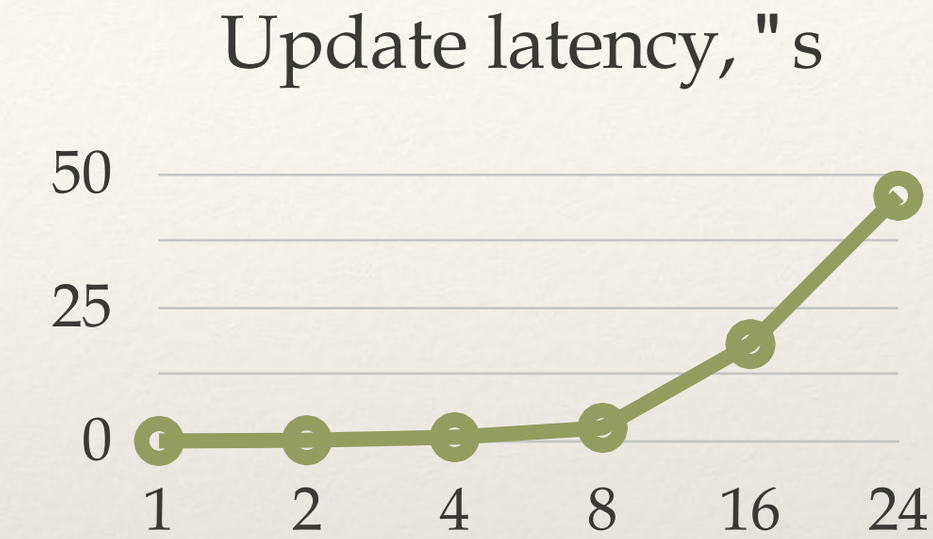


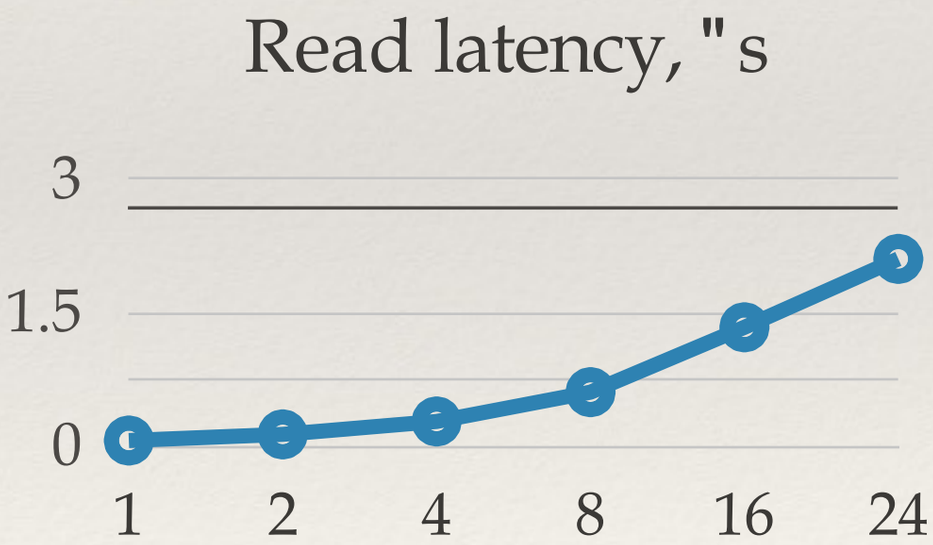


NuoDB: YCSB

Number of NuoDB Database Hosts	Transactions per Second (TPS)	Update Latency in µs	Read Latency in µs
1	115,304	91	66
2	222,735	222	135
4	406,151	788	280
8	707,563	2,538	609
16	942,238	18,205	1,337
24	1,093,169	45,988	2,105







5% updates, 95% reads

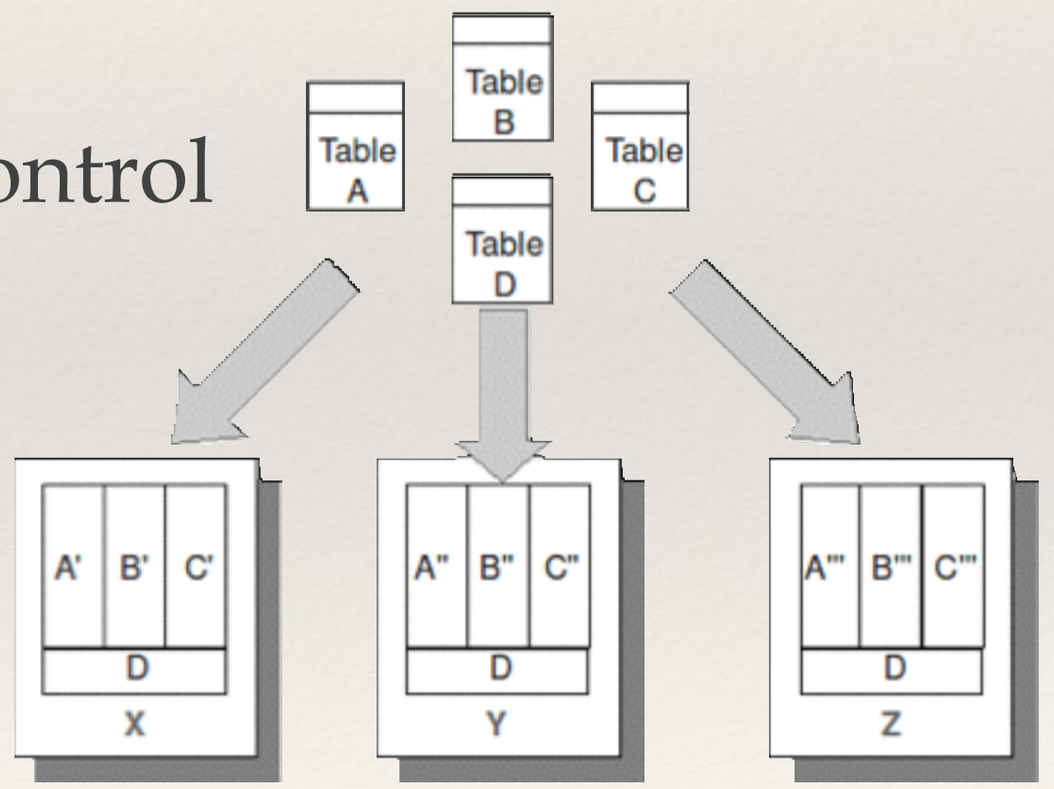
Hosts: 32GB, Xeon 8 cores, 1TB HDD, 1Gb LAN

VoltDB

- In-memory storage
- Stored procedure interface, async/sync proc execution
- Serializing all data access
- Horizontal partitioning
- Multi-master replication

VoltDB

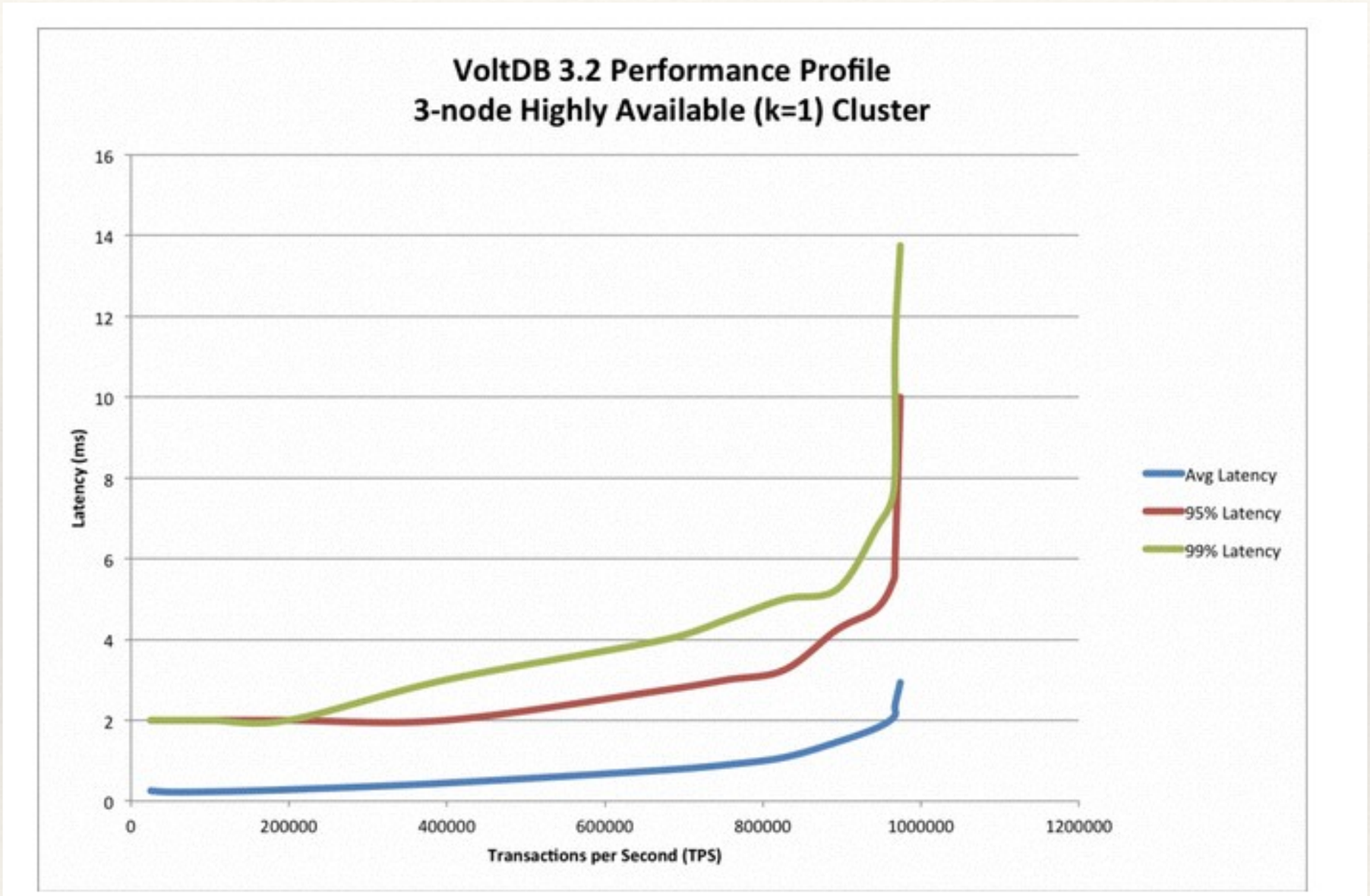
- Open-source, community edition is under GPLv3.
- Java + C++
- Partitioning and Replication control



VoltDB: CC

- Not MVCC, TO Concurrency Control
- Schedule transactions to execute **one-at-a-time** at each partition
- Partition-based concurrency control
- Hybrid architecture

VoltDB: key-value bench

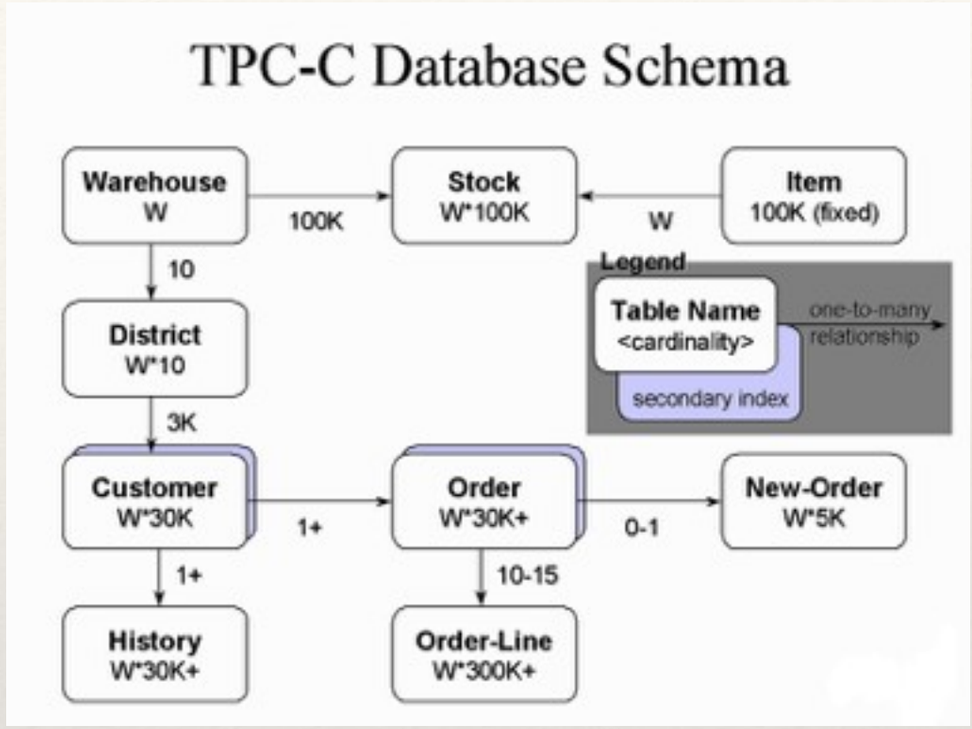


90%reads, 10%writes

3 nodes: 64GB, dual 2.93GHz intel 6 core processors

TPC-C

- Online Transaction Processing (OLTP) benchmark
- 9 types of tables
- 5 concurrent transactions of different complexity
- Productivity measured in “new-order transaction”

