**Motivation**
- Distributed data stores support complex online applications
  - e.g. social networks
- Response times affect revenue
  - Low latency storage (<10ms) needed
- Massive scalability needed
- Data is “big”
- Make system more useful
  - Causal Consistency
  - Richer Data Model
  - Read-only Transactions
  - Write-only Transactions

**Richer Data Model**
- Column-family data model
  - Map of maps of maps of columns
- Batch mutate / Multiget Slice
  - Writes / reads columns from many keys
  - Key technique for causal consistency:
    - Deps on operations not values
- Counter Columns keep a commutatively updated integer
  - e.g. Like count

**Write-Only Transactions**
- Atomically write many columns across many keys in local datacenter
- Appear atomically (in causal order) in remote datacenters
- Guarantees low latency
  - At most 2.5 local RTTs to complete
  - No locks

**Read-Only Transactions**
- Consistent view of many columns across many keys
- Guarantees low latency
  - At most 3 local RTTs to complete
  - Normally only 1 local RTT to complete
- Use logical time metadata to ensure consistency

**Causal Consistency**
- Related ops appear in the correct order
- Track with dependencies on previous ops

**Evaluation**
- Competitive with eventually-consistent and transaction-free Cassandra
- Write transactions are competitive with non-transactional batch updates

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**Geo Replication**

**Data Store**

**Web Tier**

**Causal Consistency**

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- Track with dependencies on previous ops

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**Cohorts**

**Coordinator**

**Client**

**Datacenter Accepting**

**Remote Datacenter**

**Logical Time**

**Causality Graph**

**Dependency Graph**