Dynamic Scalable State Machine Replication

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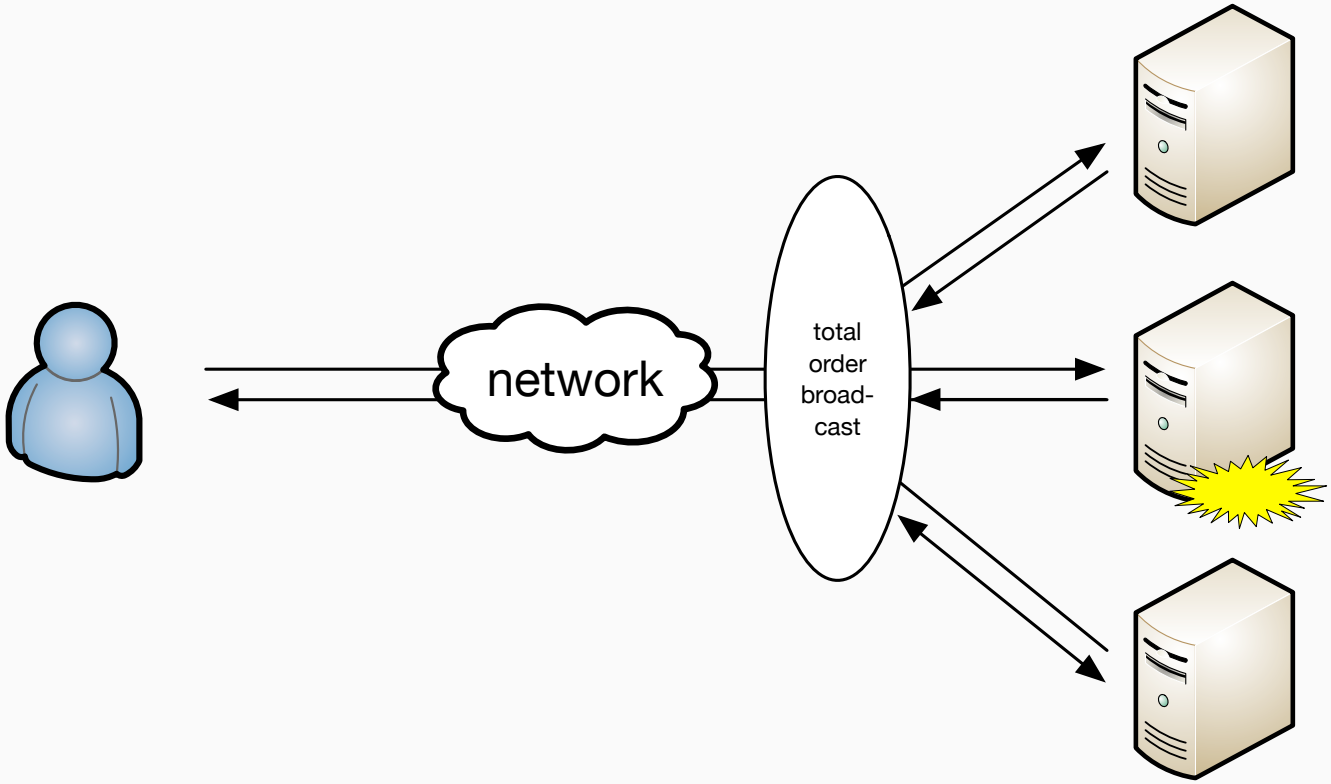
Outlines

1. Motivation
2. Dynamic Scalable State Machine Replication
3. Implementation & Evaluation
4. Conclusion

Motivation

The need of availability



State Machine Replication (SMR)

Providing fault-tolerance, strong consistency

- All replicas start in the same initial state
- Apply same set of commands in the same order
- The executions of commands are deterministic
- Proceed through the same set of states

State Machine Replication

Production systems

- Keep critical managements service online
  - Google's Chubby, Apache Zookeeper
- Persistent storage in distributed databases
  - Google Spanner, Windows azure storage, CockroachDB, Apache H-Store

Scaling State Machine Replication

SMR lacks of scalability:

- Every replica executes all commands.
- Adding servers does not increase the maximum throughput

Different techniques have been developed to deal with these limitations

- Scaling up
- Scaling out

Scalable State Machine Replication (SSMR)

