CS 138: Dynamo

Dynamo

- Highly available and scalable distributed data store
- Manages state of services that have high reliability and performance requirements
  - best-seller lists
  - shopping carts
  - customer preferences
  - session management
  - sales rank
  - product catalog

Background

- Amazon e-commerce platform
  - hundreds of services
    - from recommendations to fraud detection
  - tens of thousands of servers
    - across many data centers worldwide
- RDBMS?
  - no …
  - don't need complex queries
  - RDBMS replication strategies are inefficient
- Simple queries
  - key/value pairs (blobs), < 1MB

Transactions at Amazon

- ACID properties
  - atomicity ✓
    - pretty important
  - consistency 
    - weak is good …
  - isolation X
    - forget it …
  - durability ✓
    - pretty important

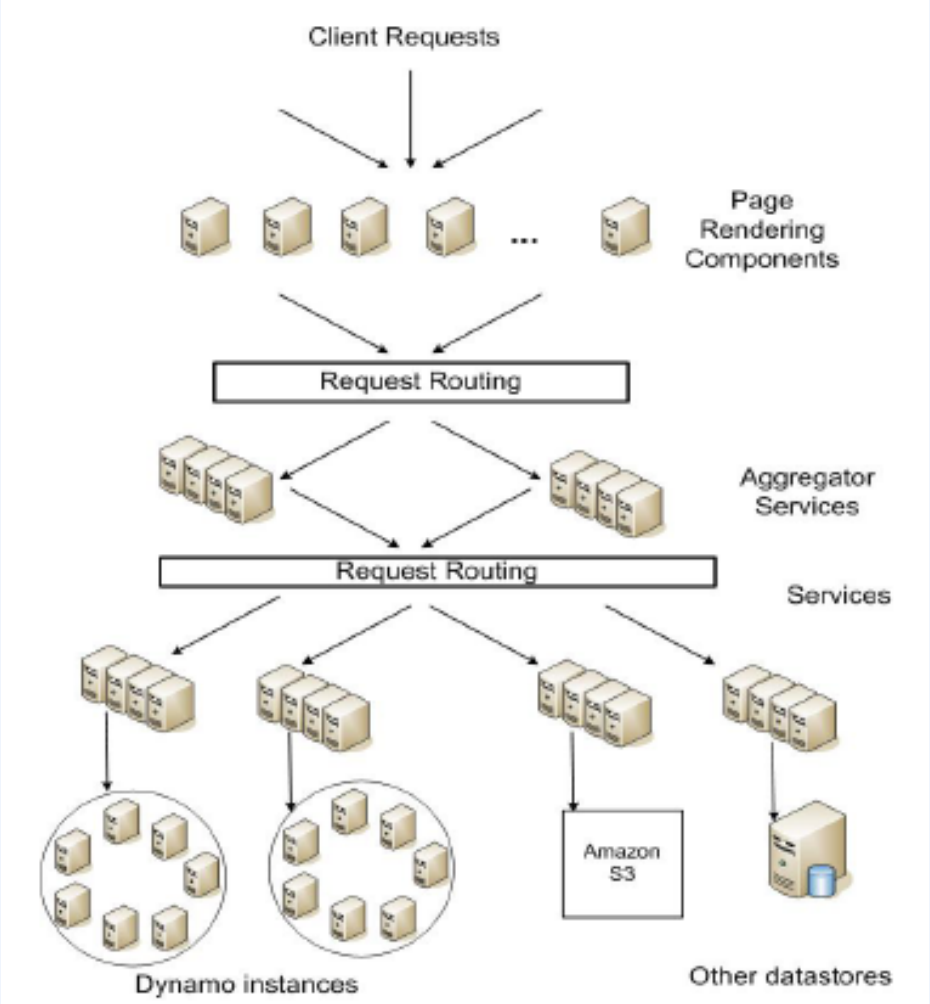
Efficiency

- Strict latency requirements for services
  - measured at 99.9th percentile
- Typical request to put together a page requires responses from 150 services
- Services rely on dynamo for storage

Service-Level Agreements

- Contract between client and server
- Example
  - provide a response within 300 ms for 99.9% of its requests at a peak load of 500 requests/sec
- Requires *admission control*
  - not discussed