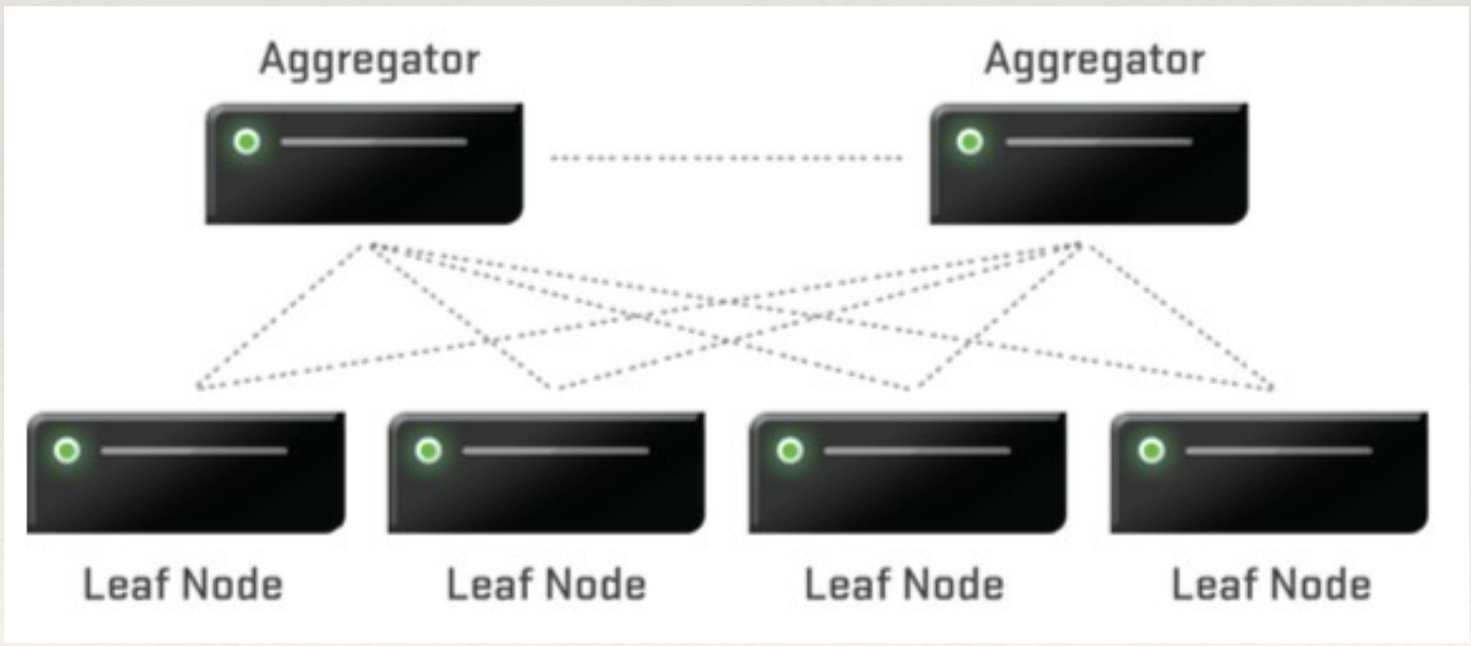


MemSQL

- In-Memory Storage for OLTP
- Column-oriented Storage for OLAP
- Compiled Query Execution Plans (+cache)
- Local ACID transactions (no global txs for distributed)
- Lock-free, MVCC
- Fault tolerance, automatic replication, redundancy (=2 by default)
- [Almost] no penalty for replica creation

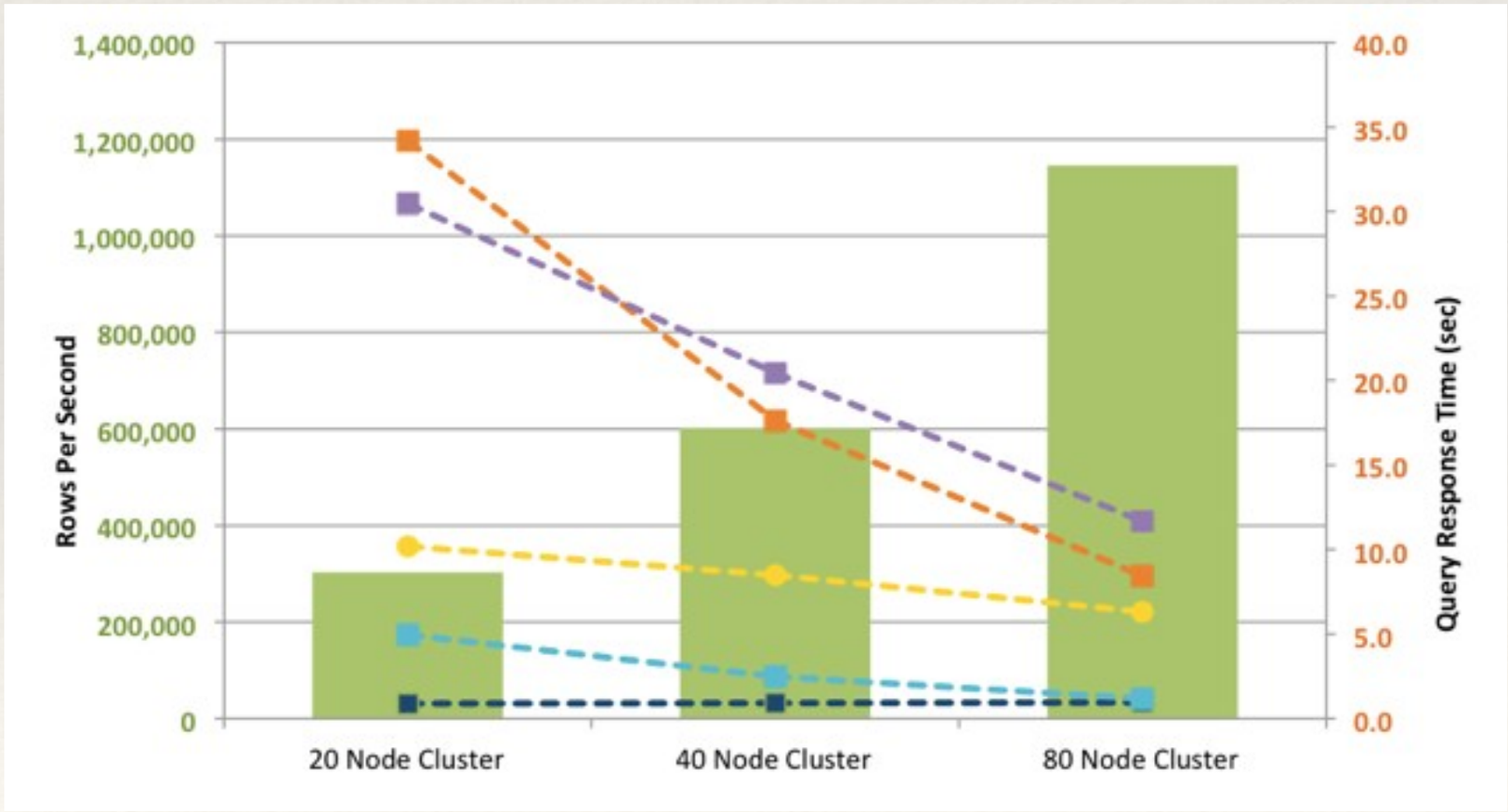
MemSQL

- Two-tiered shared-nothing architecture
  - Aggregators for query routing
  - Leaves for storage and processing
- Integration:
  - SQL
  - MySQL protocol
  - JSON API



MemSQL: Performance

- Adapted TPC-H
- OLAP Reads & OLTP writes simultaneously
- AWS EC2 VPC



Overview

	Max Isolation	Scalable	Open Source	Free to try	Language
PostgreSQL	S	?	Yes	Yes	C
NuoDB	CR	Yes	No	<5 domains	C++
VoltDB	S	Yes	Yes	Yes (wo HA)	Java/C++
ScaleDB	RC	Yes	No	?	?
ClustrixDB	RR	Yes	No	Trial (via email req)	C ?
FoundationDB	S	Yes	Partly	<6 processes	Flow(C++)
MemSQL	RC	Yes	No	?	C++

S: Serializable, RR: Repeated Read, RC: Read Committed, CR: Consistent Read

Conclusions

- NewSQL is an established trend with a number of options
- Hard to pick one because they're not on a common scale
- No silver bullet
- Growing data volume requires ever more efficient ways to store and process it

Spanner

What is Spanner ?

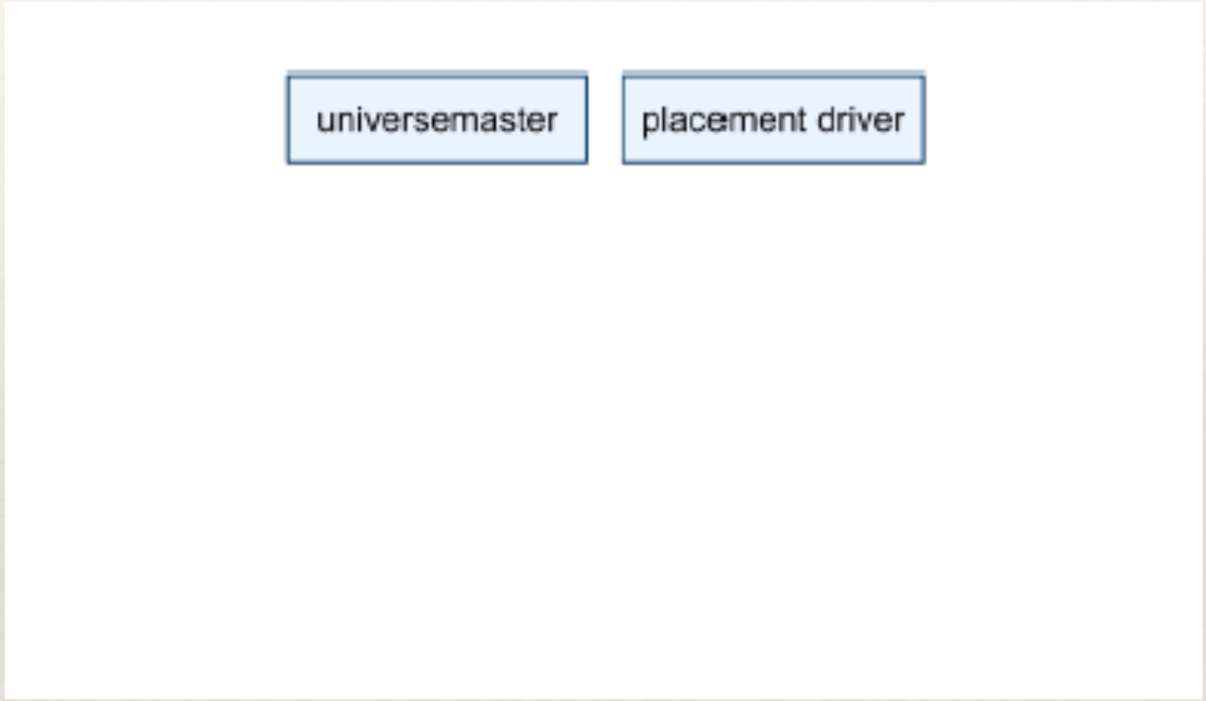
- Globally distributed multi-version database
  - General-purpose transactions (ACID)
  - SQL-like query language
  - Schematized semi-relational tables
- Currently running in production
  - Storage for Google's F1 adv.backend data
  - Replaced a sharded MySQL database

Overview

- Lock-free distributed read transactions
- Global external consistency of distributed transactions
  - Same as linearizability: if a transaction T_1 commits before another transaction T_2 starts, then T_1's commit timestamp is smaller than T_2's.
- Used technologies: concurrency control, replication, 2PC and 2PL
- The key technology: TrueTime service

Spanner server organization

- A Spanner deployment is called an *universe*
- It have two singletons: the universe master and the placement driver



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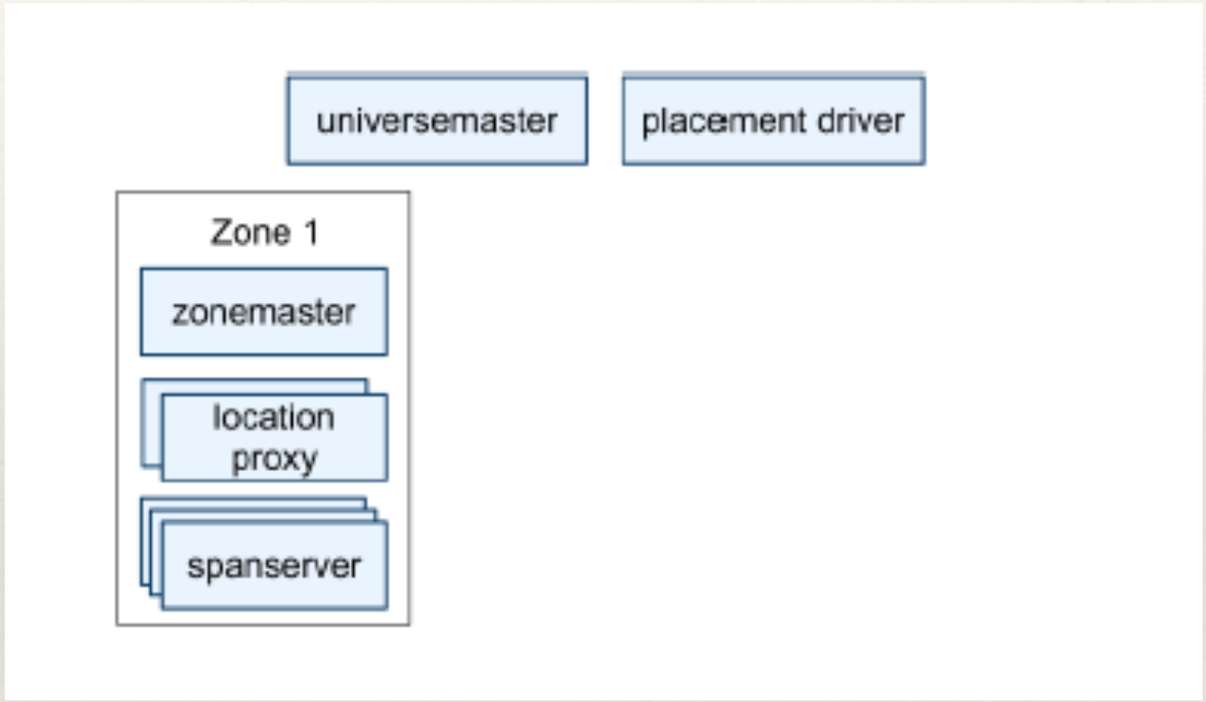

