# Distributed Systems

## 19. Spanner

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Spanner
(Google's successor to Bigtable … sort of)

# Spanner

**Take Bigtable and add:**

- Familiar SQL-like multi-table, row-column data model
  - One primary key per table
- Synchronous replication (Bigtable was eventually consistent)
- Transactions across arbitrary rows

**Spanner**

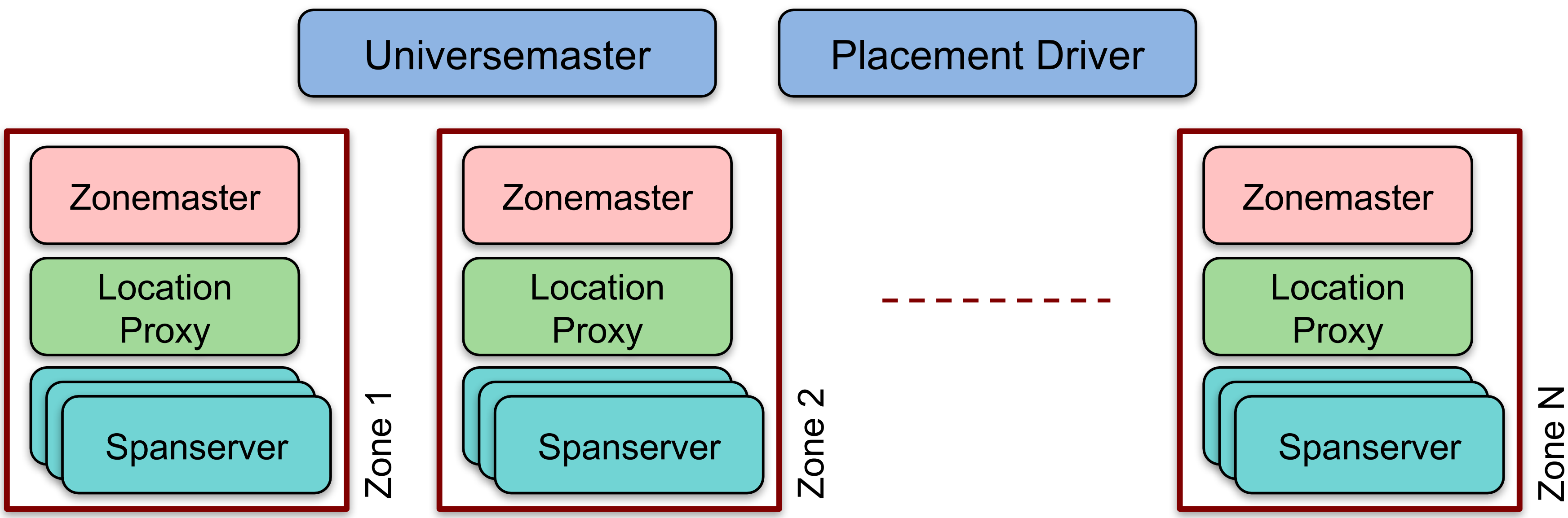
- **Globally distributed multi-version database**
- ACID (general purpose transactions)
- Schematized tables (Semi-relational)
  - Built on top of a key-value based implementation
  - SQL-like queries
- Lock-free distributed read transactions

**Goal: make it easy for programmers to use**

Working with eventual consistency & merging is hard ⇒ don't make developers deal with it

# Data Storage

- Tables sharded across rows into *tablets* (like bigtable)
- Tablets stored in spanservers
- 1000s of spanservers per zone
  - Collection of servers – can be run independently
- Zonemaster allocates data to spanservers
- Location proxies – Used by clients to locate spanservers that hold the data they need
- Universemaster – status of all zones
- Placement driver – transfers data between zones



# Data Storage

- Universe holds 1 or more databases
  - Database holds 1 or more tables
  - Table = arbitrary number of rows and columns
    - Table storage may be interleaved
    - All data in a table has version information (timestamp)
- Shards (tablets) are replicated
  - Synchronous replication via Paxos
- Transactions across shards use 2-phase commit
- Directory = set of contiguous keys
  - Unit of data allocation
  - Granularity for data movement between Paxos groups
    - Done in background

# Transactions

- ACID properties
- Transactions are serialized: strict 2-phase locking used

1. Acquire all locks

   – *do work* –

2. **Get a commit timestamp**
3. Log the commit timestamp via Paxos to majority of replicas
4. Do the commit
   - Apply changes locally & to replicas
5. Release locks

# 2-Phase locking can be slow

We can use *read locks* and *write locks*

But

- *read locks* block behind *write locks*
- *write locks* block behind *read locks*

Multiversion concurrency to the rescue!

- Take a snapshot of the database for transactions up to a point in time
- You can read old data without getting a lock
  - Great for long-running reads (e.g., searches)
- Because you are reading before a specific point in time
  - Results are consistent

We need ***commit timestamps*** that will enable meaningful snapshots

# Getting good commit timestamps

- Vector clocks work
  - Pass along current server's notion of time with each message
  - Receiver updates its concept of time (if necessary)

- But not feasible in large systems
  - Pain in HTML (have to embed vector timestamp in HTTP transaction)
  - Doesn't work if you introduce things like phone call logs

- **Spanner: use physical timestamps**
  - If $T_1$ commits before $T_2$, $T_1$ *<u>must</u>* get a smaller timestamp
  - Commit order matches global wall-time order

# TrueTime

Remember: we can't know global time across servers!

- **Global wall-clock time** = time + interval of uncertainty
  - TT.now().earliest = time guaranteed to be <= current time
  - TT.now().latest = time guaranteed to be >= current time

- Each data center has a GPS receiver & atomic clock
- Atomic clock synchronized with GPS receivers
  - Validates GPS receivers
- Spanservers periodically synchronize with time servers
  - Know uncertainty based on interval
  - Synchronize ~ every 30 seconds: clock uncertainty < 10 ms

# Commit Wait

We don't know the *exact* time

… but we can wait out the uncertainty

average worst-case wait is ~10 ms

1. Acquire all locks

   *– do work –*

2. Get a commit timestamp: t = TT.now().latest
3. **Commit wait**: wait until TT.now().earliest > t
4. Commit
5. Release locks

# Integrate replication with concurrency control

1. Acquire all locks

   *– do work –*

2. Get a commit timestamp: t = TT.now().latest
3. (a) Start consensus for replication
   (b) Commit wait (in parallel)

   **Make the replicas & wait for all to finish**

4. Commit
5. Release locks

# Spanner Summary

- Semi-relational database of tables
  - Supports externally consistent distributed transactions
  - No need for users to try deal with eventual consistency
- Multi-version database
- Synchronous replication
- Scales to millions of machines in hundreds of data centers
- SQL-based query language

- Used in F1, the system behind Google's Adwords platform
- May be used in Gmail & Google search

# Spanner Conclusion

- ACID semantics not sacrificed
  - Life gets easy for programmers
  - Programmers don't need to deal with eventual consistency
- Wide-area distributed transactions built-in
  - Bigtable did not support distributed transactions
  - Programmers had to write their own
  - Easier if programmers don't have to get 2PC right
- Clock uncertainty is known to programmers
  - You can wait it out

# The end