# Object Storage on CRAQ

High throughput chain replication for read-mostly workloads

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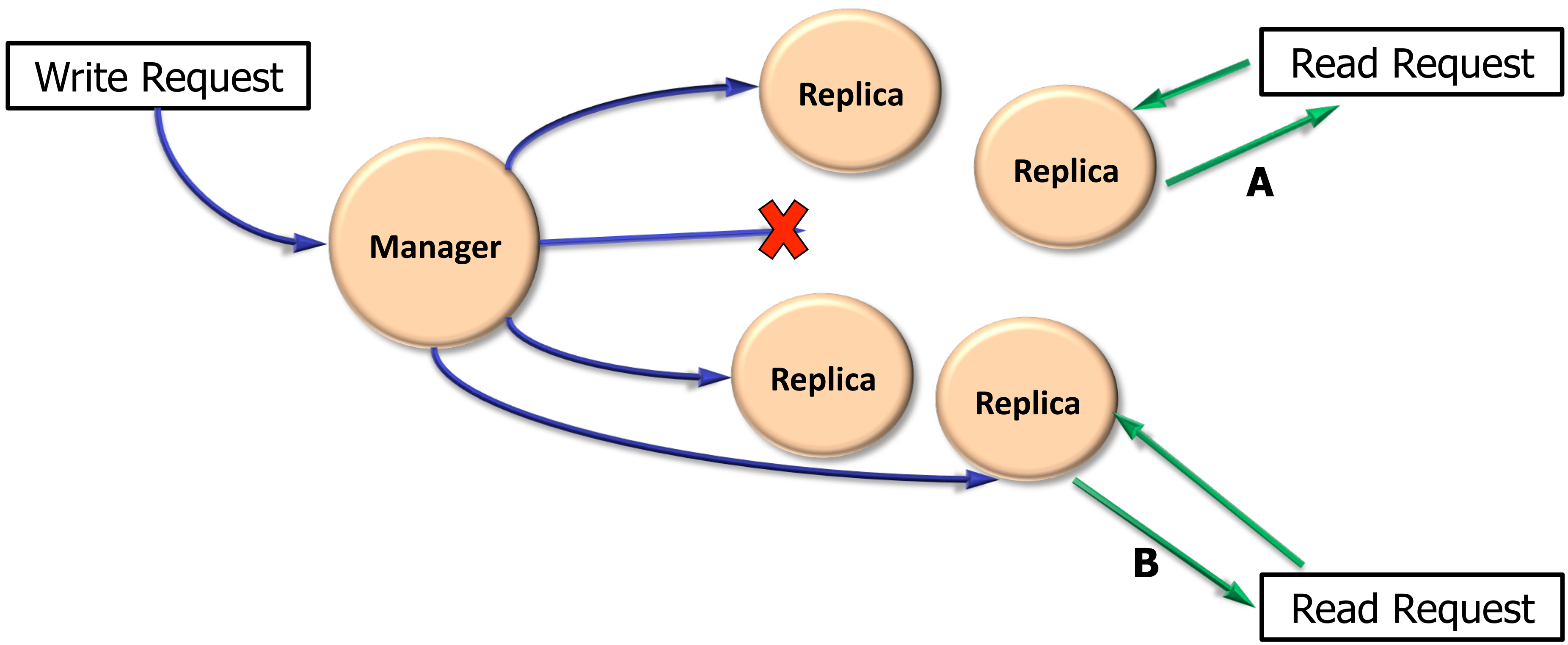
# Data Storage Revolution

- Relational Databases

- Object Storage (put/get)
  - Dynamo
  - PNUTS
  - CouchDB
  - MemcacheDB
  - Cassandra