Spanner server organization

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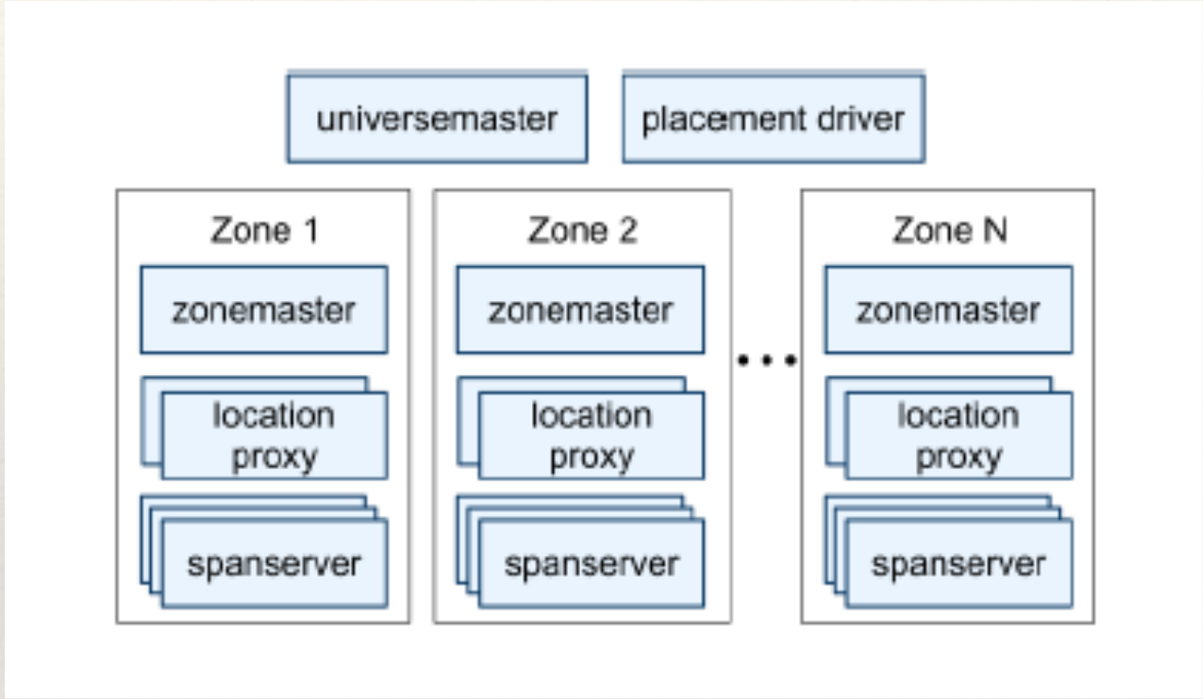
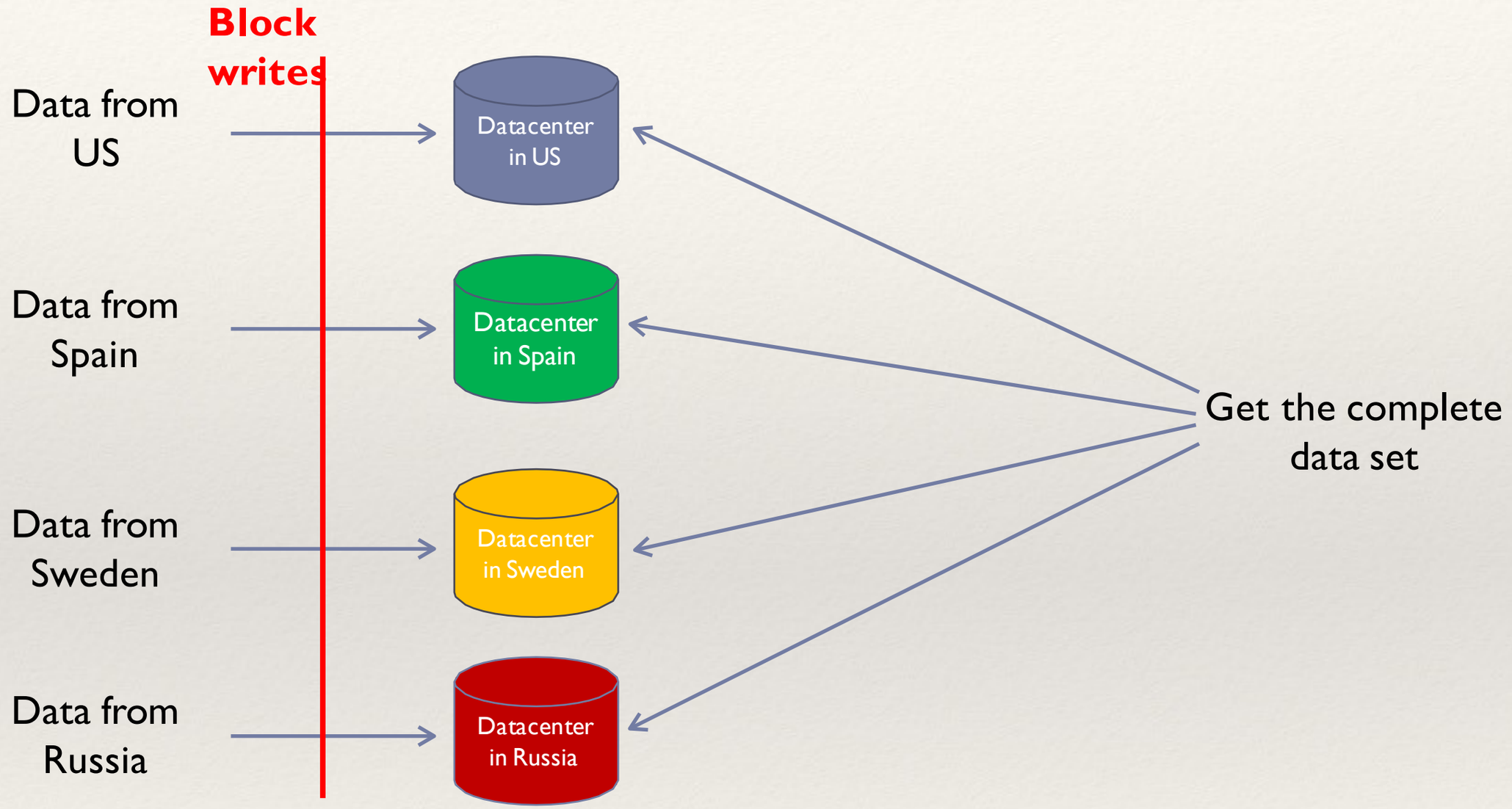
- Can have up to several thousands spanservers
- Organized as a set of zones



Serving data from multiple datacenters



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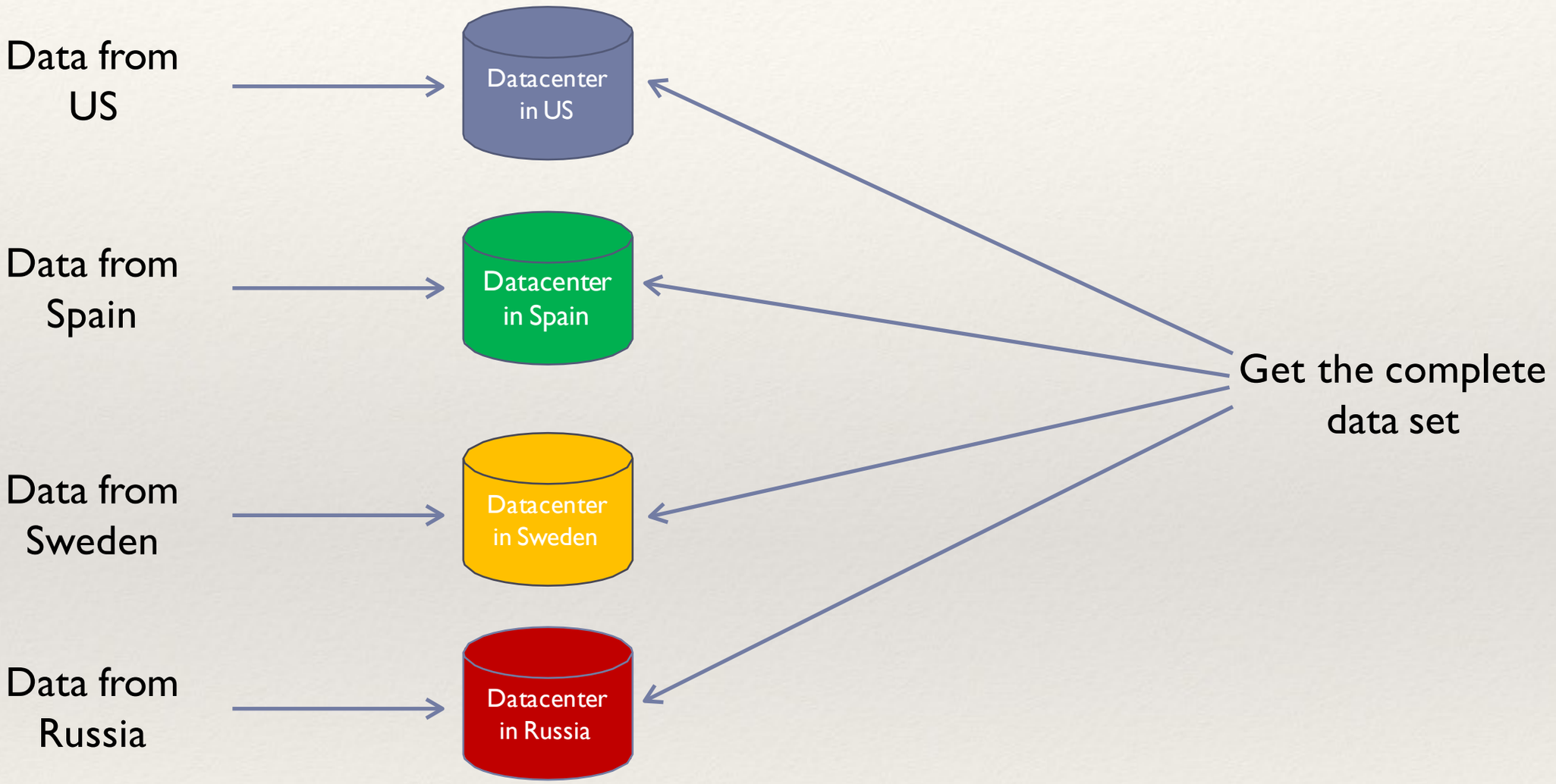

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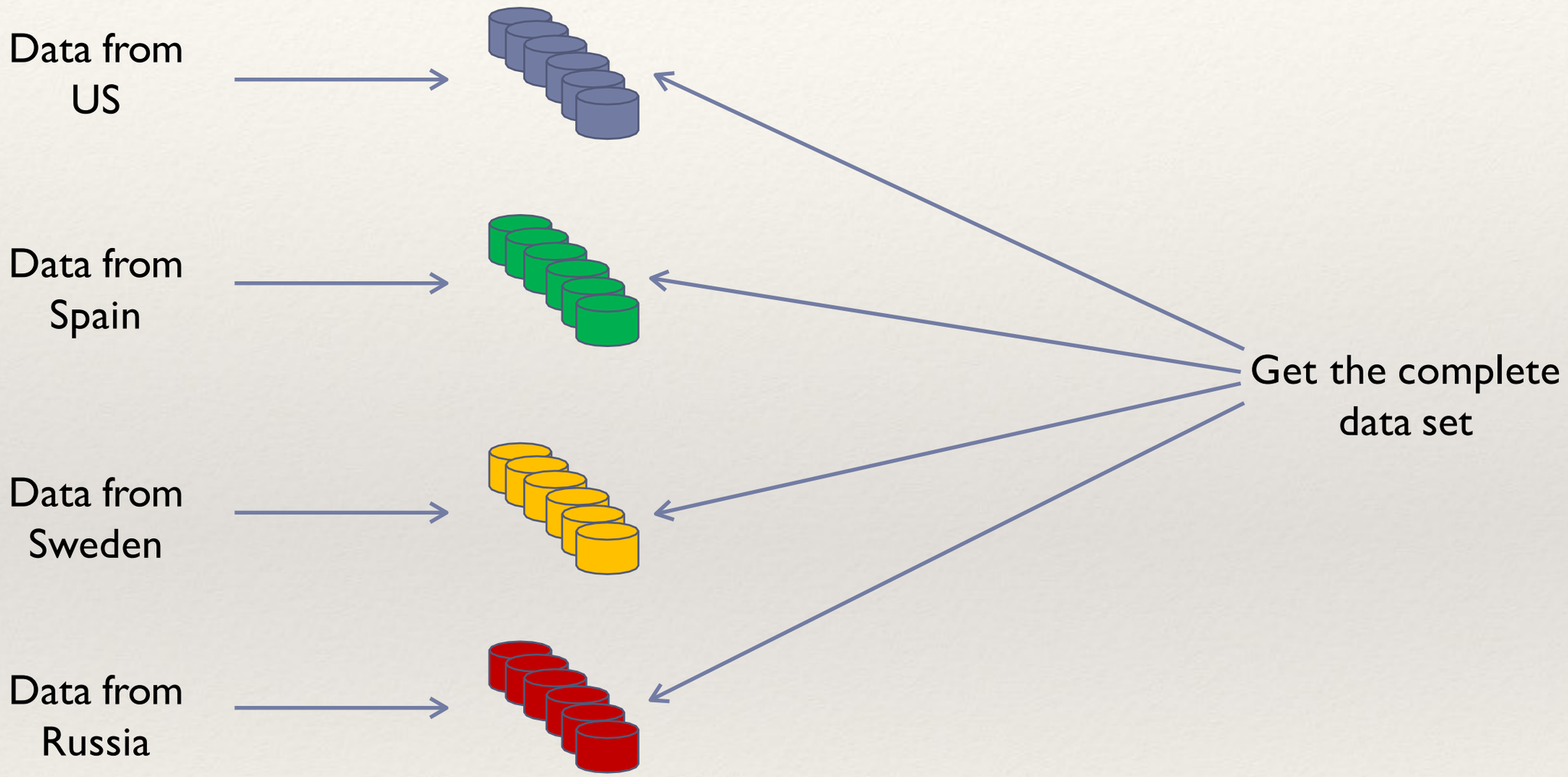