Partitions application's state and replicates each partition

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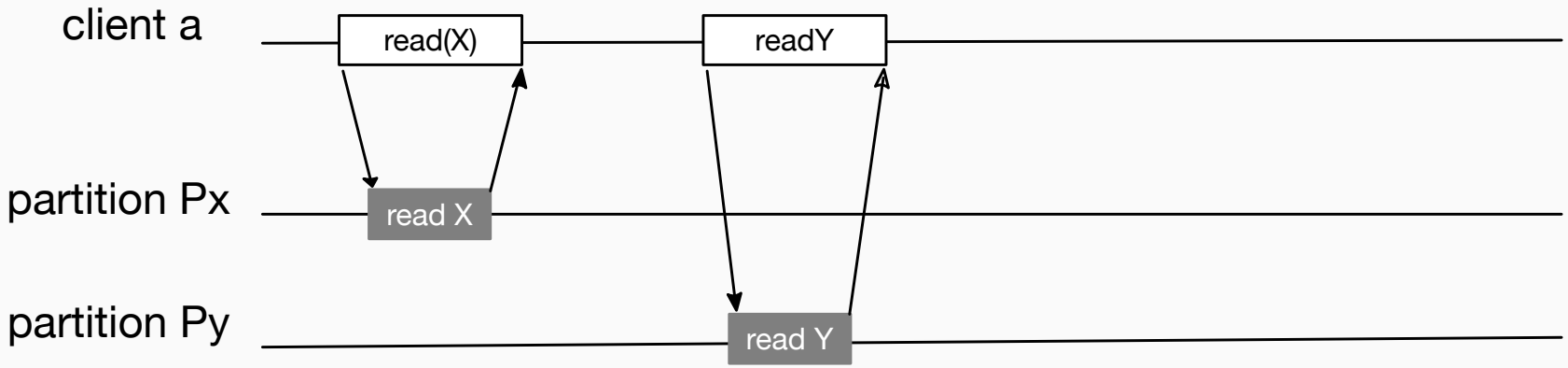

Scalable State Machine Replication (SSMR)

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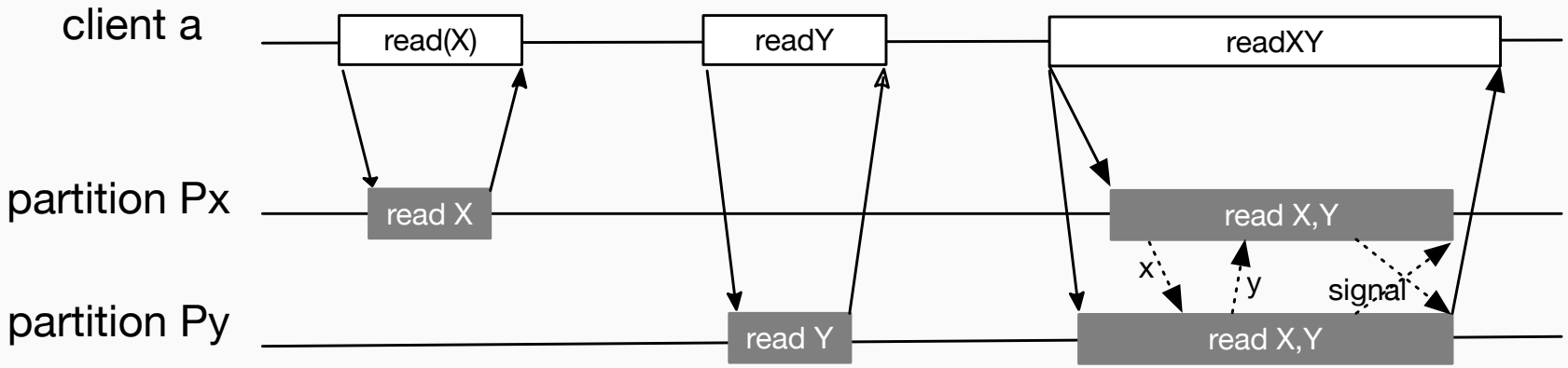