Amazon Architecture



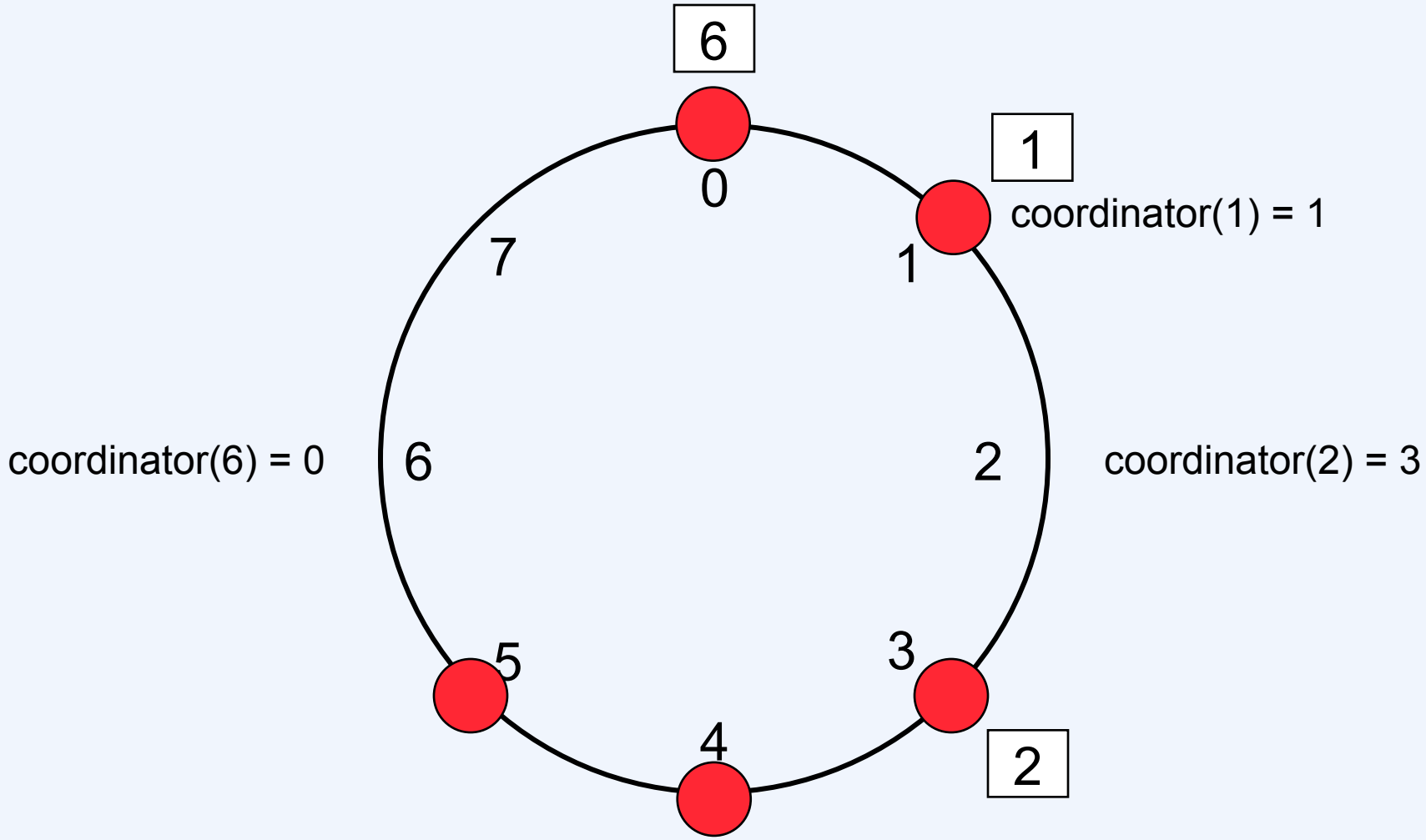
Design Considerations

- Replication important for durability and availability
- Tradeoff between consistency and performance
  - writes should never be delayed
  - reads should return quickly, despite possible inconsistencies