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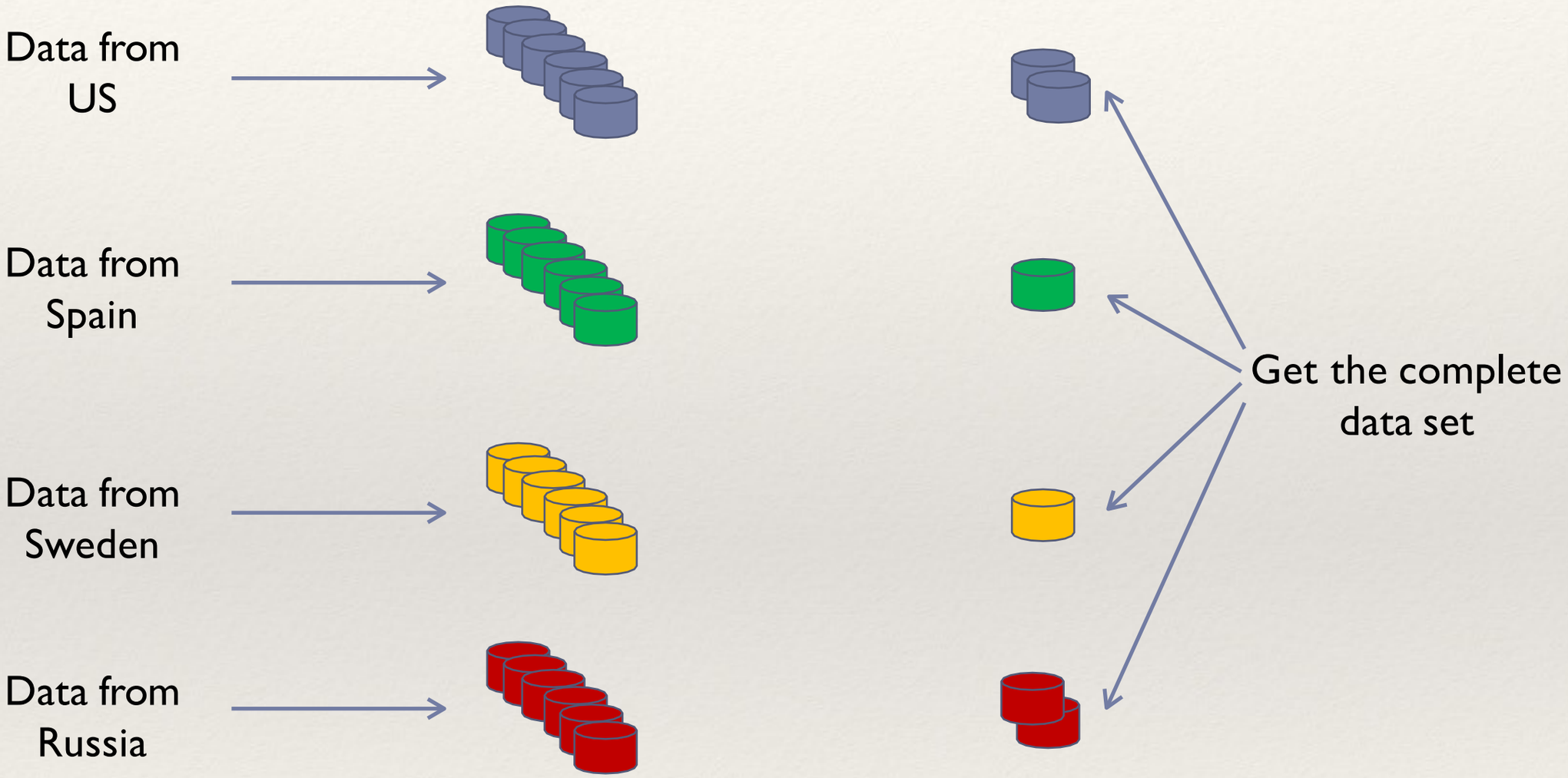
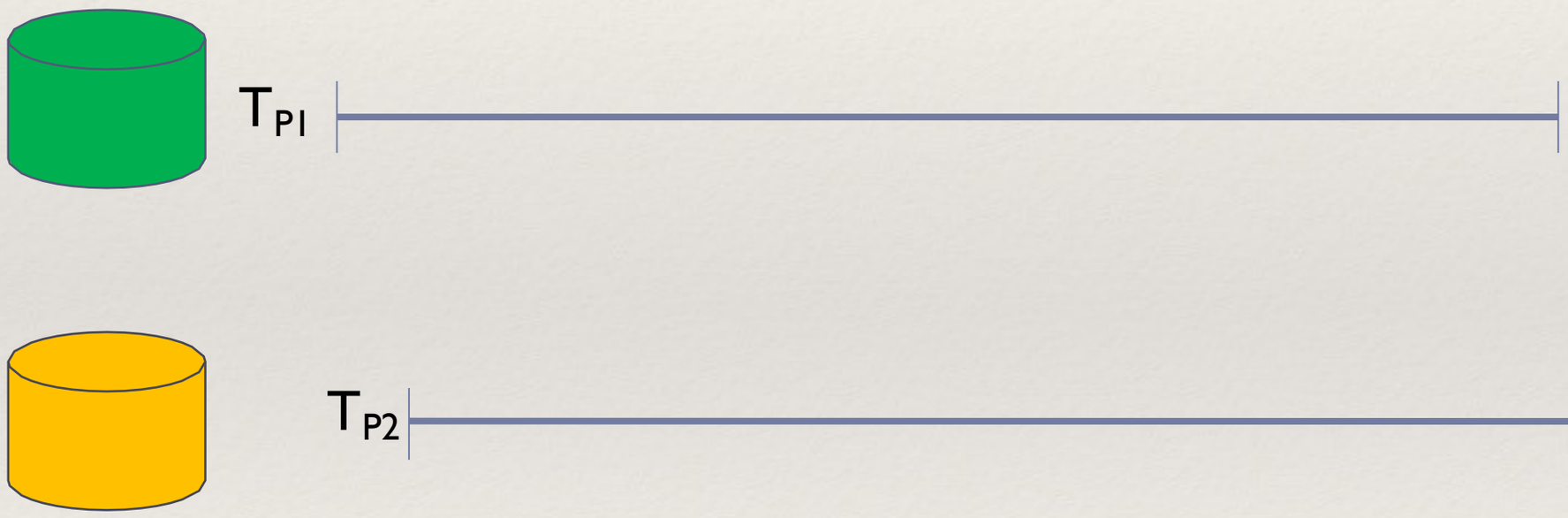


Transaction example



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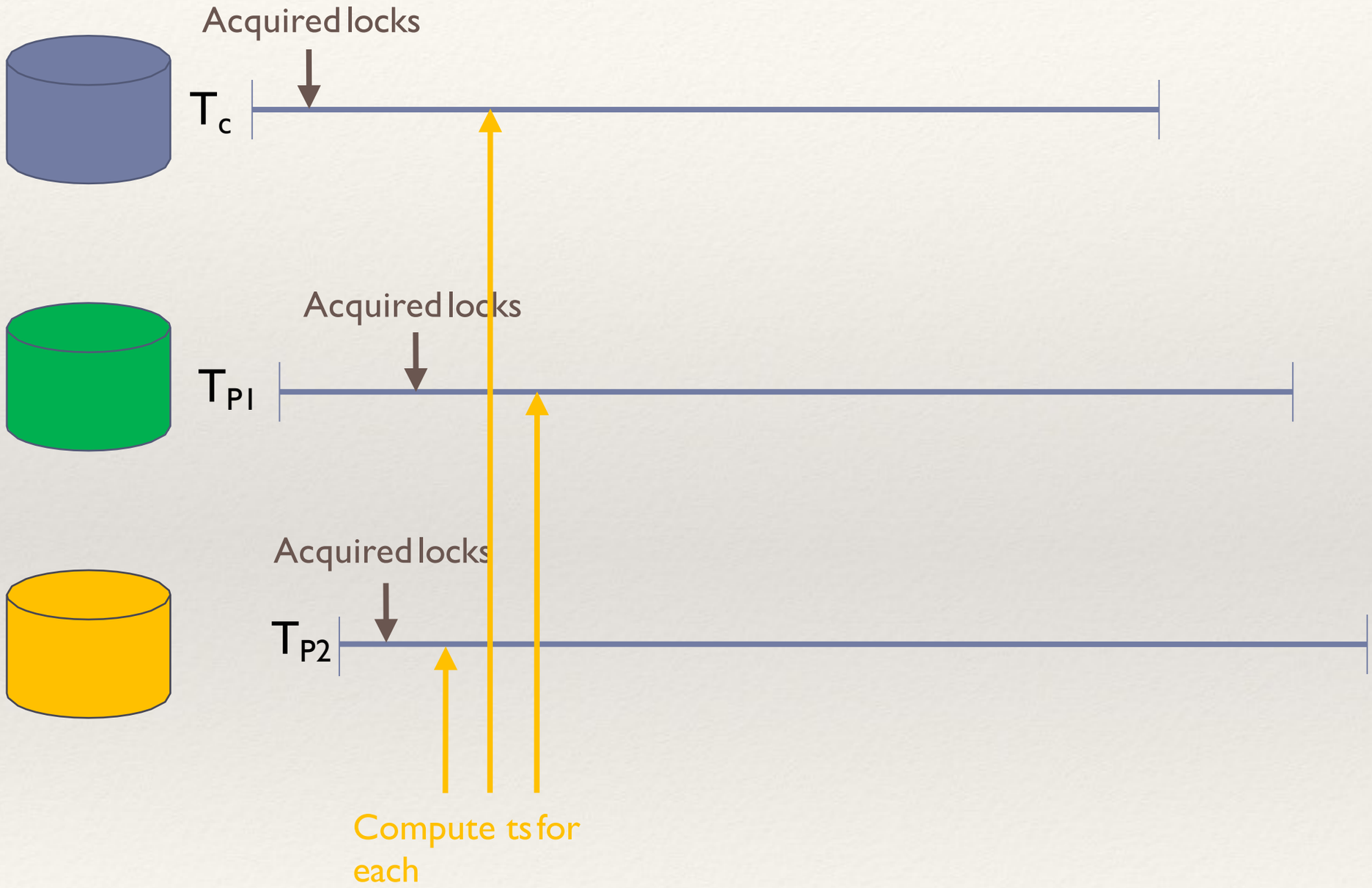

True Time API

- Provides an absolute time denoted as „Global wall-clock time“.
- Has bounded uncertainty ε,which varies between 1 to 7 ms over each poll interval
- Values derived from the worst case local-clock drift scenario

Method	Returns
TT.now()	TTinterval:[earliest, latest]
TT.after(t)	true if t has definitely passed
TT.before(t)	true if t has definitely not arrived

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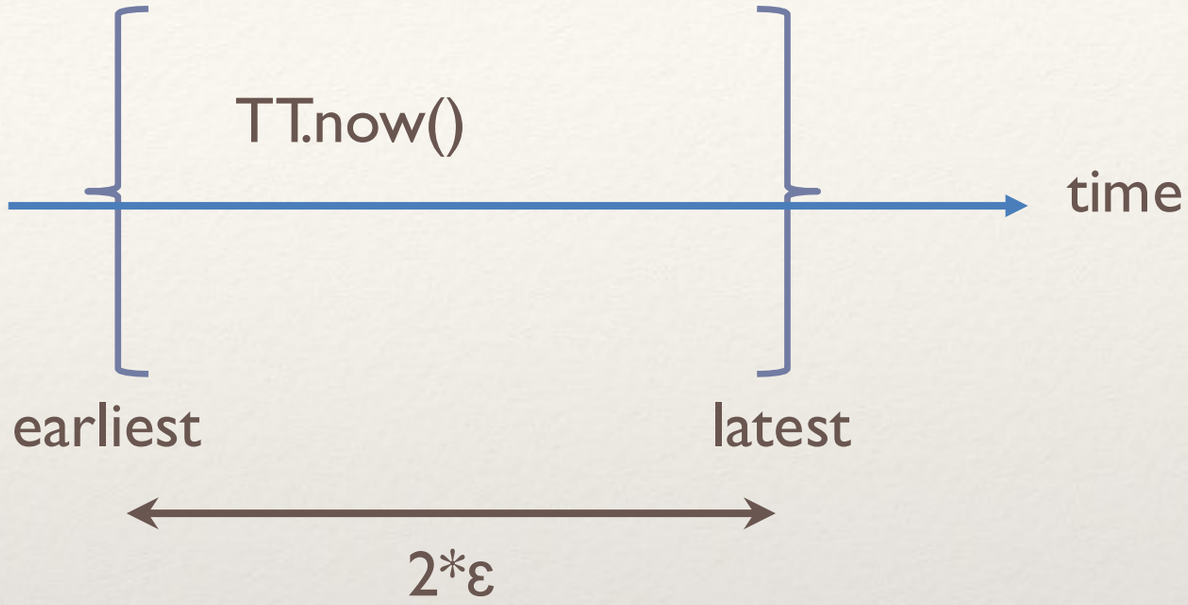

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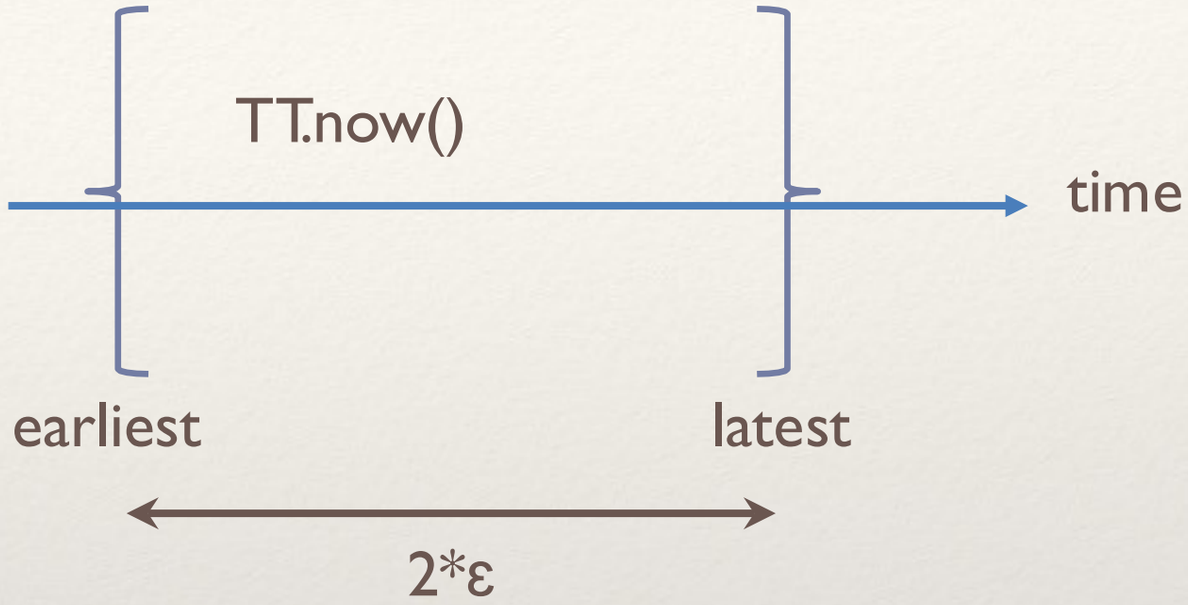
- Values derived from the worst case local-clock drift scenario
- Magic number: 200 µs/s