Speed
Scalability
Availability
Throughput
No Complexity

# Eventual Consistency



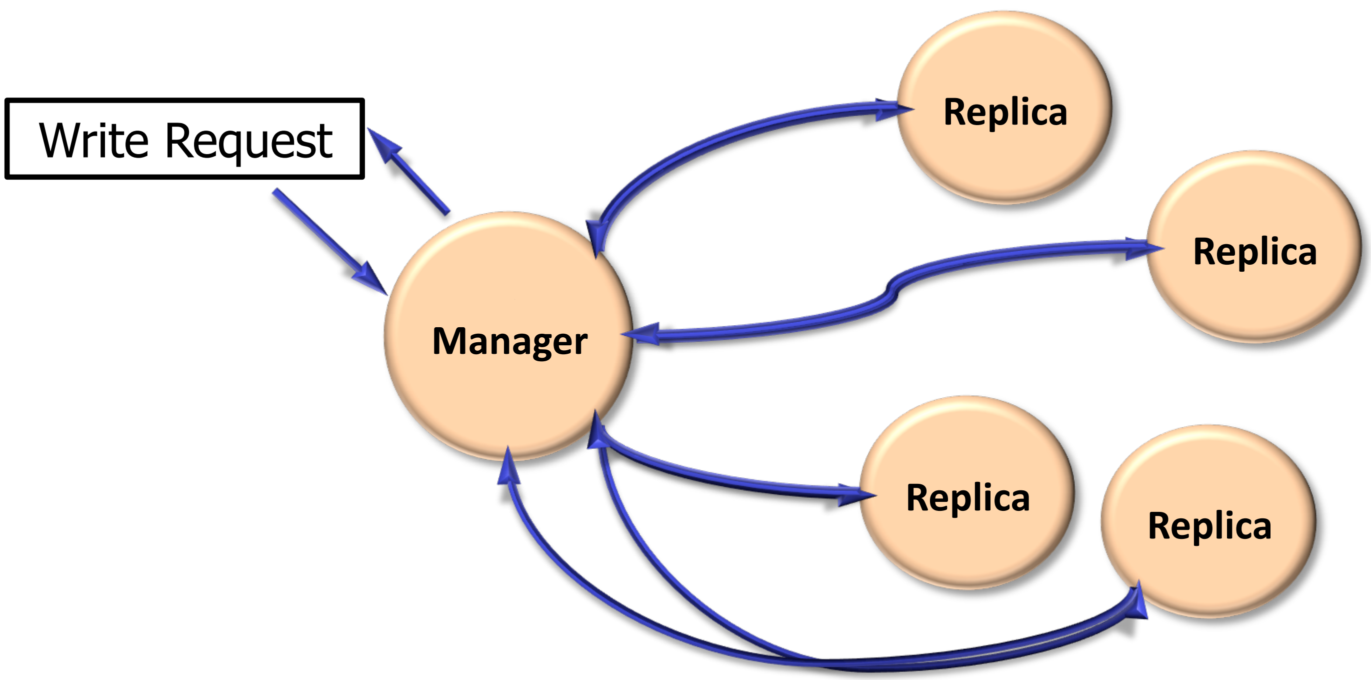
# Eventual Consistency

- Writes ordered after commit
- Reads can be out-of-order or stale

- Easy to scale, high throughput 

- Difficult application programming model 

# Traditional Solution to Consistency




**Two-Phase Commit:**

1. Prepare
2. Vote: Yes
3. Commit
4. Ack

# Strong Consistency

- Reads and Writes strictly ordered

- Easy programming 

- Expensive implementation
- Doesn’t scale well

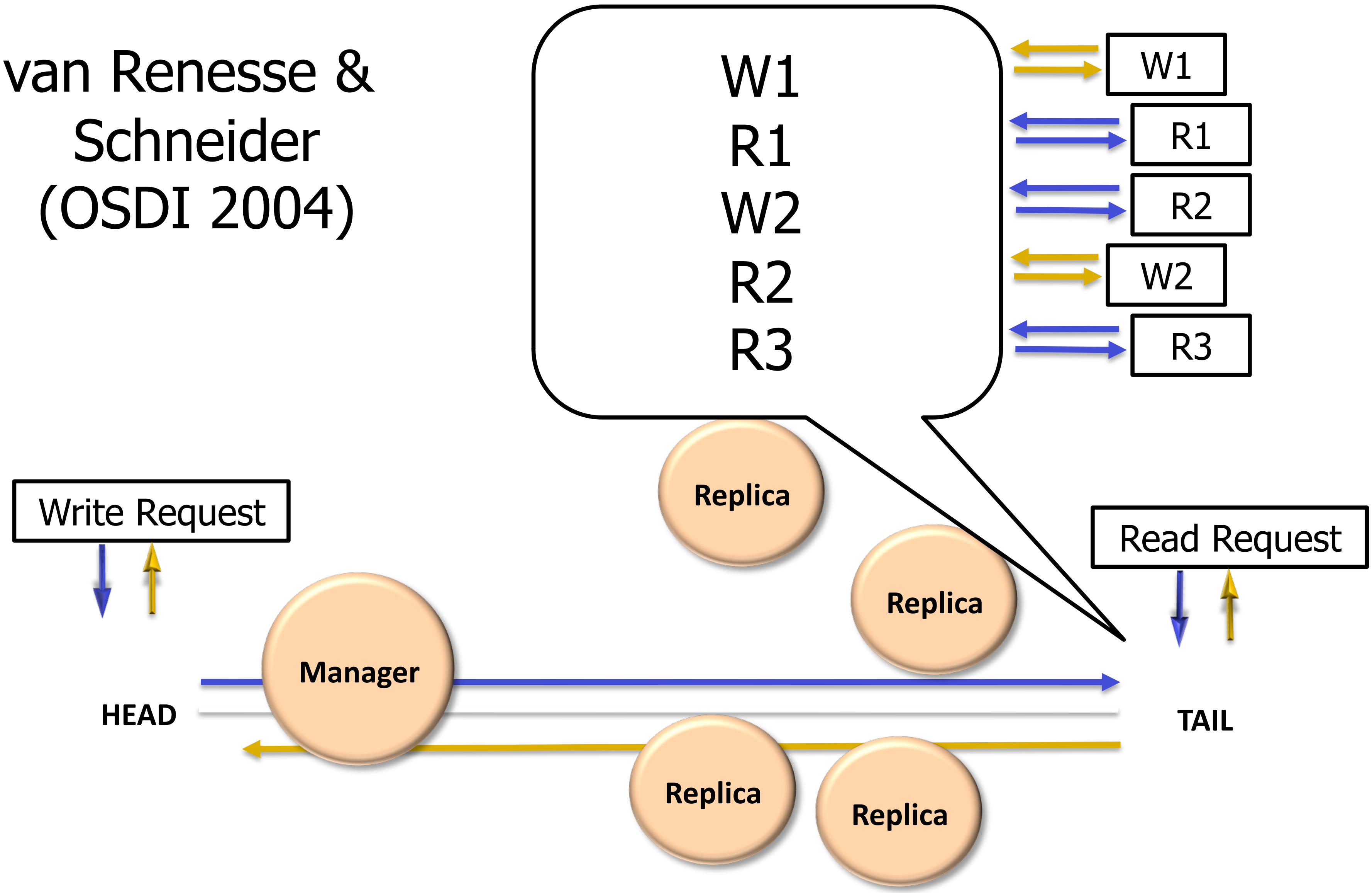
# Our Goal

- Easy programming

- Easy to scale, high throughput

# Chain Replication

van Renesse &
Schneider
(OSDI 2004)



# Chain Replication

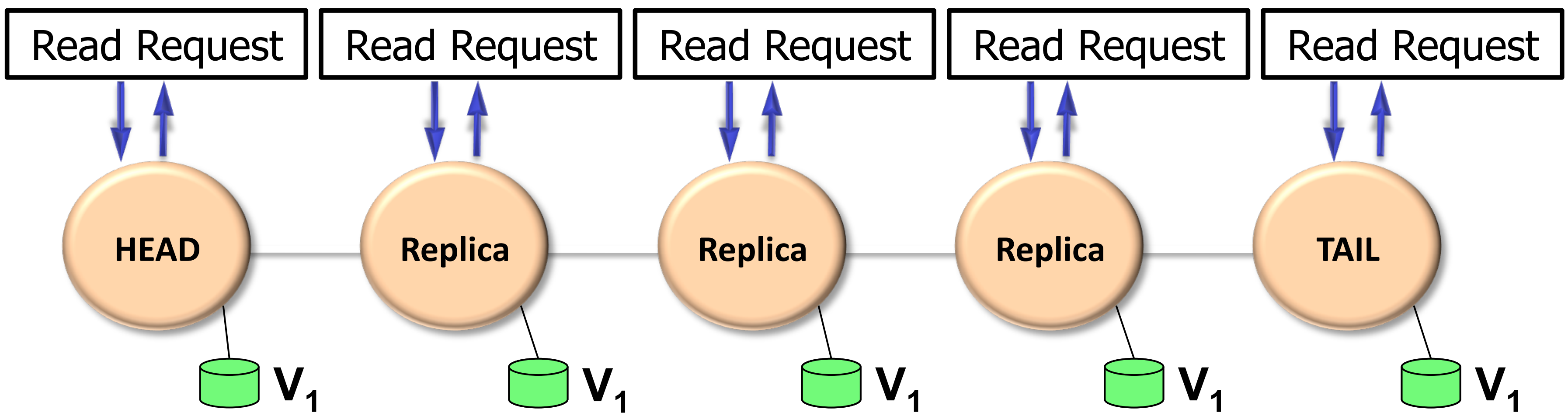
- Strong consistency
- Simple replication 
- Increases write throughput