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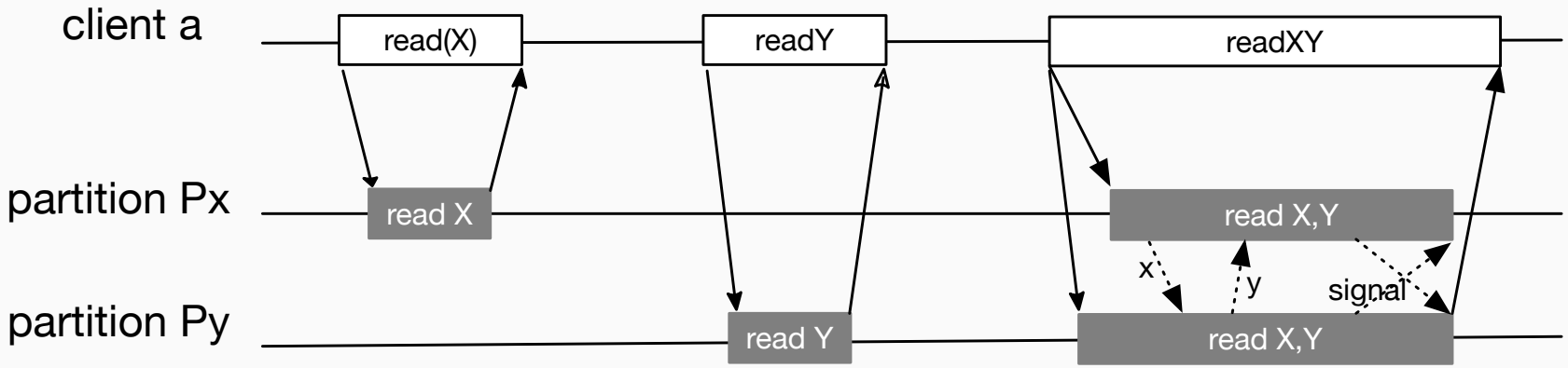

Guarantees strong consistency (i.e., linearizability)

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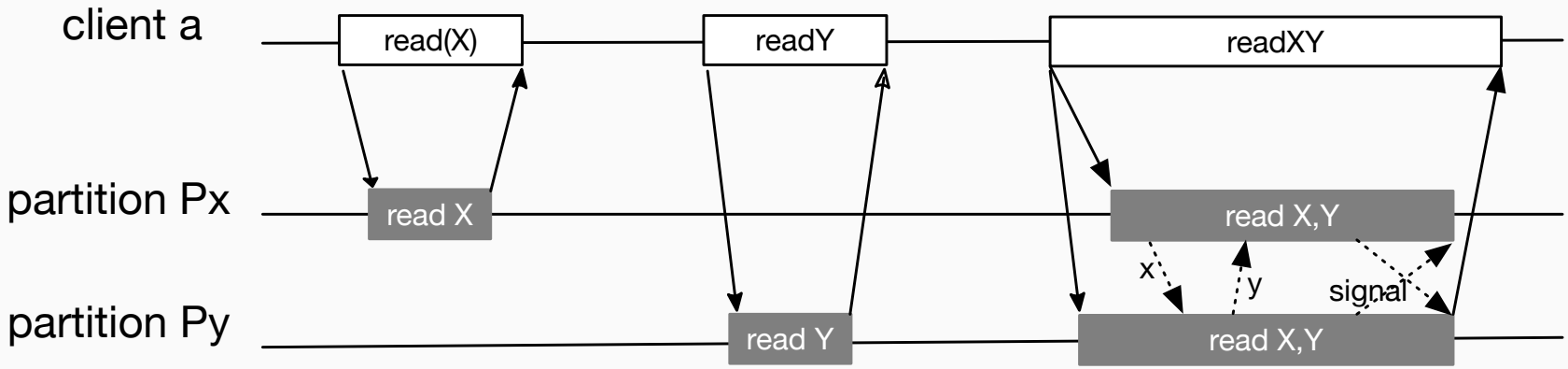
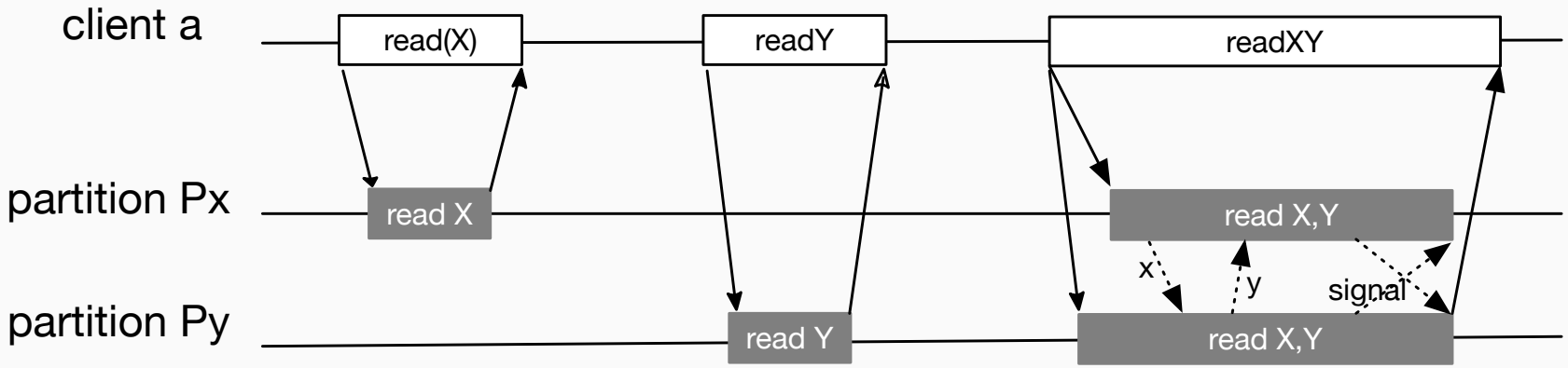