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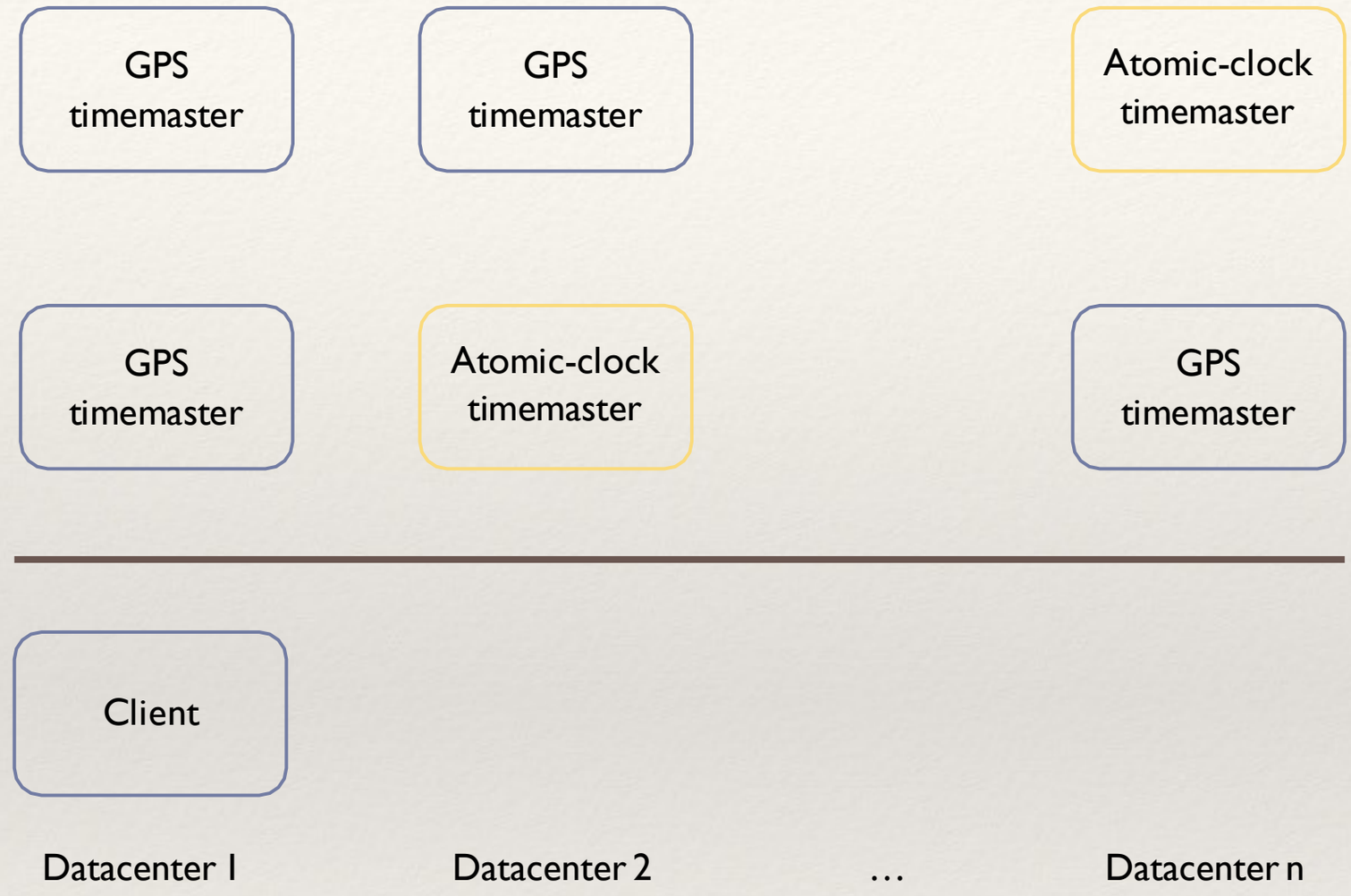
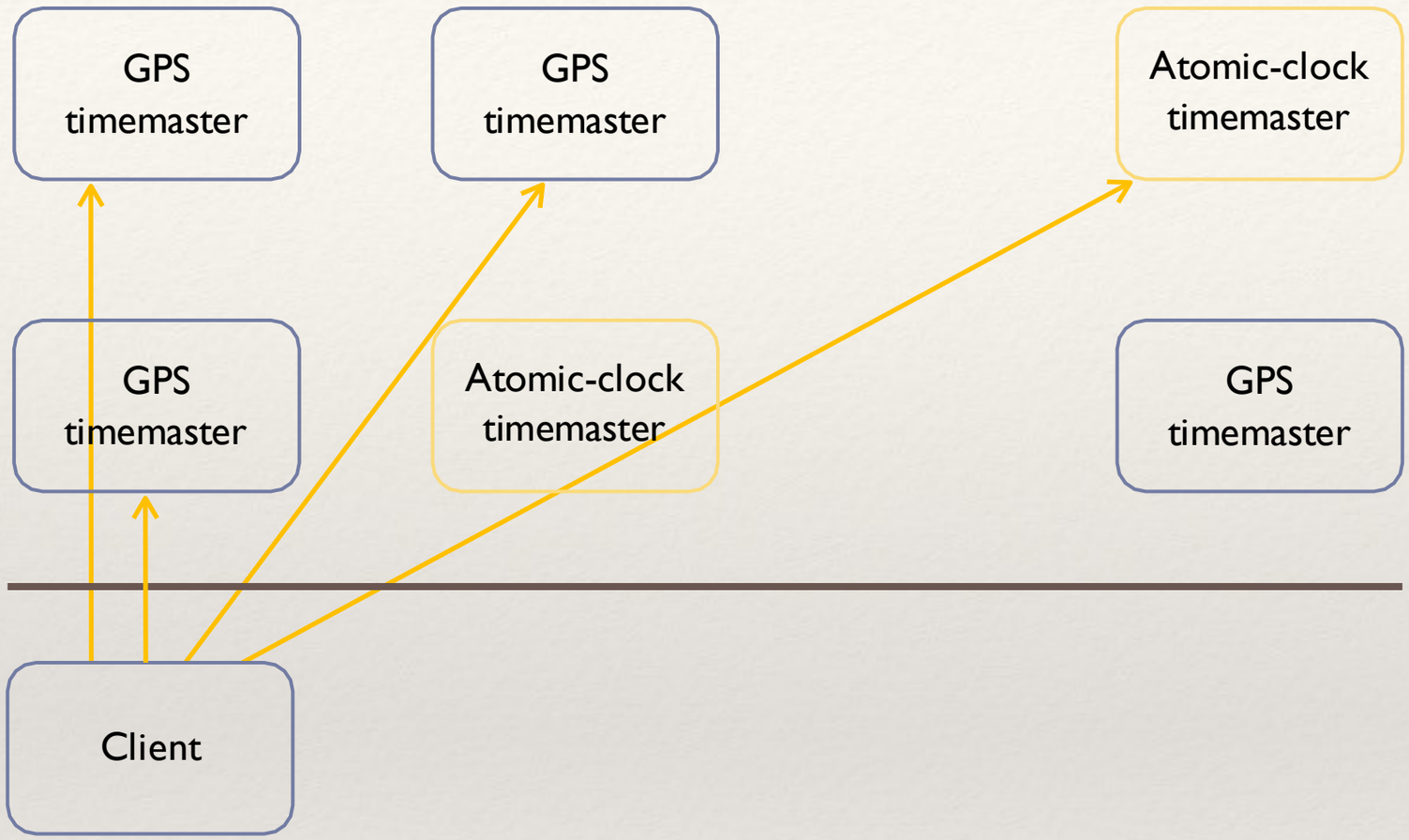
True Time Architecture



now = reference now + local-clock offset

ε = reference ε + worst-case local-clock drift

True Time Architecture



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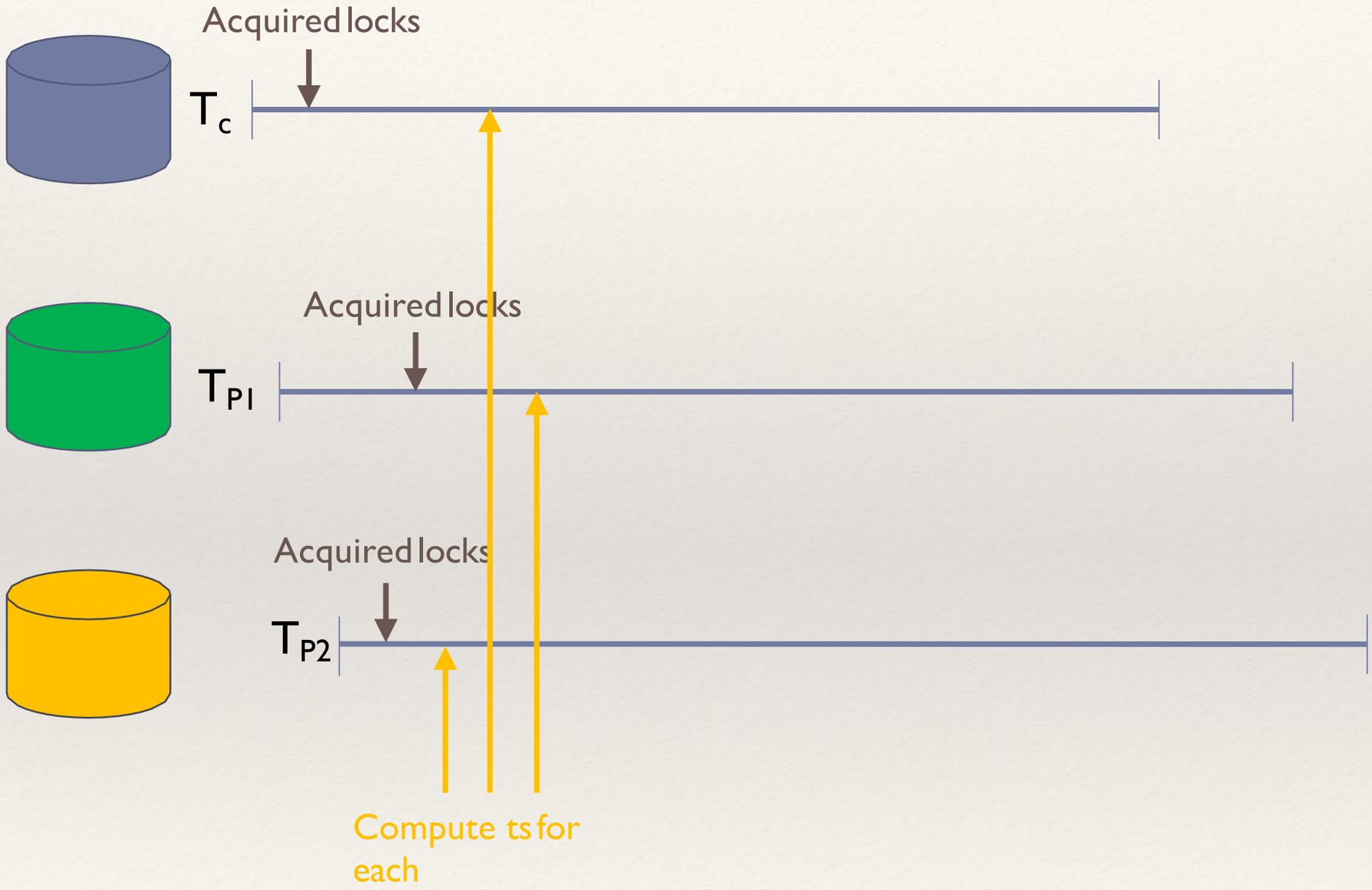
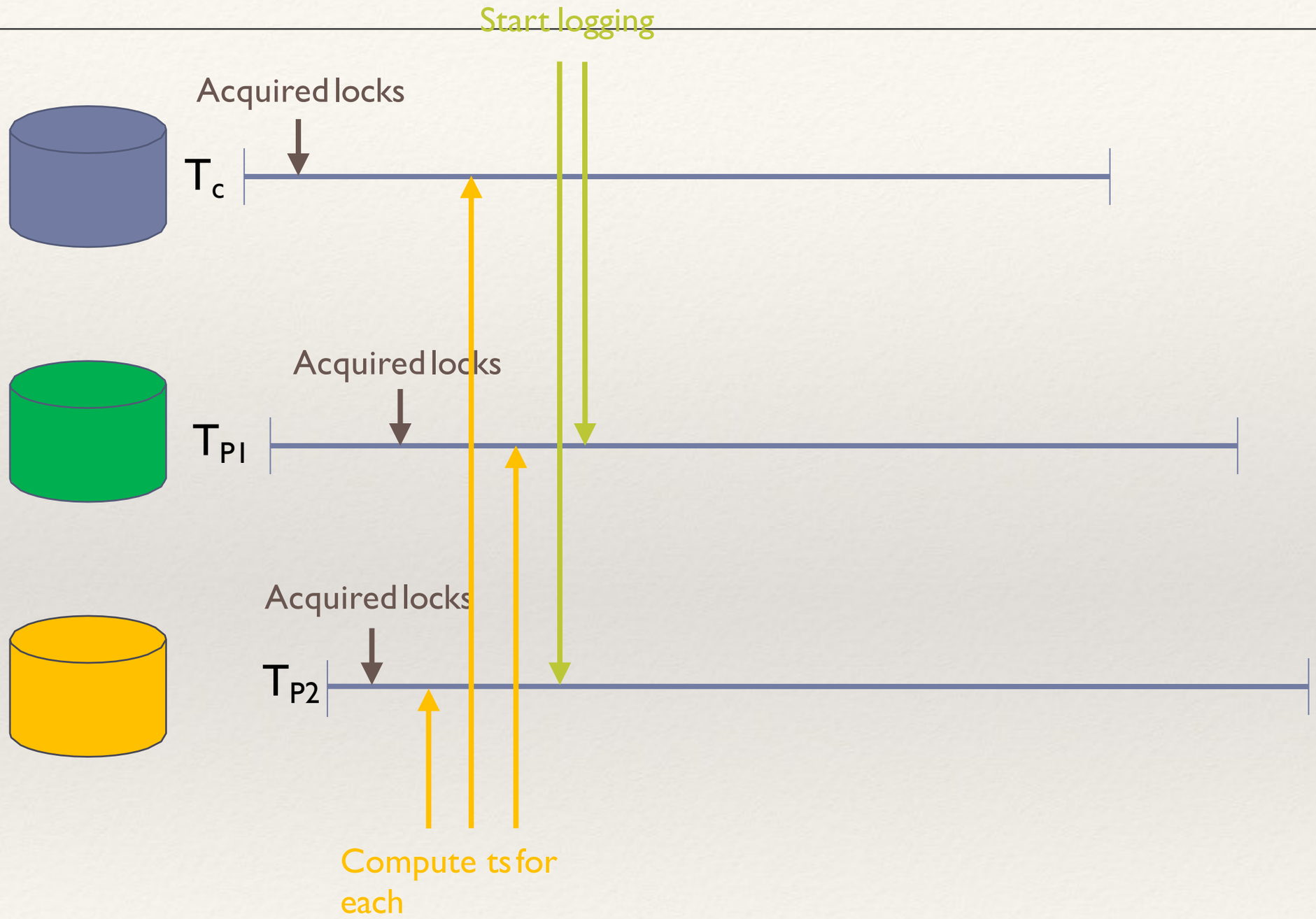
Transaction example