- Low read throughput 

- Can we increase throughput?
- Insight:
  - Most applications are read-heavy (100:1)

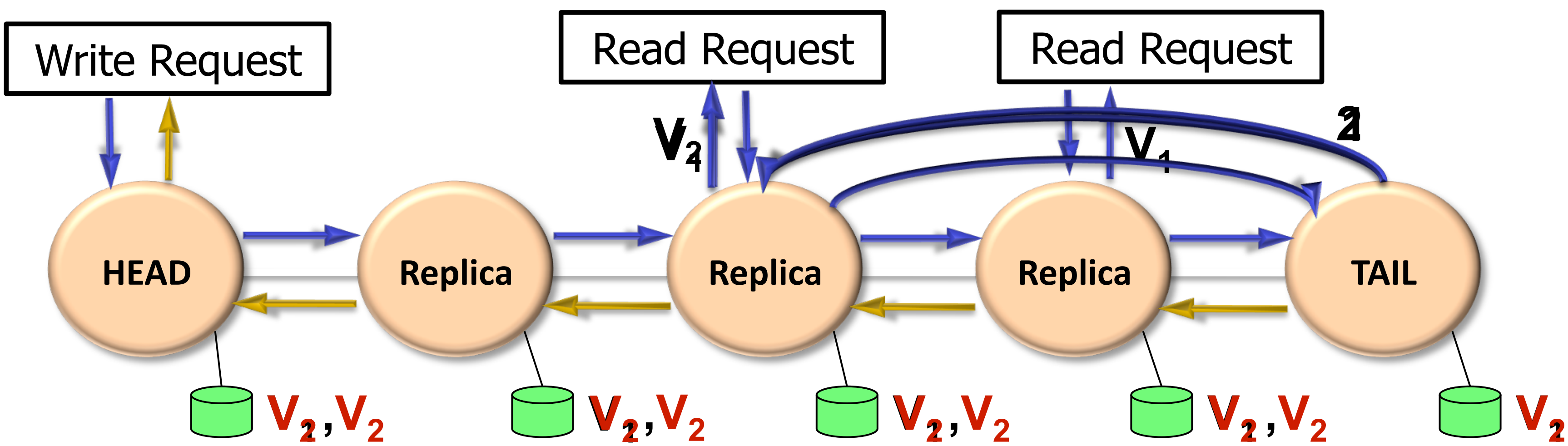
# CRAQ

- Two states – **clean** and **dirty**



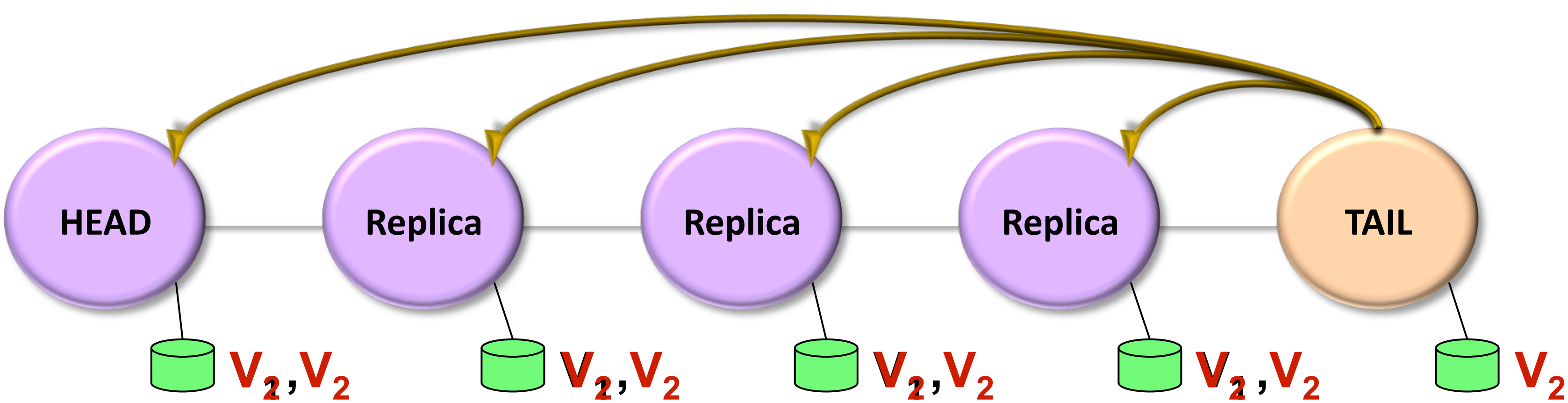
# CRAQ

- Two states per object – **clean** and **dirty**
- If latest version is **clean**, return value
- If **dirty**, contact **tail** for latest version number



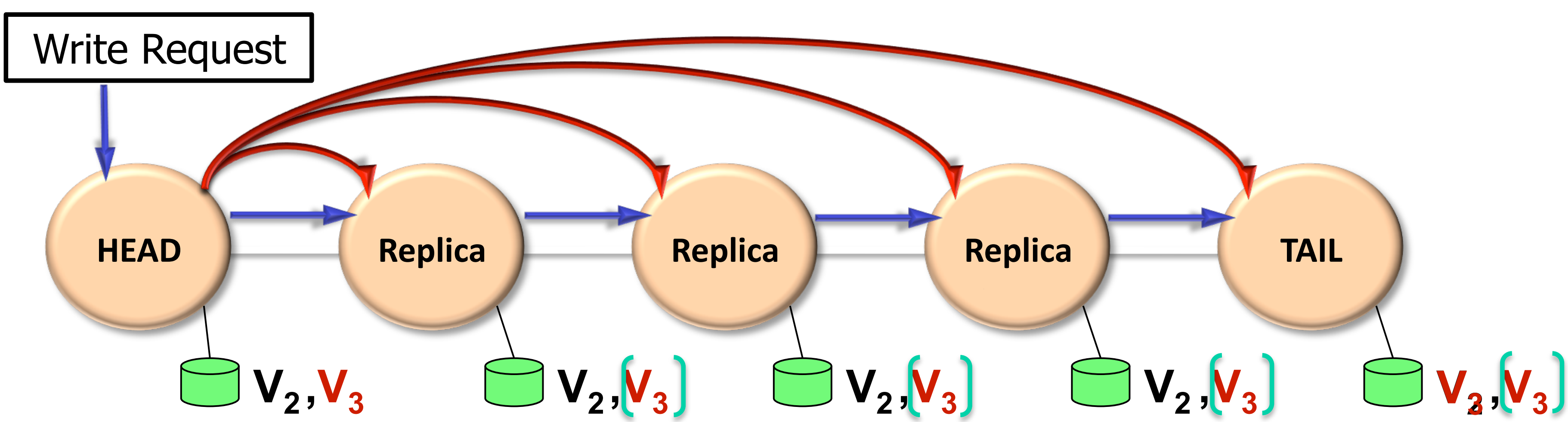
# Multicast Optimizations

- Each chain forms group
- Tail multicasts ACKs



# Multicast Optimizations

- Each chain forms group
- Tail multicasts ACKs
- Head multicasts write data



# CRAQ Benefits

- From Chain Replication
  - Strong consistency
  - Simple replication
  - Increases write throughput