Guarantees strong consistency (i.e., linearizability)

Expensive cost of multi-partition commands

Scalable State Machine Replication (SSMR)

Partitions application's state and replicates each partition



Guarantees strong consistency (i.e., linearizability)

Expensive cost of multi-partition commands

Assumes a static workload partitioning

Dynamic Scalable State Machine Replication

System Model

Crash-stop failure model

- No Byzantine behavior

Communication by message passing

- One-to-one communication use reliable multicast
- One-to-many communication relies on atomic multicast
- Messages can be lost, reordered, but not corrupted

System is partially synchronous

- No delay bound

Consistency level: linearizability

General idea

Dynamically changing the state partitioning by exploiting locality

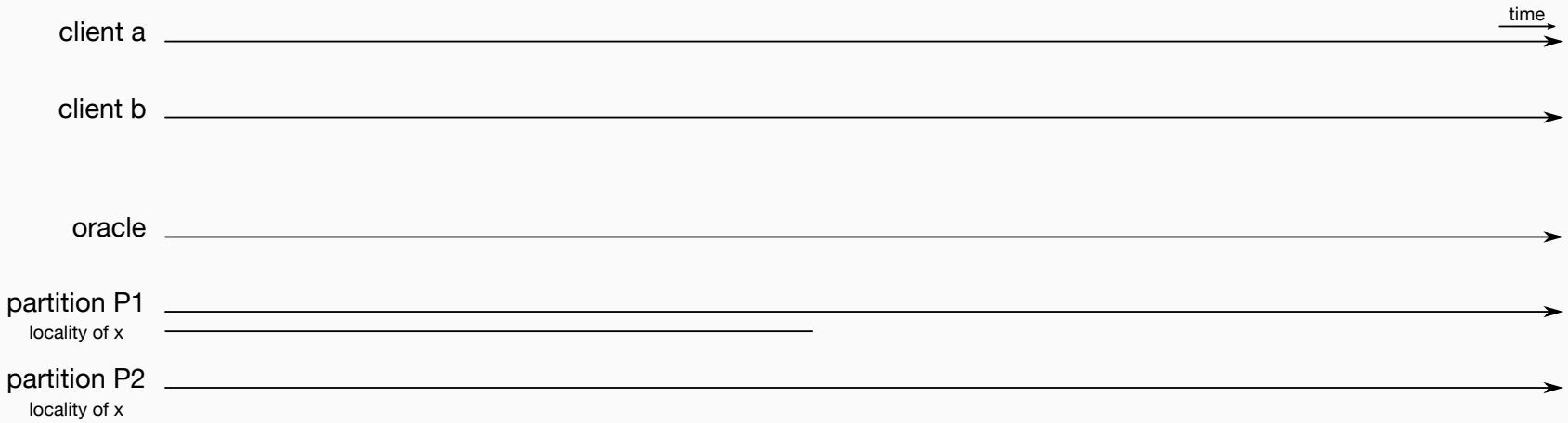
- Involved variables are moved to a single partition
- Command is executed against this partition
- Supported commands: *consult*, *create*, *access*, *move*, *delete*

Variables that are usually accessed together are moved to the same partition

Variable mapping managed by an Oracle partition and client cache

DS-SMR falls back to S-SMR execution after few unsuccessful attempts.