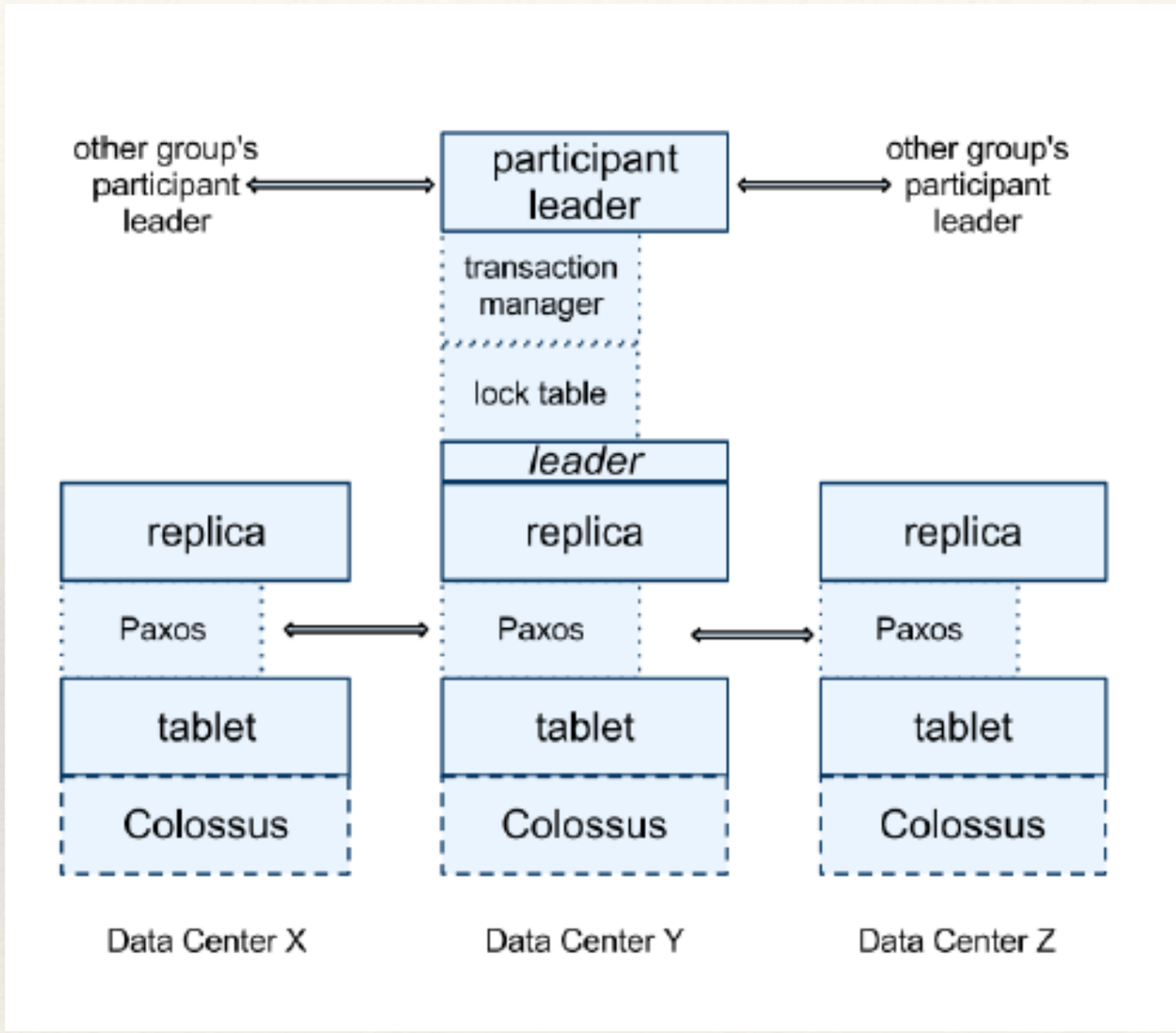


Transaction example



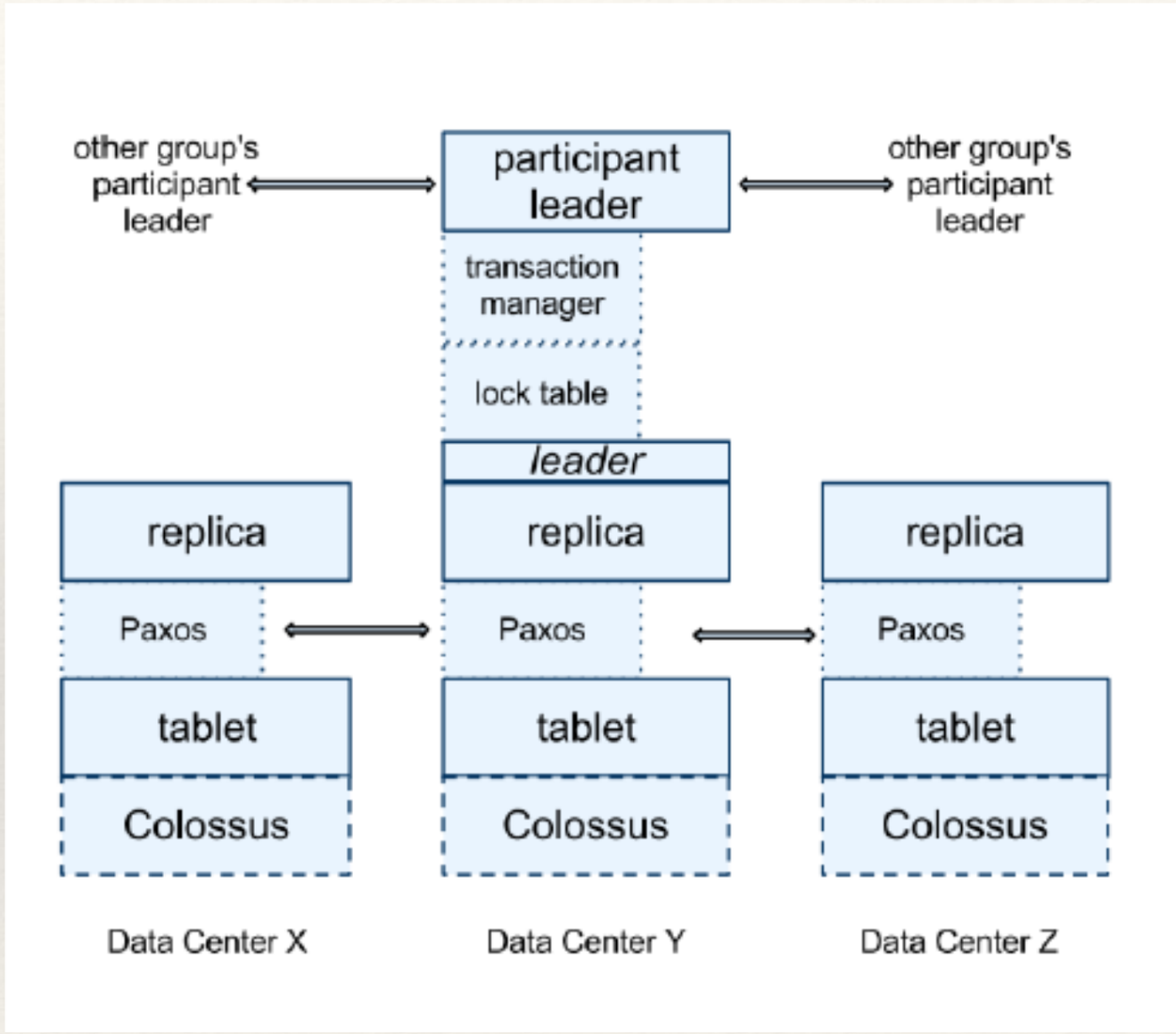
Spanserver software stack

- Tablet implements mappings:
  (key, timestamp) -> string

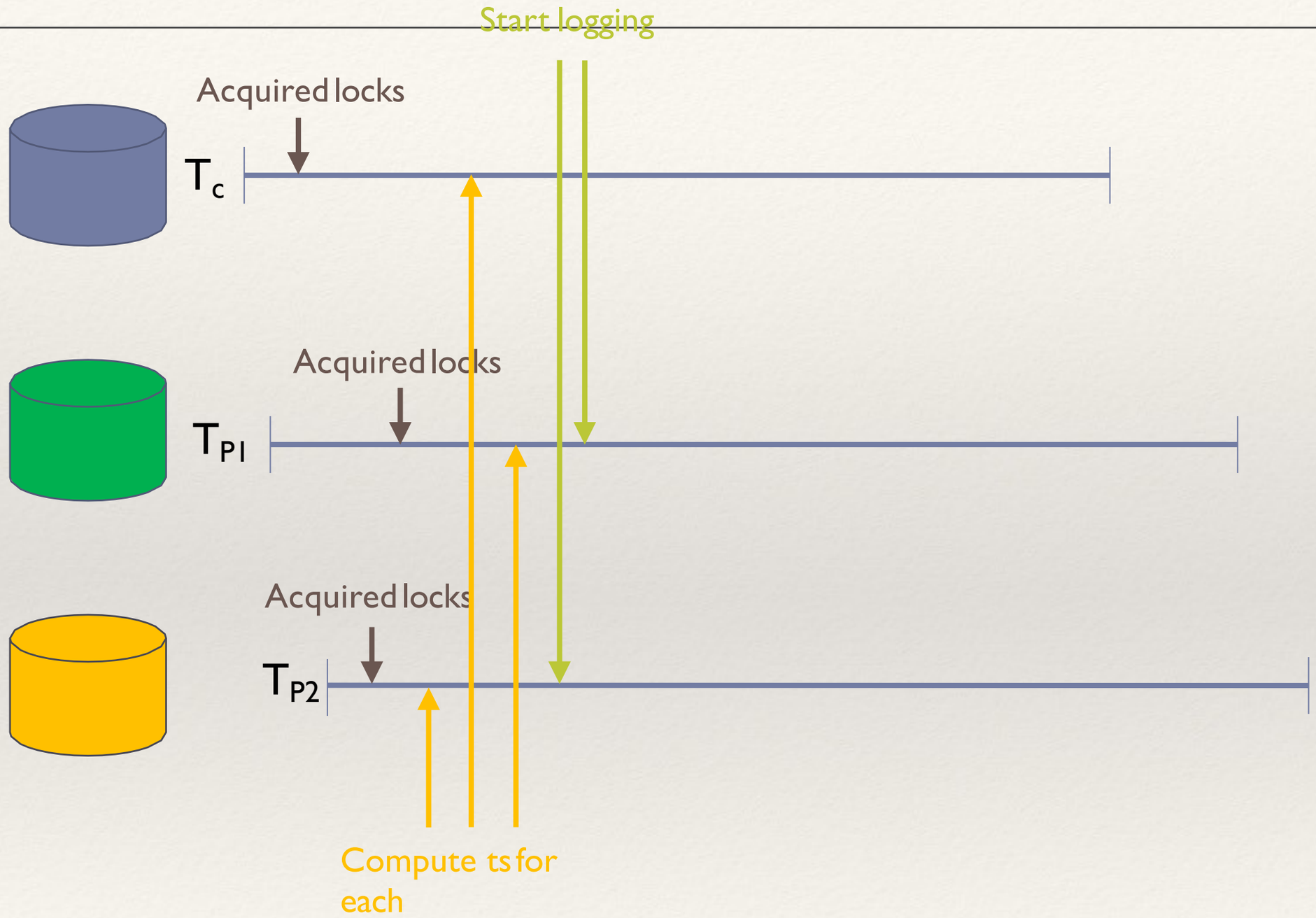


Spanserver software stack

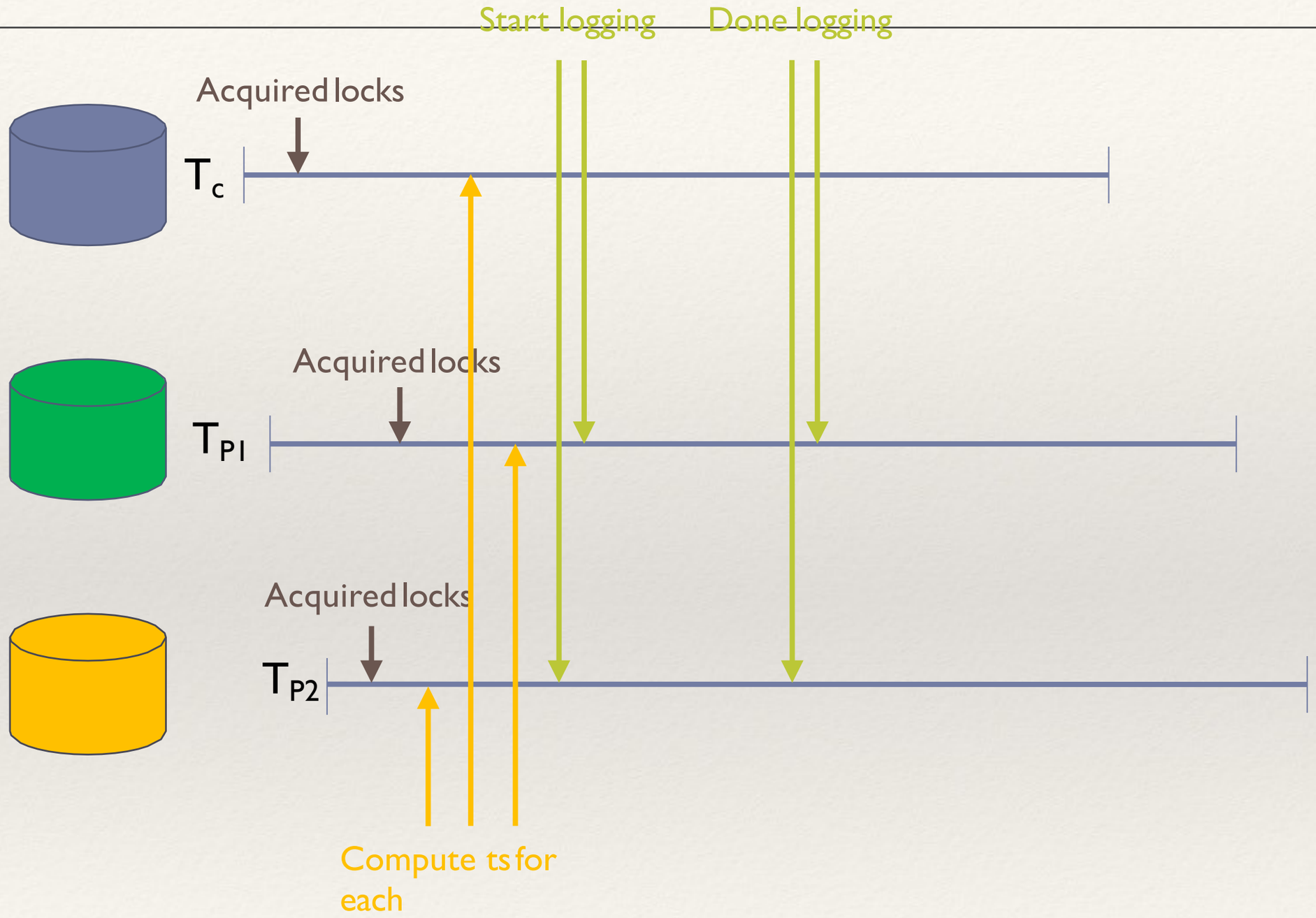
- Tablet implements mappings: (key, timestamp) -> string
- The Paxos state machine for replication support
- Writes initiate the Paxos protocol at the leader
- Focuses on long-lived transactions