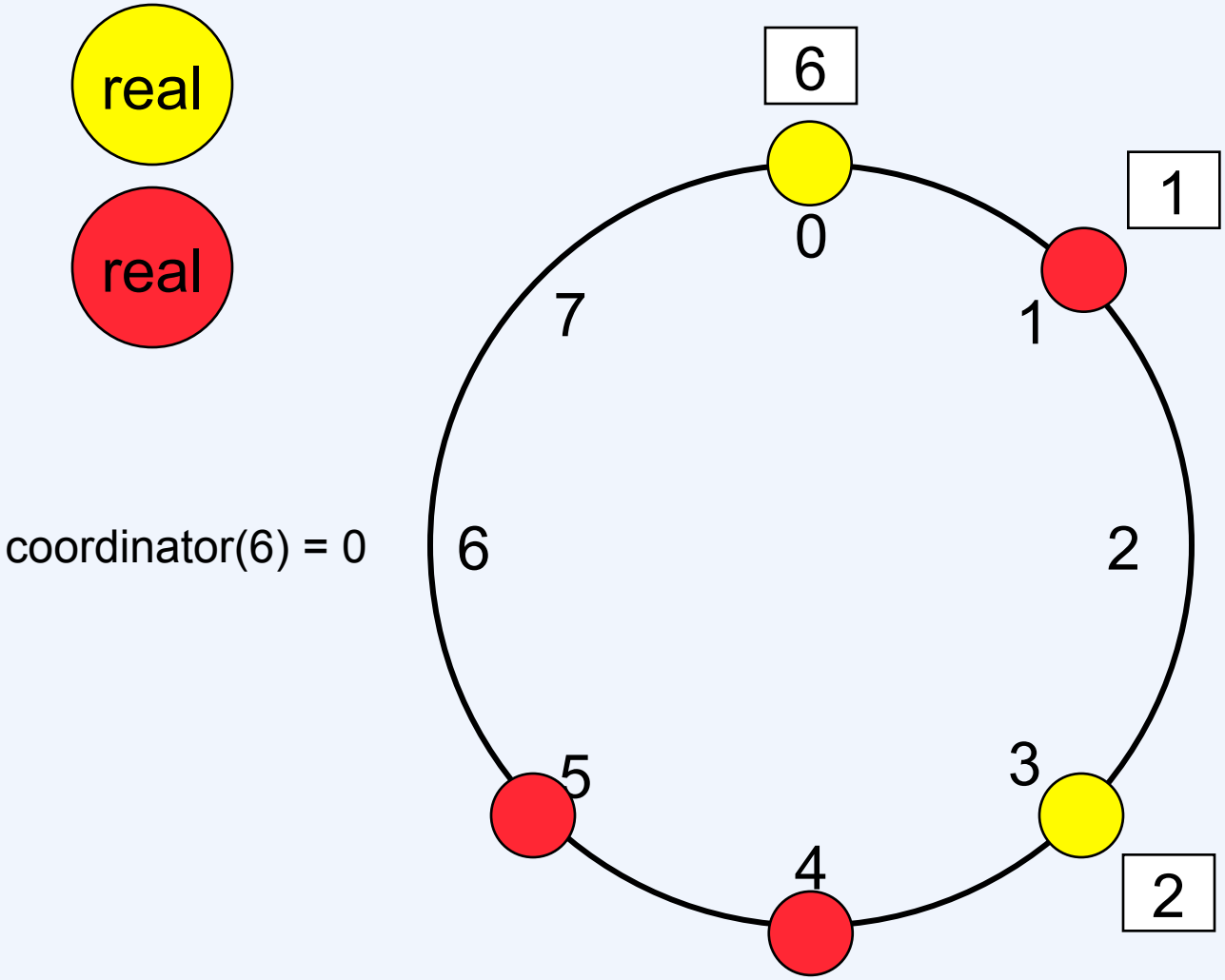
Assigning Data to Nodes

- Consistent hashing (as in Chord)
  - no finger tables
  - each node knows the complete assignment
- Issues
  - replication
  - coping with nodes of varying performance

Consistent Hashing



Virtual Nodes



coordinator(6) = 0

Adding and Deleting Nodes

- Without virtual nodes (e.g., Chord)
  - added nodes acquire objects only from successors
  - deleted nodes give objects only to successors
- With (randomly distributed) virtual nodes
  - added nodes acquire objects uniformly distributed
  - deleted nodes give objects to uniformly distributed others