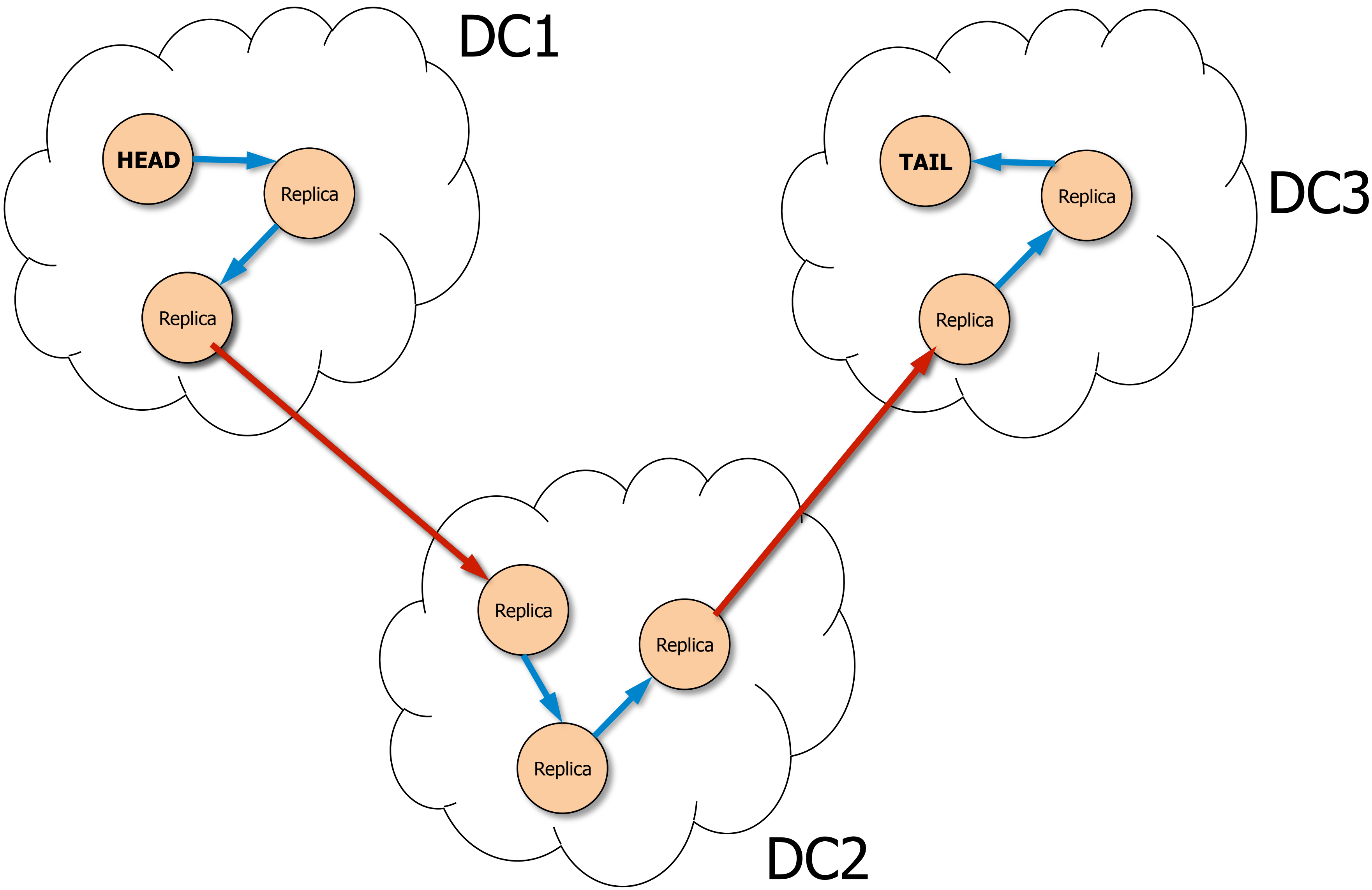
- Additional Contributions
  - Read throughput scales :
    - Chain Replication with **Apportioned** Queries
  - Supports Eventual Consistency

# High Diversity

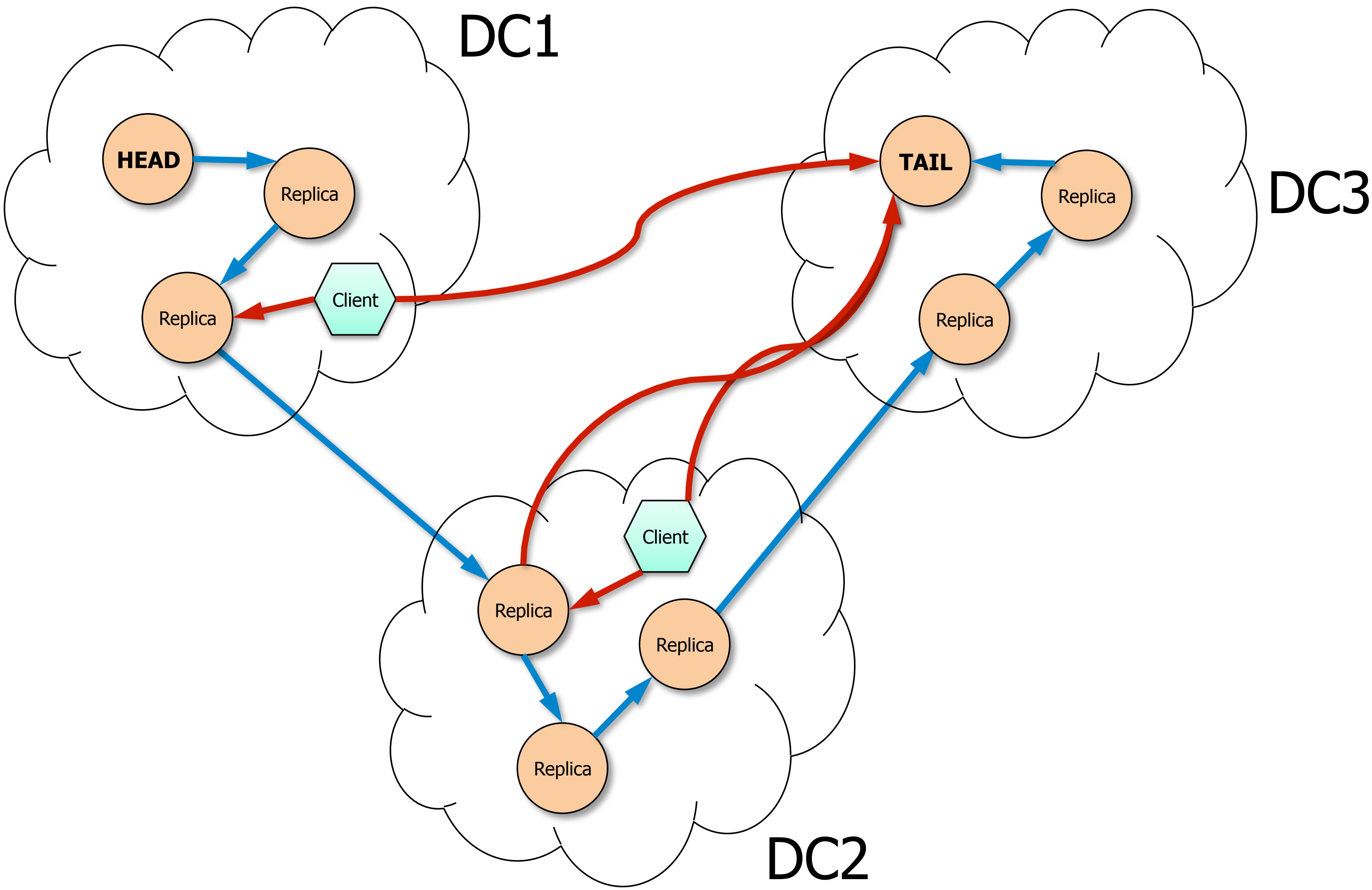
- Many data storage systems assume locality
  - Well connected, low latency
- Real large applications are geo-replicated
  - To provide low latency
  - Fault tolerance