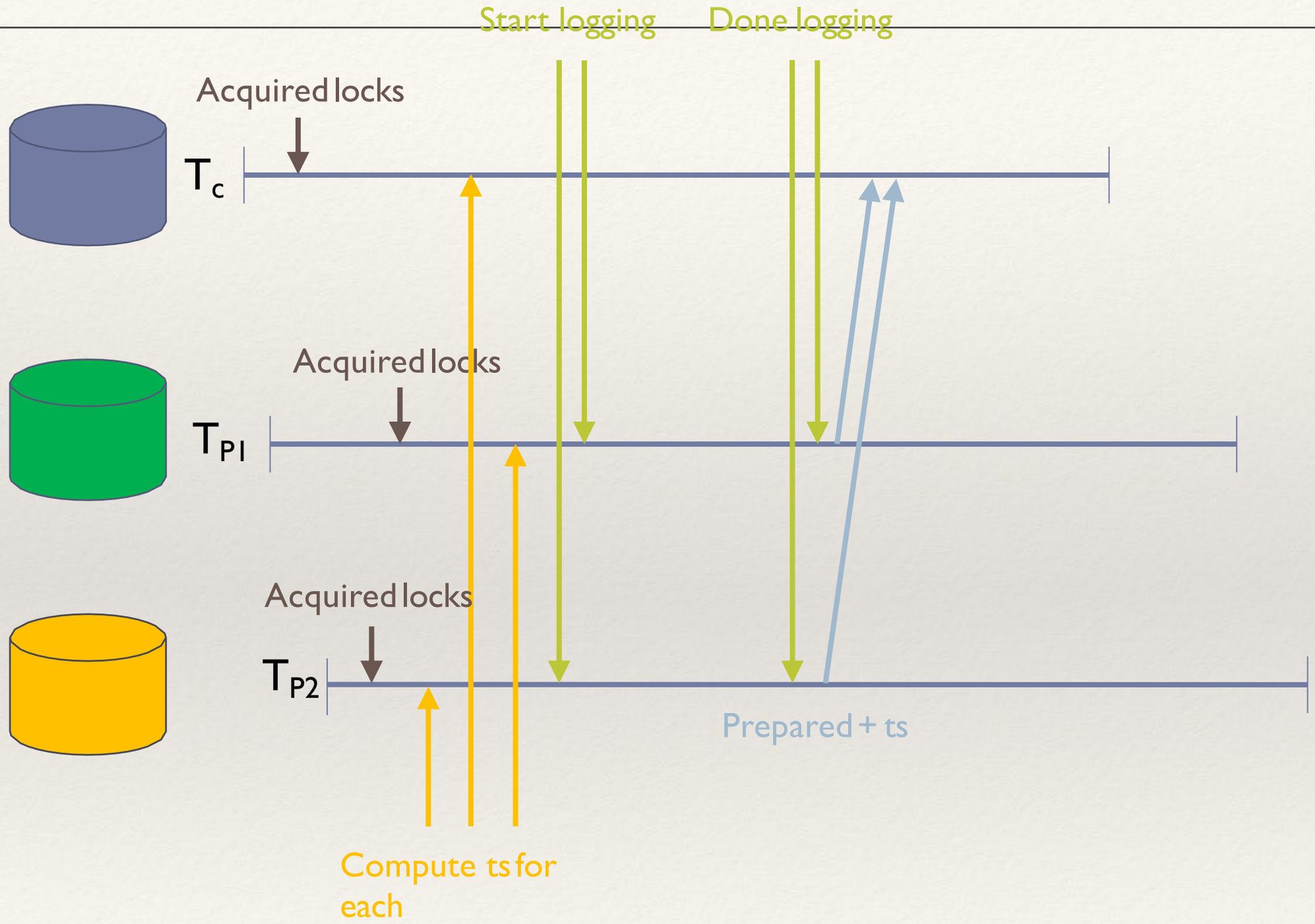
Transaction example



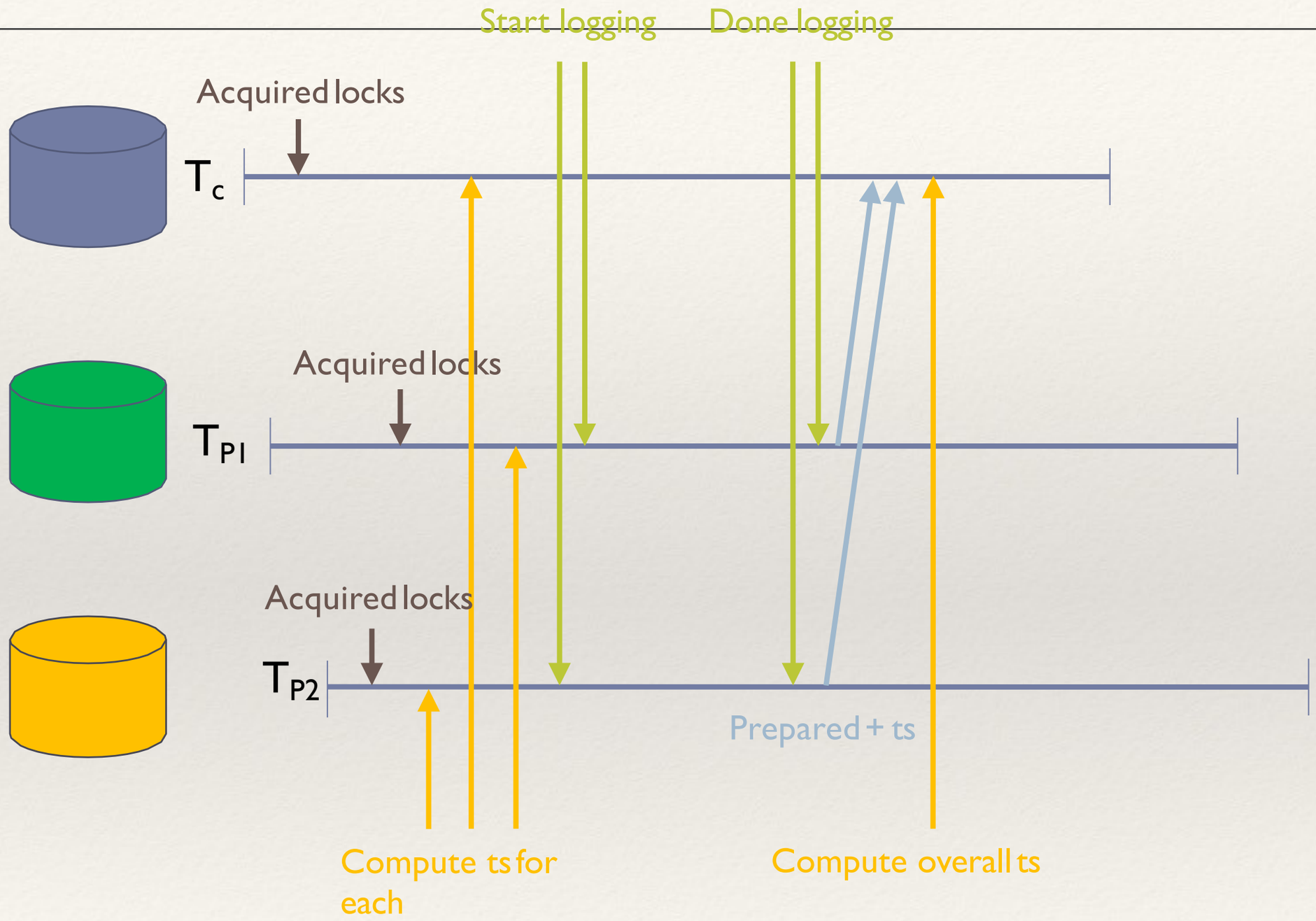
Transaction example



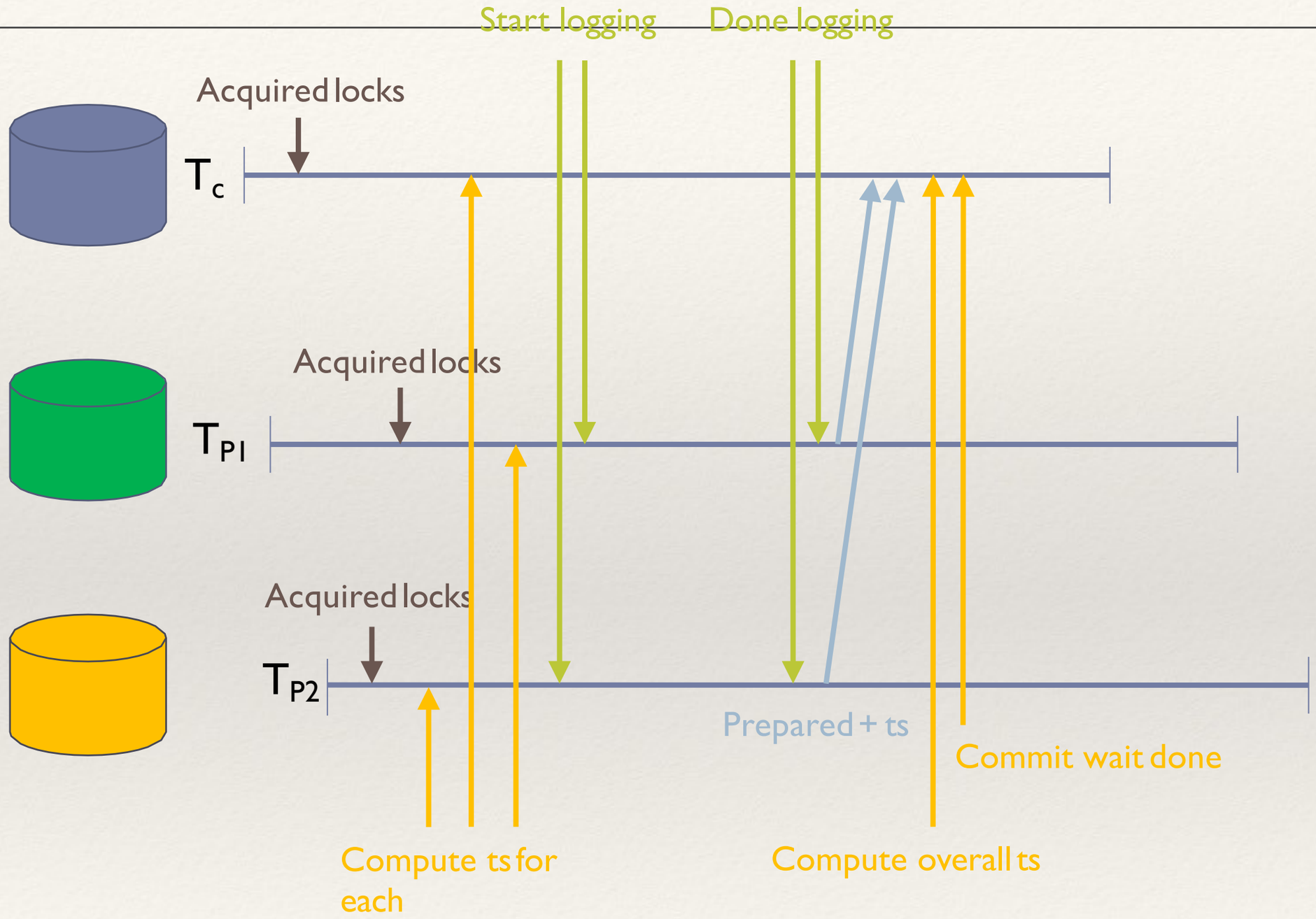
Transaction example



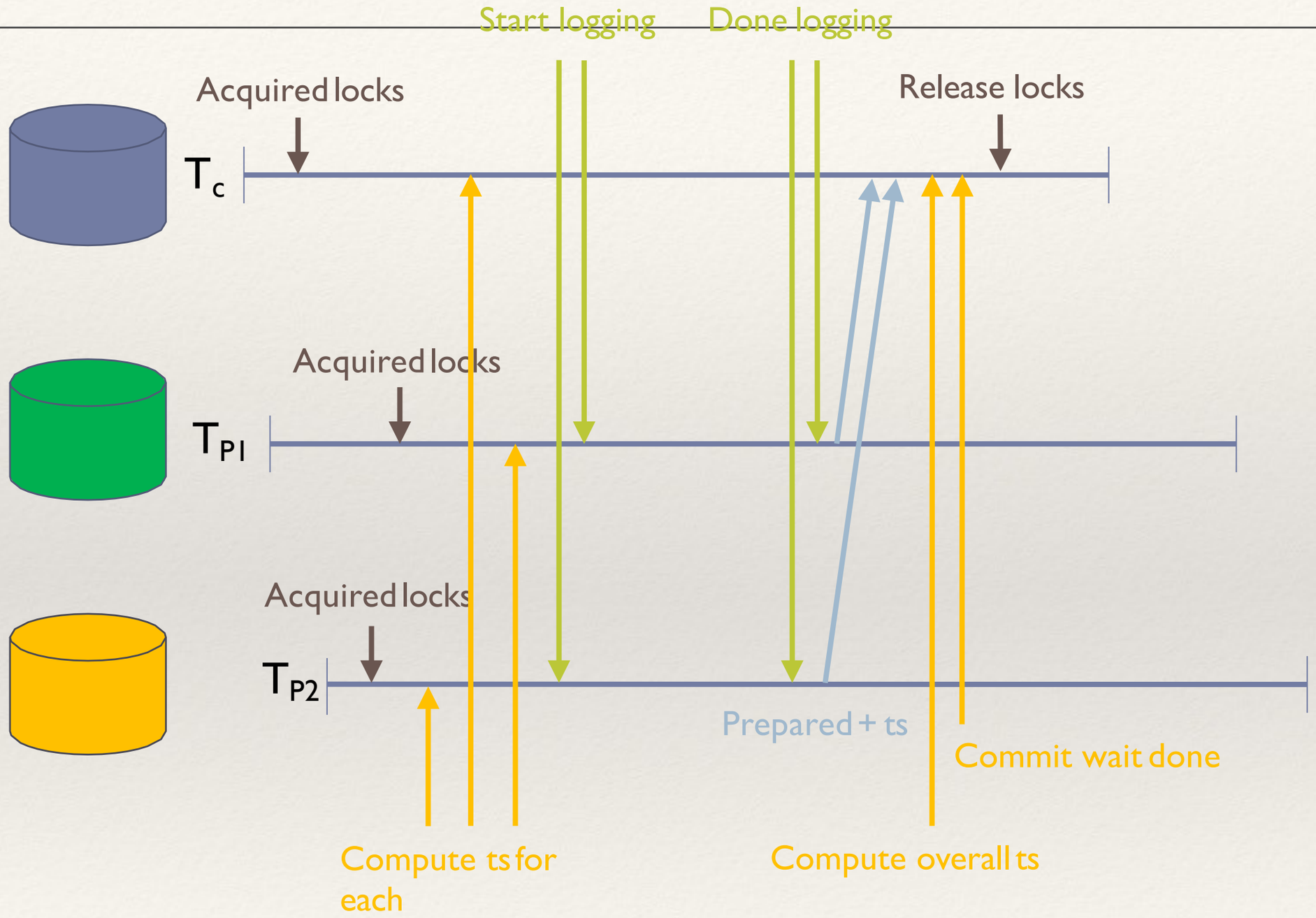
Transaction example



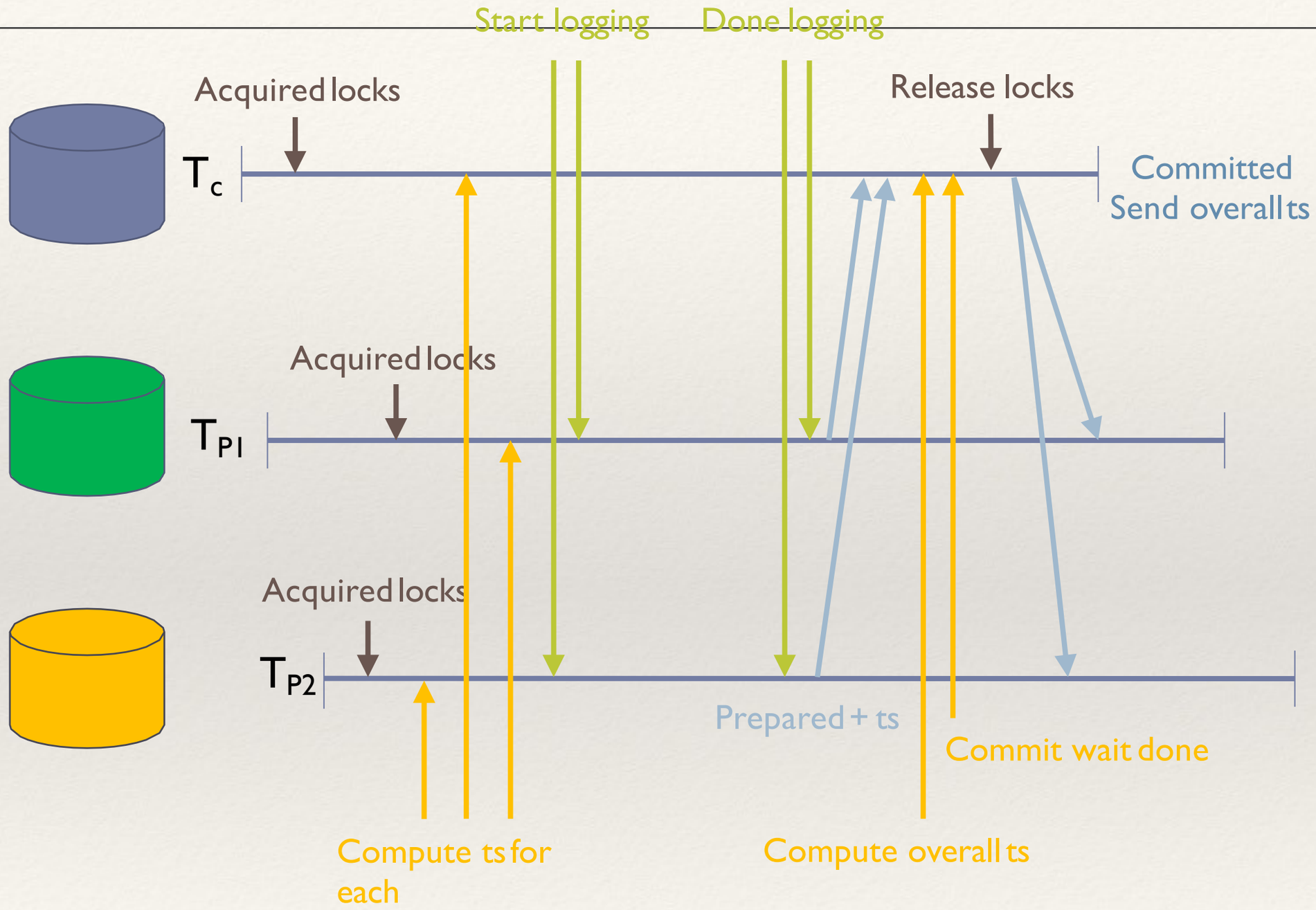
Transaction example



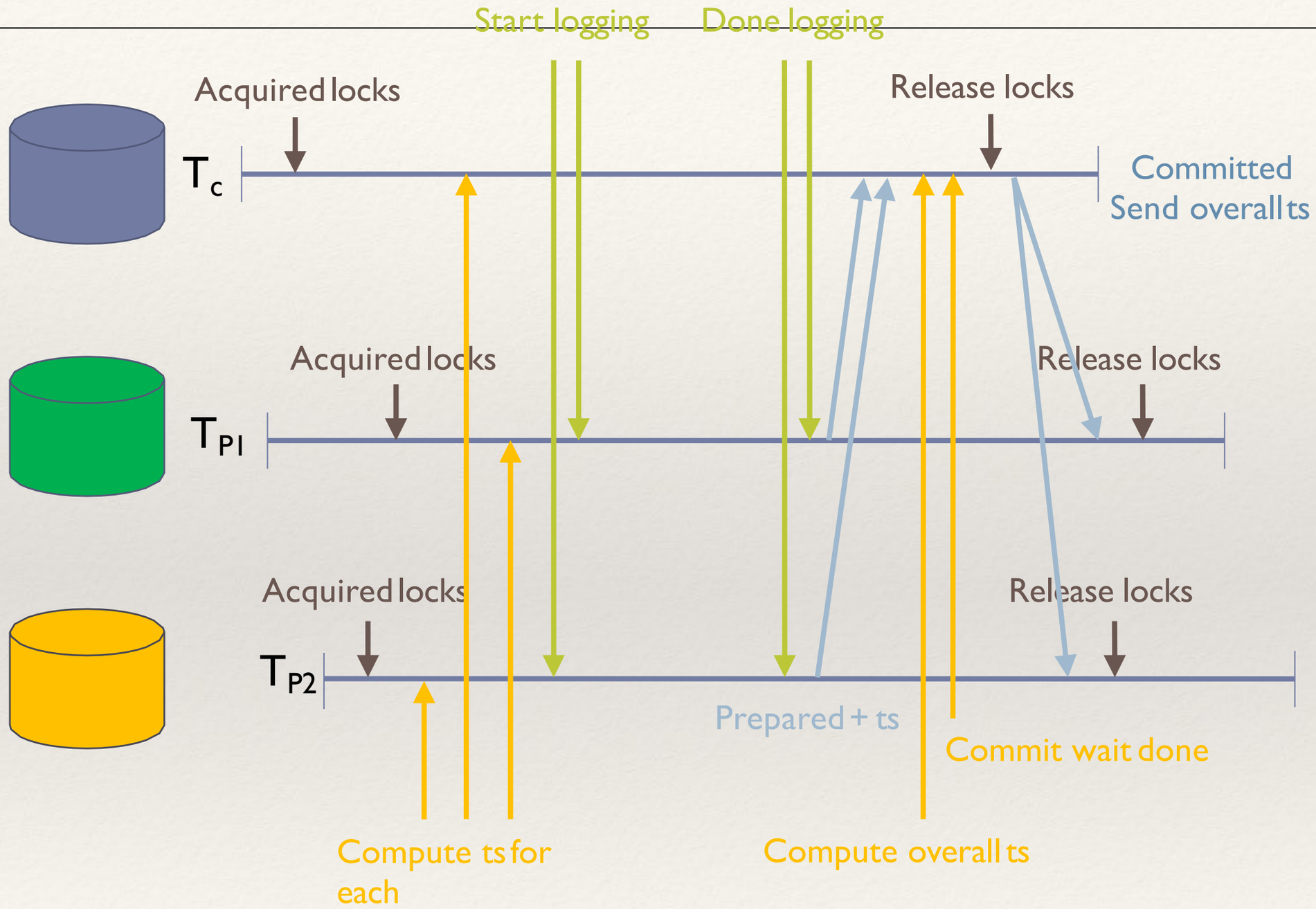
Transaction example



Transaction example



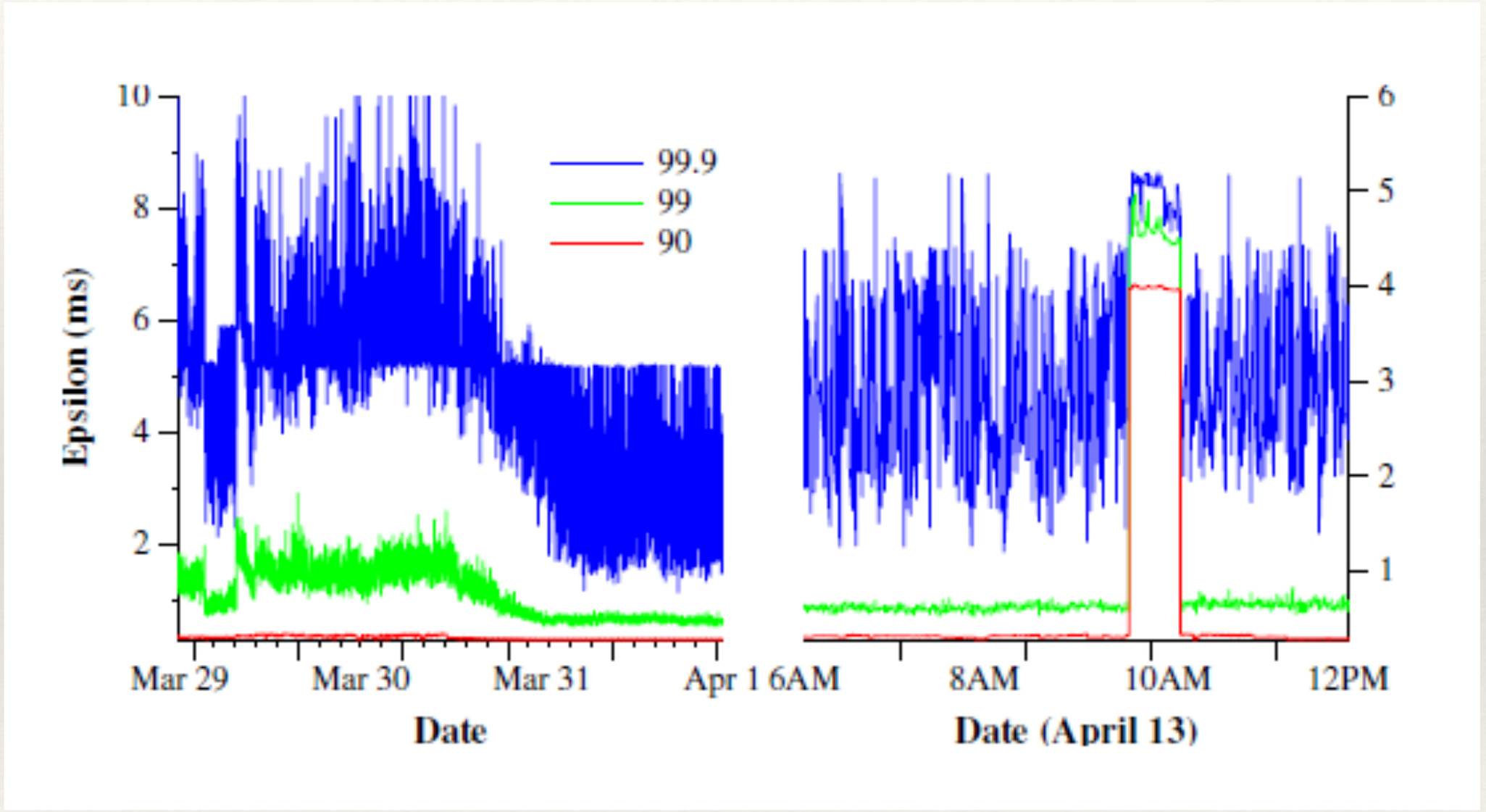
Transaction example



Additional uncovered bits

- Supports atomic schema changes
- Non-blocking snapshot reads in the past
- How to read at the present time
- Paxos protocol restriction
  - Does not support in-Paxos configuration changes

Evaluation: TrueTime uncertainty



Distribution of TrueTime ε values, sampled right after time-slave daemon polls the time masters

Evaluation: F1 study case

# fragments	# directories
1	>100M
2-4	341
5-9	5336
10-14	232
15-99	34
100-500	7

operation	latency (ms)		count
	mean	std dev	
all reads	8,7	376,4	21,5B
single-site commit	72,3	112,8	31,2M
multi-site commit	103,0	52,2	32,1M

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Distribution of directory-fragment counts

Perceived operation latencies (over 24 hour course)

operation	latency (ms)		count