Replication

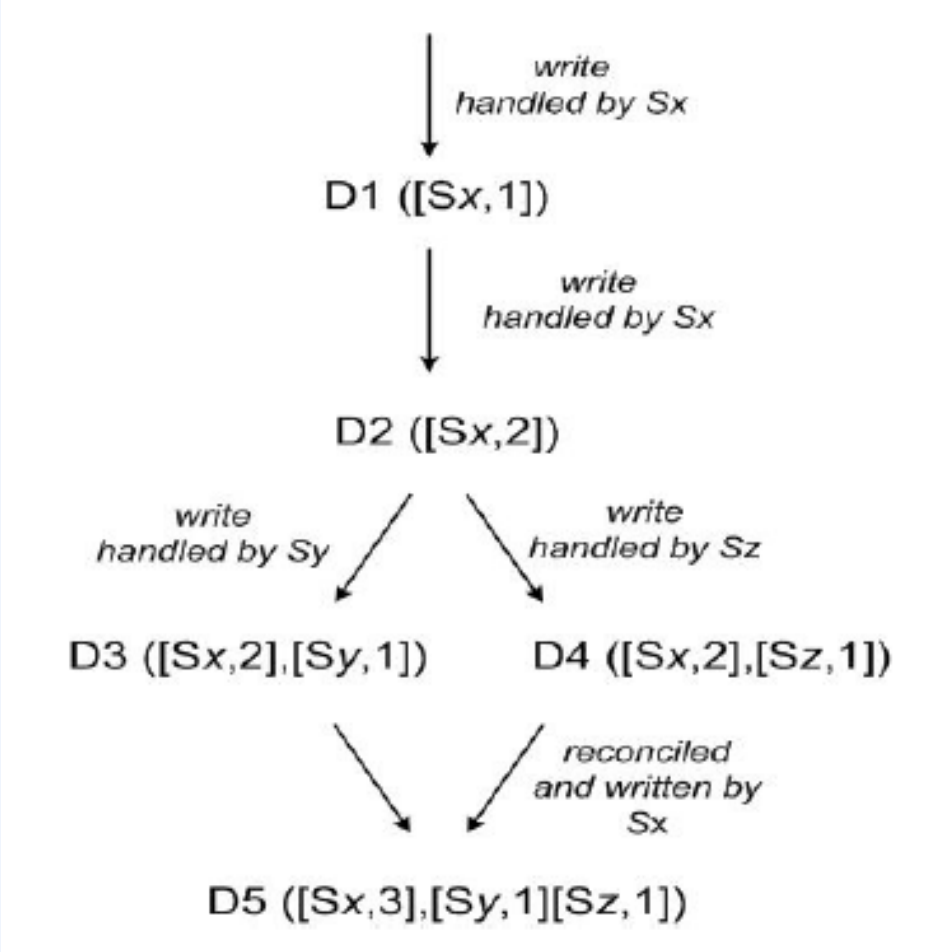
- Each key assigned to coordinator node
  - via DHT
- Coordinator replicates data items at n-1 other nodes
  - n is an application parameter
  - next n-1 distinct real nodes on ring
- Set of n nodes for a data item is called its *preference list*

Versioning

- Eventual consistency
  - update request may return to caller before it is propagated to all replicas
  - delete request may reach replica that doesn't have what is being deleted
    - delete requests treated as "put" requests
  - versions are immutable (but garbage collectible)

The Shopping Cart …

Vector Clocks



Reconciliation

- Reconciliation done only on reads, which may return multiple values
  - easy reconciliation if values are causally ordered
  - application handles it otherwise

Quorums

- *get*s and *put*s go to coordinator, if available
- *put*:
  - coordinator writes new version locally
  - sends it to next n-1 nodes
  - when w-1 respond, put is considered successful
- *get*:
  - coordinator requests existing versions from next n-1 nodes
  - waits for r responses before returning to client
- r+w>n
  - typically n=3, r=w=2

“Sloppy” Quorum

- What if not all n nodes (or even w nodes) are available?
  - don’t want to deny a put request
- Use first n healthy nodes encountered
  - data tagged with the node it should go on
  - written back to that node when available
- Handles failures of entire data centers!
  - storage nodes spread across data centers