(source: Data Center Knowledge)

# Multi-Datacenter CRAQ



# Multi-Datacenter CRAQ



# Chain Configuration

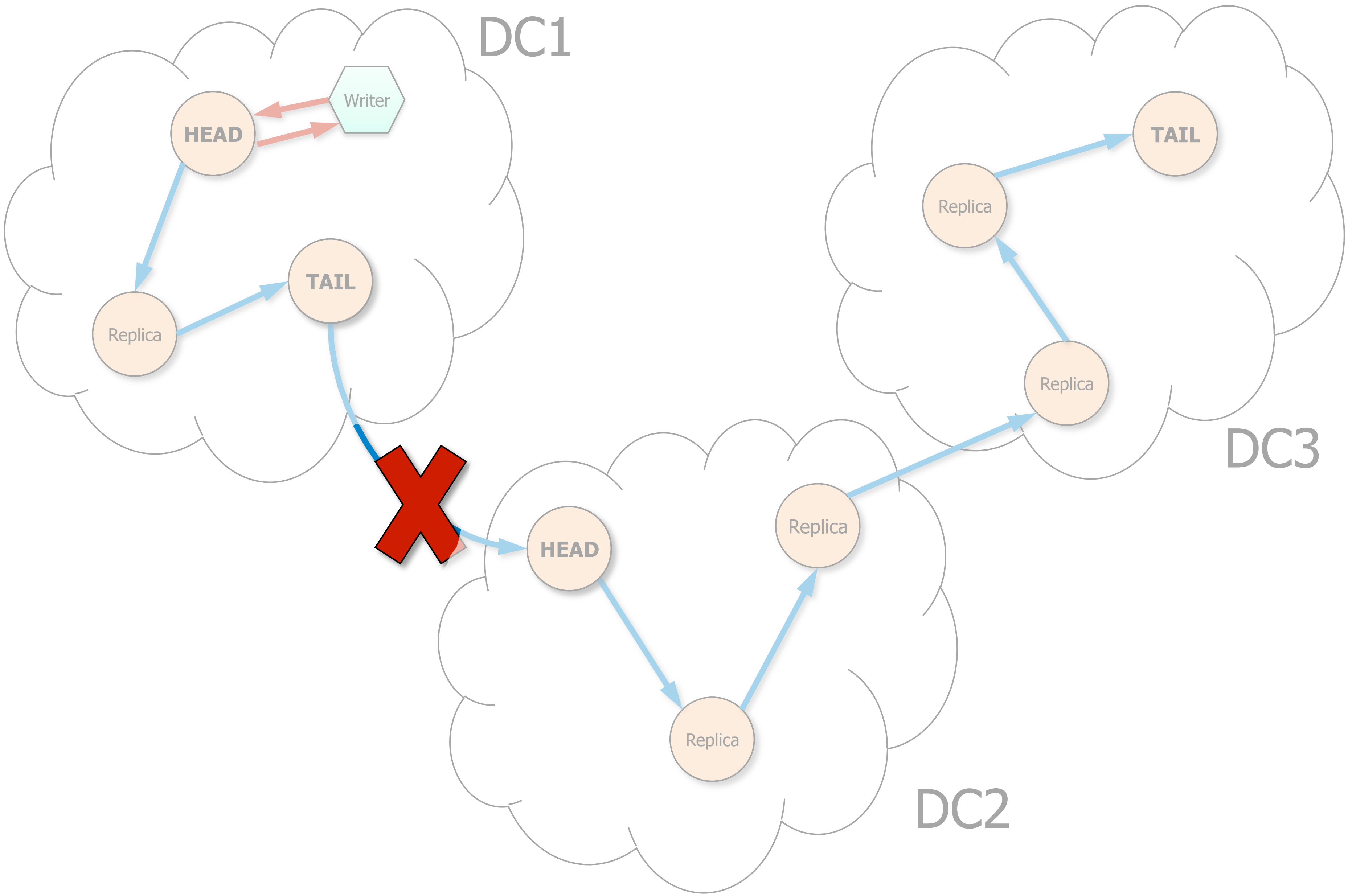
## Motivation

1. Popular vs. scarce objects
2. Subset relevance
3. Datacenter diversity
4. Write locality

## Solution

1. Specify chain size
2. List datacenters
   – $dc_1$, $dc_2$, … $dc_N$
3. Separate sizes
   – $dc_1$, chain_size$_1$, …
4. Specify master