	mean	std dev	
all reads	8,7	376,4	21,5B
single-site commit	72,3	112,8	31,2M
multi-site commit	103,0	52,2	32,1M

Evaluation: Microbenchmarks

replicas	latency (ms)			throughput (Kops/sec)		
	write	read-only transactions	snapshot read	write	read-only transactions	snapshot read
1D	9,4±0,6	-	-	4,0±0,3	-	-
1	14,4±1,0	1,4±0,1	1,3±0,1	4,1±0,05	10,9±0,4	13,5±0,1
3	13,9±0,6	1,3±0,1	1,2±0,1	2,2±0,5	13,8±3,2	38,5±0,3
5	14,4±0,4	1,4±0,05	1,3±0,04	2,8±0,3	25,3±5,2	50,0±1,1

Evaluation: Microbenchmarks

replicas	latency (ms)			throughput (Kops/sec)		
	write	read-only transactions	snapshot read	write	read-only transactions	snapshot read
1D	9,4±0,6	-	-	4,0±0,3	-	-
1	14,4±1,0	1,4±0,1	1,3±0,1	4,1±0,05	10,9±0,4	13,5±0,1
3	13,9±0,6	1,3±0,1	1,2±0,1	2,2±0,5	13,8±3,2	38,5±0,3
5	14,4±0,4	1,4±0,05	1,3±0,04	2,8±0,3	25,3±5,2	50,0±1,1

participants	latency (ms)	
	mean	99th percentile
1	17,0±1,4	75,0±34,9
2	24,5±2,5	87,6±35,9
5	31,5±6,2	104,5±52,2
10	30,0±3,7	95,6±25,4
25	35,5±5,6	100,4±42,7
50	42,7±4,1	93,7±22,9
100	71,4±7,6	131,2±17,6
200	150,5±11,0	320,3±35,1

Conclusion

- The first service to provide global externally consistent multi-version database

- Relies on novel time API (TrueTime)

- Improvements introduced over previous services