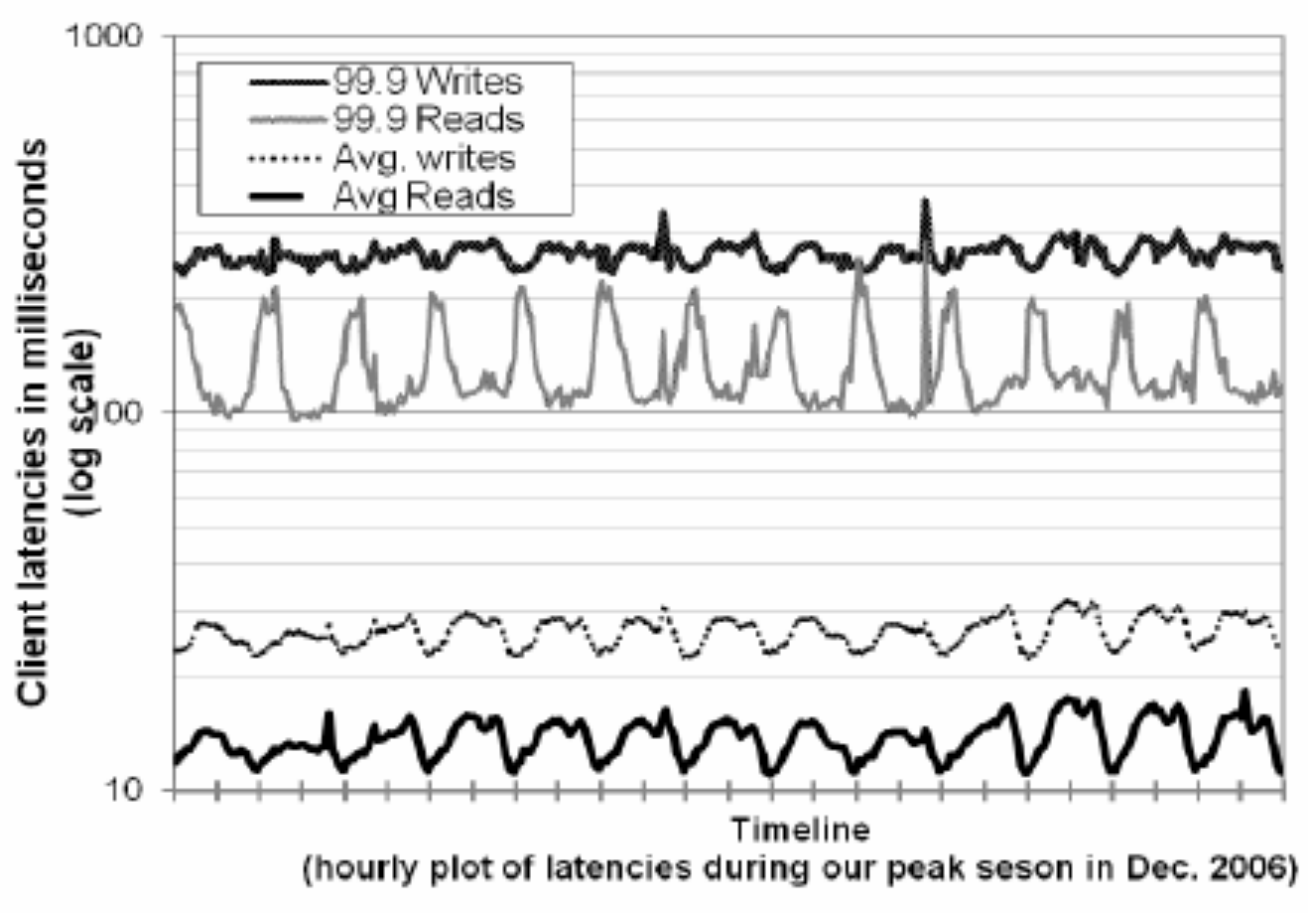
Anti-Entropy

- Replicas synced in background
- How to determine whether replicas differ?
- Merkle trees used to compare contents
  - leaves are hashes of contents
  - parents are hashes of children
- Nodes maintain Merkle trees of key ranges
  - each virtual node defines a key range