# Master Datacenter

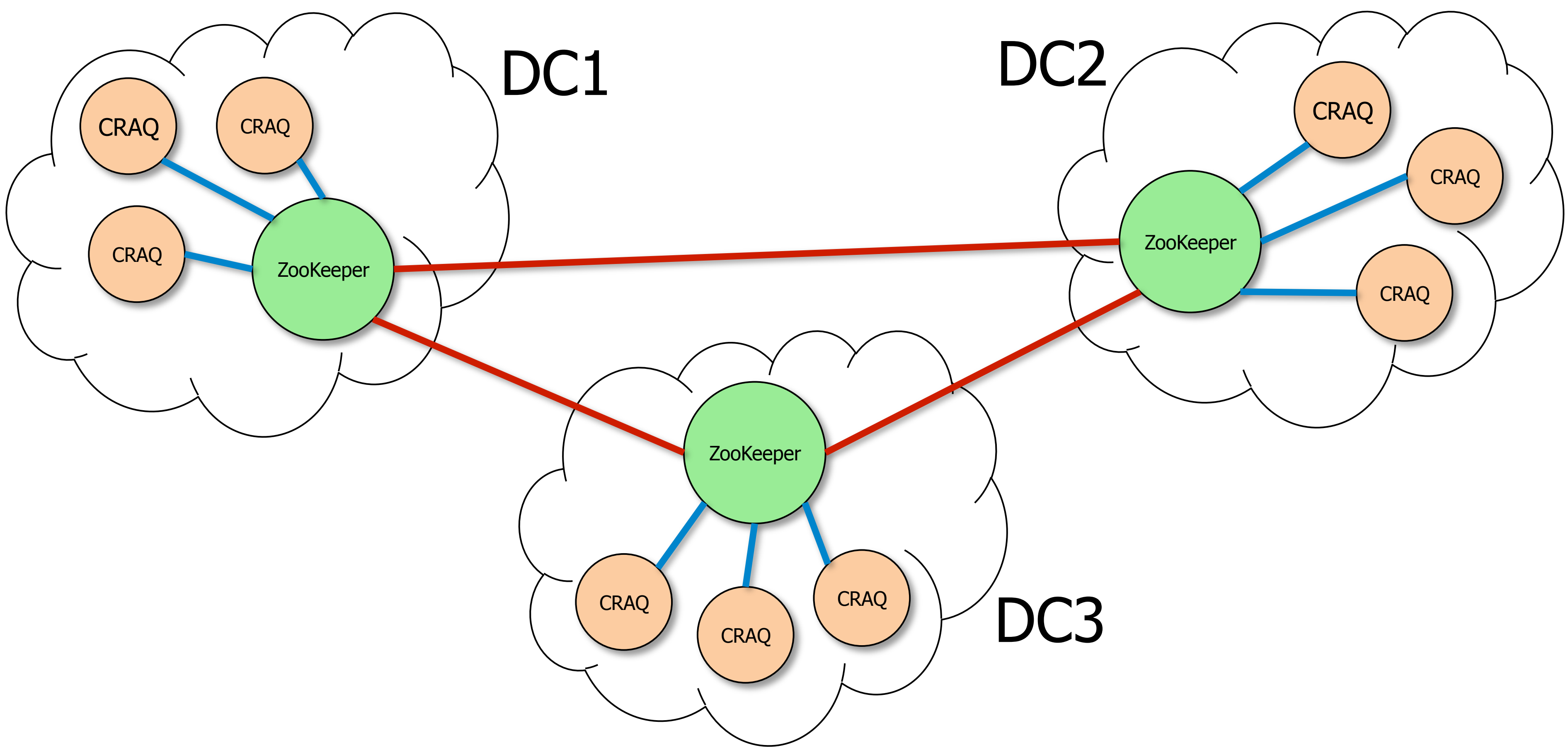


# Implementation

- Approximately 3,000 lines of C++
- Uses Tame extensions to SFS asynchronous I/O and RPC libraries
- Network operations use Sun RPC interfaces
- Uses Yahoo's ZooKeeper for coordination