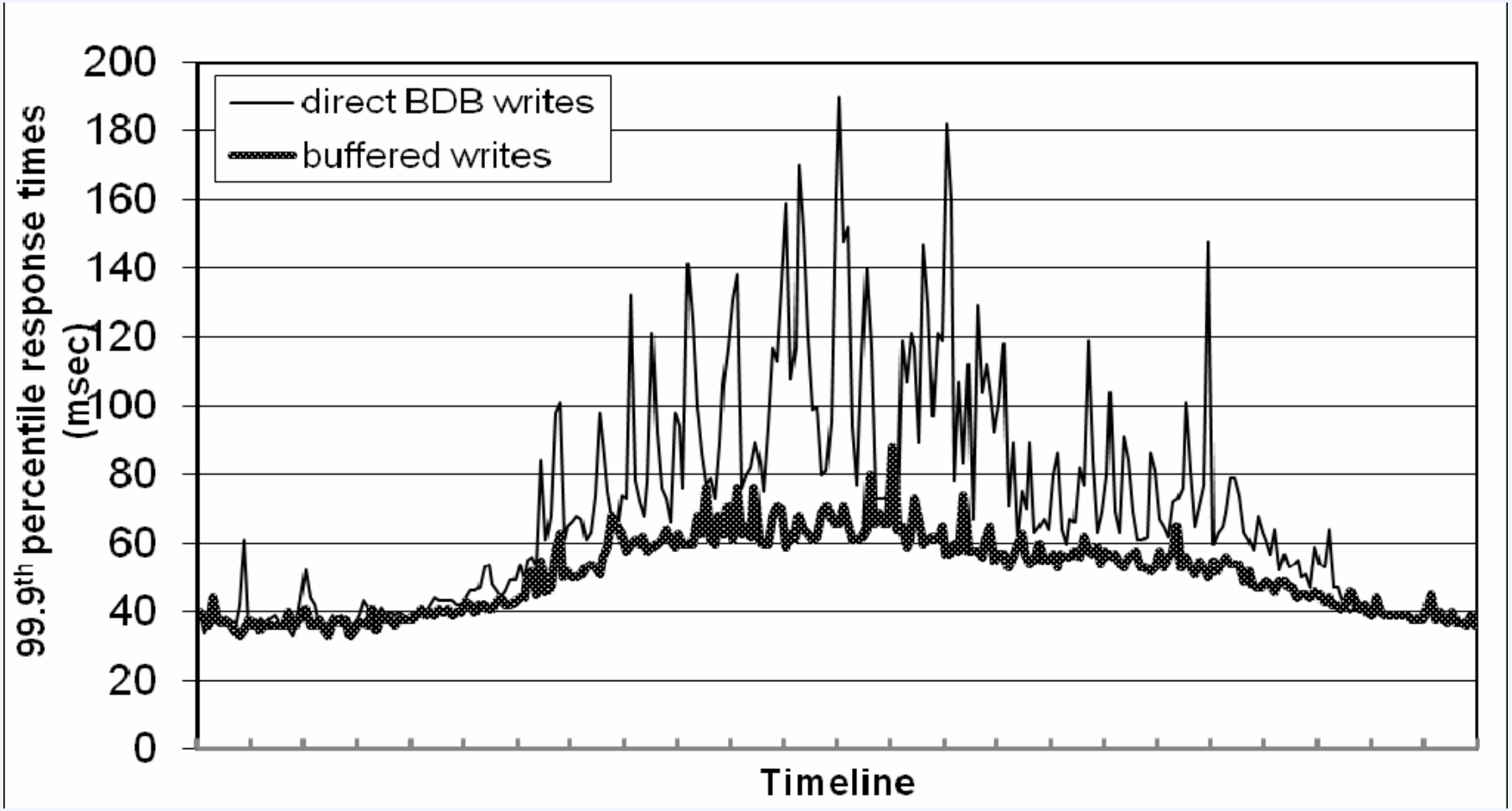
Ring Membership

- Gossip protocol used to distribute membership info and key ranges
- Failure detection
  - simple time-out on communication