# Coordination Using ZooKeeper

- Stores chain metadata
- Monitors/notifies about node membership

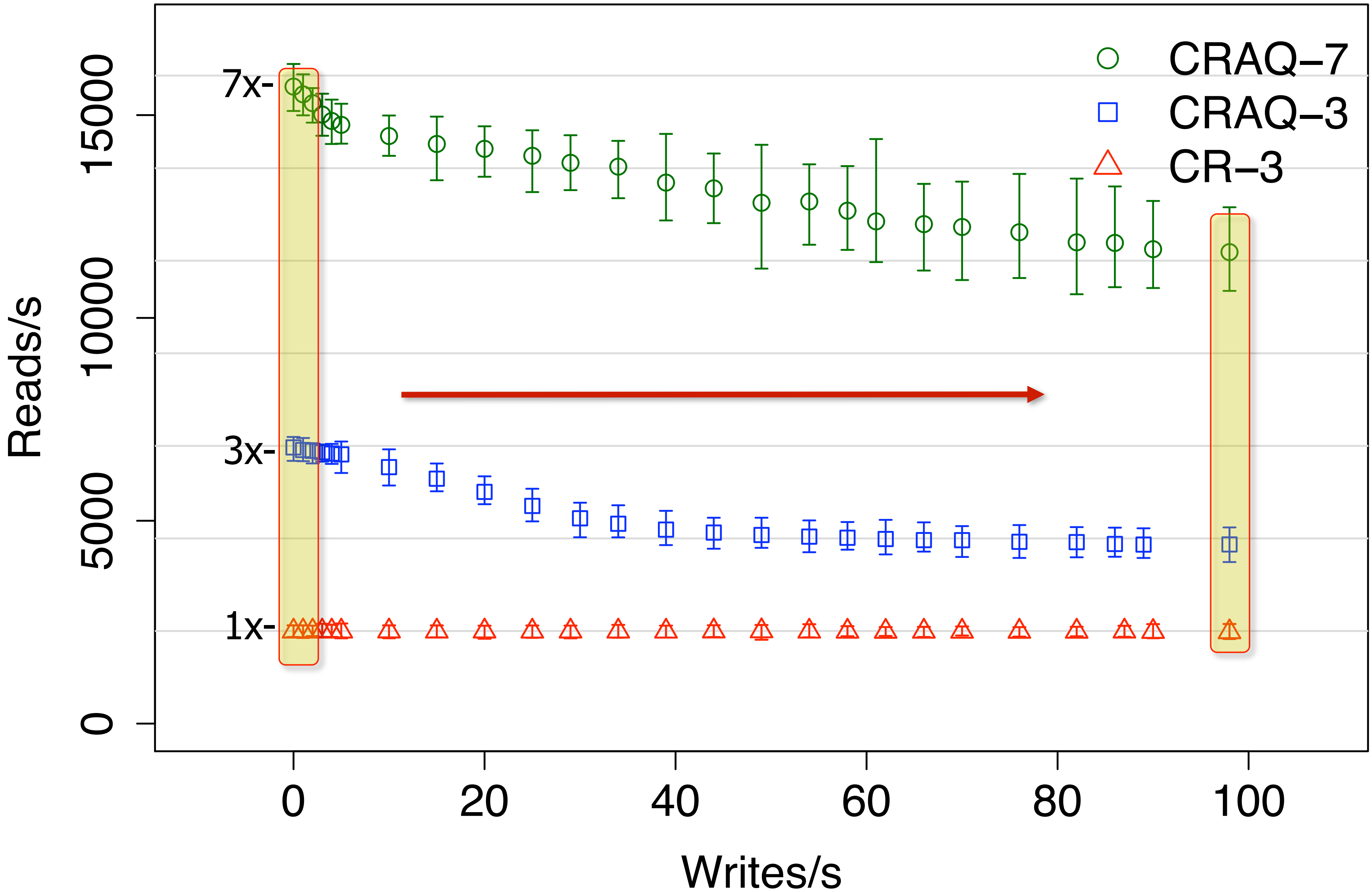


# Evaluation

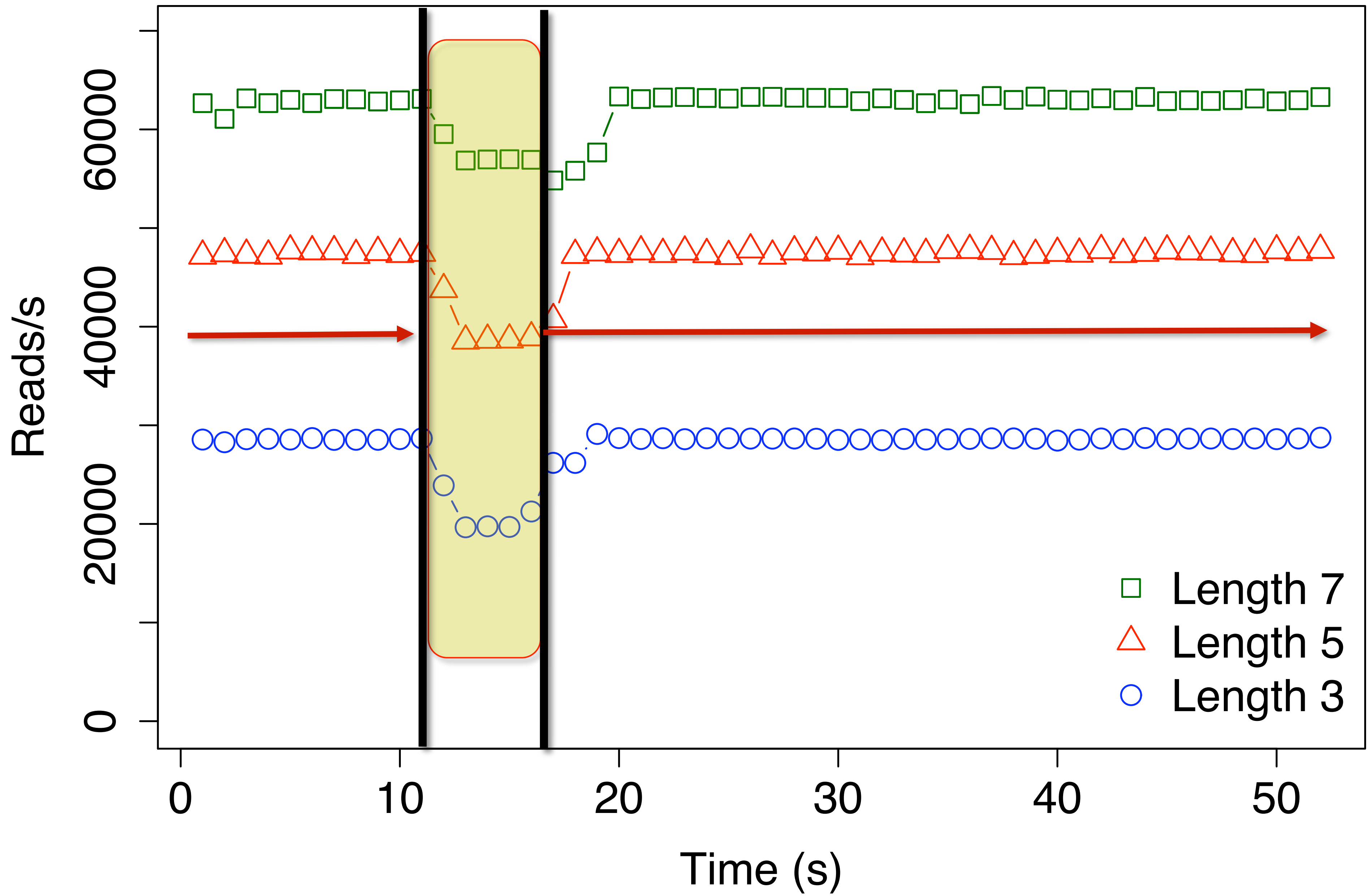
- Does CRAQ **scale** vs. CR?
- How does **write rate** impact performance?
- Can CRAQ recover from **failures**?
- How does **WAN** effect CRAQ?