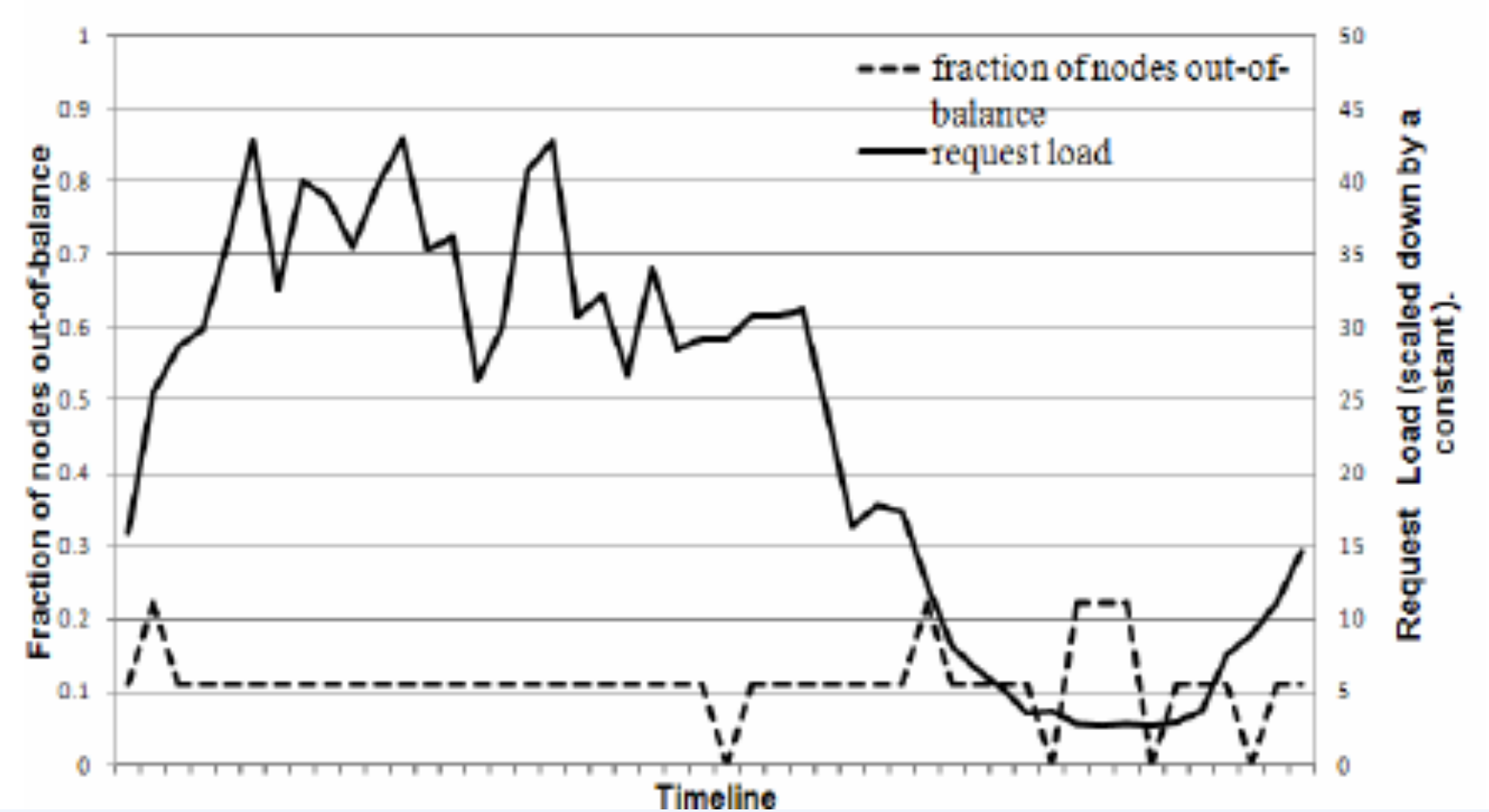
Performance: Latency



Performance: Buffering



Performance: Load Balancing



Example Uses

- Business-logic-specific reconciliation
  - data replicated across multiple nodes
  - reconciliation is application-specific
    - e.g.: shopping carts merged
- Timestamp-based reconciliation
  - real-time stamp used: “last write wins”
  - used to maintain customer session information
- High-performance read engine
  - r=1, w=n
  - used for product catalog and promotional items

Divergent Versions

- Is it a real problem with shopping carts?
- In one 24-hour period:
  - 99.94% of requests saw exactly one version
- Divergent versions usually not due to failures
- Due to concurrent writers
  - writers probably aren't human!

Post 2007

- Dynamo successful, but not popular among developers
  - difficult to integrate and manage
- SimpleDB preferred
  - easier to use
  - much less robust
- DynamoDB released in January 2012
  - combines both
  - no details