- Tests use Emulab network emulation testbed

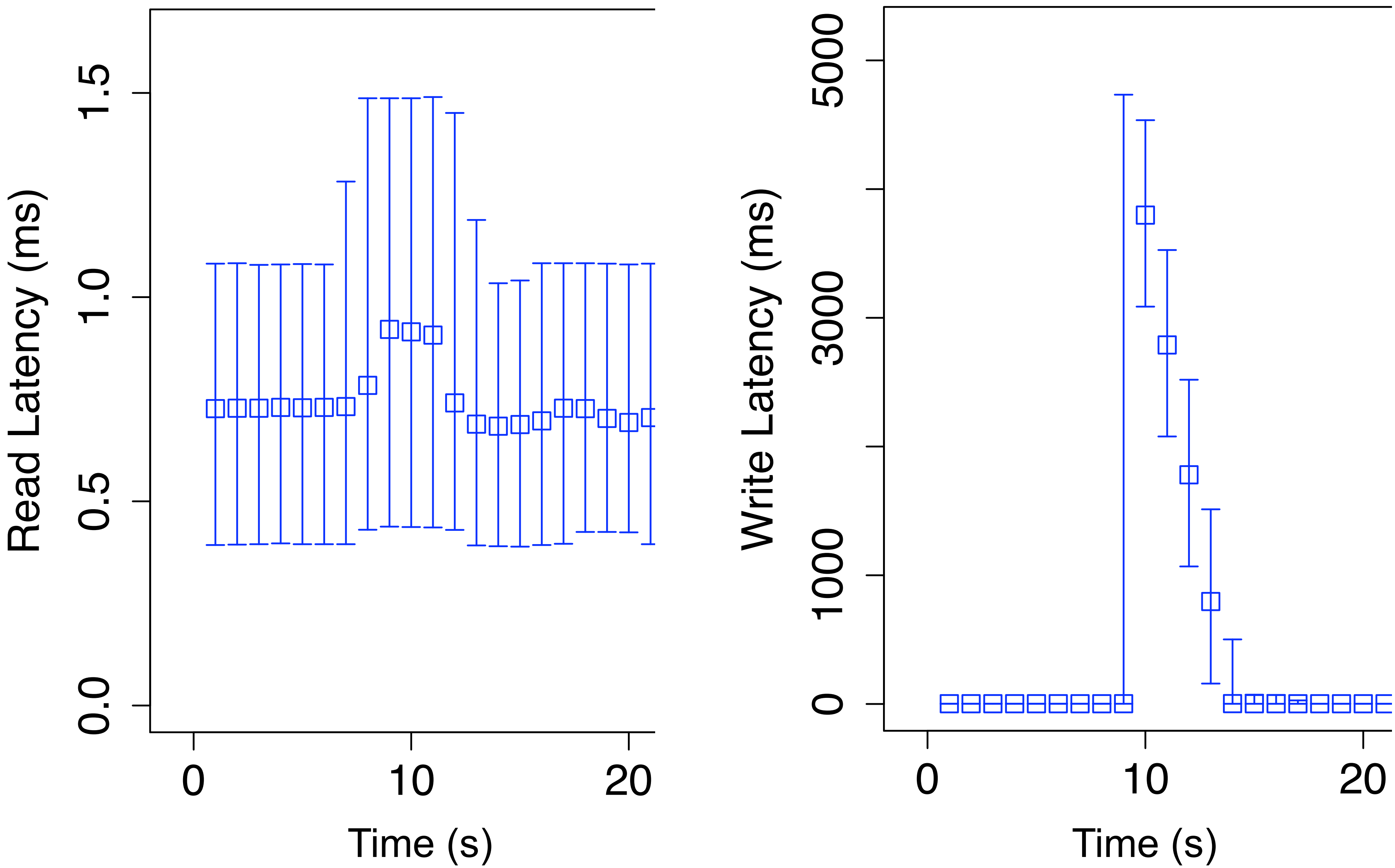
# Read Throughput as Writes Increase



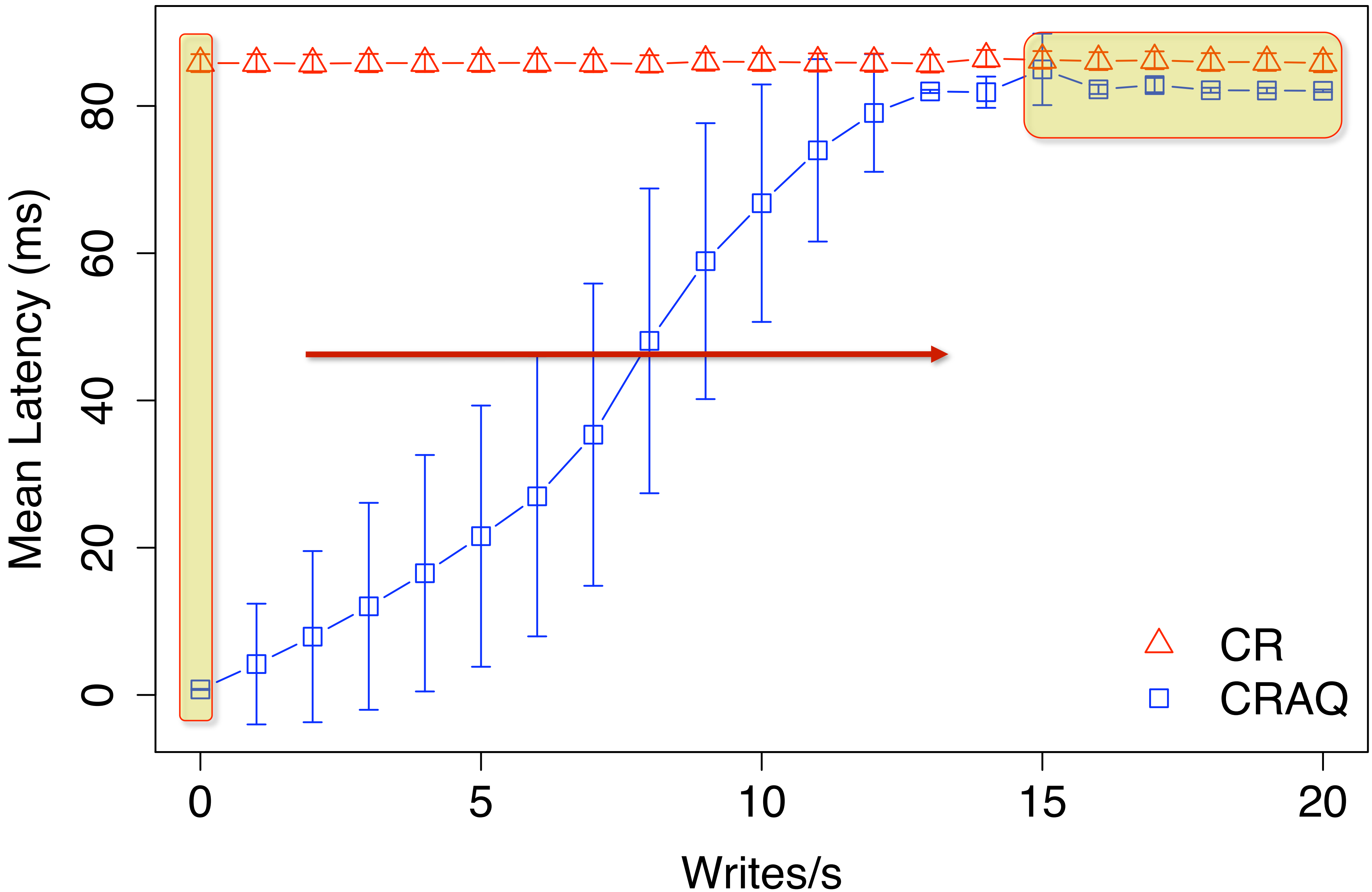
# Failure Recovery (Read Throughput)



# Failure Recovery (Latency)



# Geo-replicated Read Latency



# If Single Object Put/Get Insufficient

- Test-and-Set, Append, Increment
  - Trivial to implement
  - Head alone can evaluate
- Multiple object transaction in same chain
  - Can still be performed easily
  - Head alone can evaluate
- Multiple chains
  - An agreement protocol (2PC) can be used
  - Only heads of chains need to participate
  - Although degrades performance (use carefully!)

# Summary

- CRAQ Contributions?
  – Challenges trade-off of consistency vs. throughput
- Provides strong consistency
- Throughput scales linearly for read-mostly
- Support for wide-area deployments of chains
- Provides atomic operations and transactions

Thank You

Questions?