General idea



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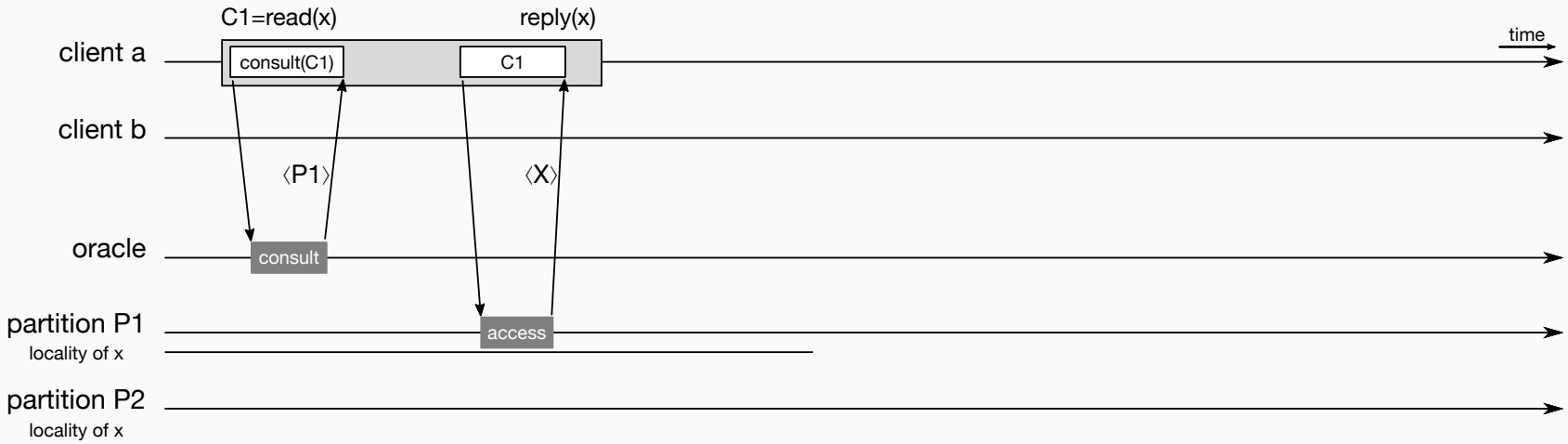

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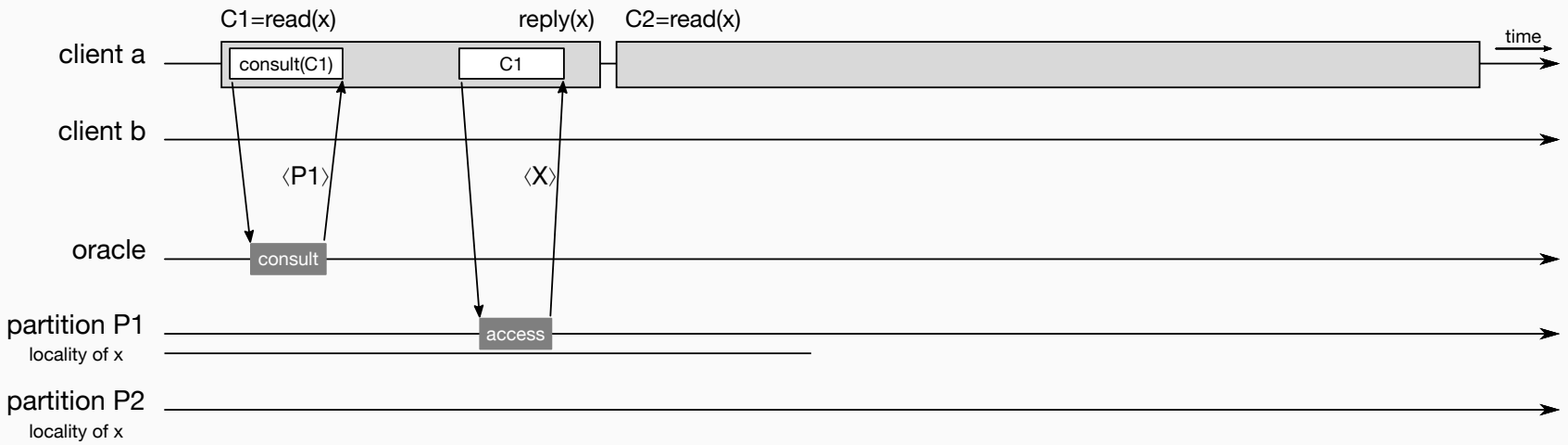

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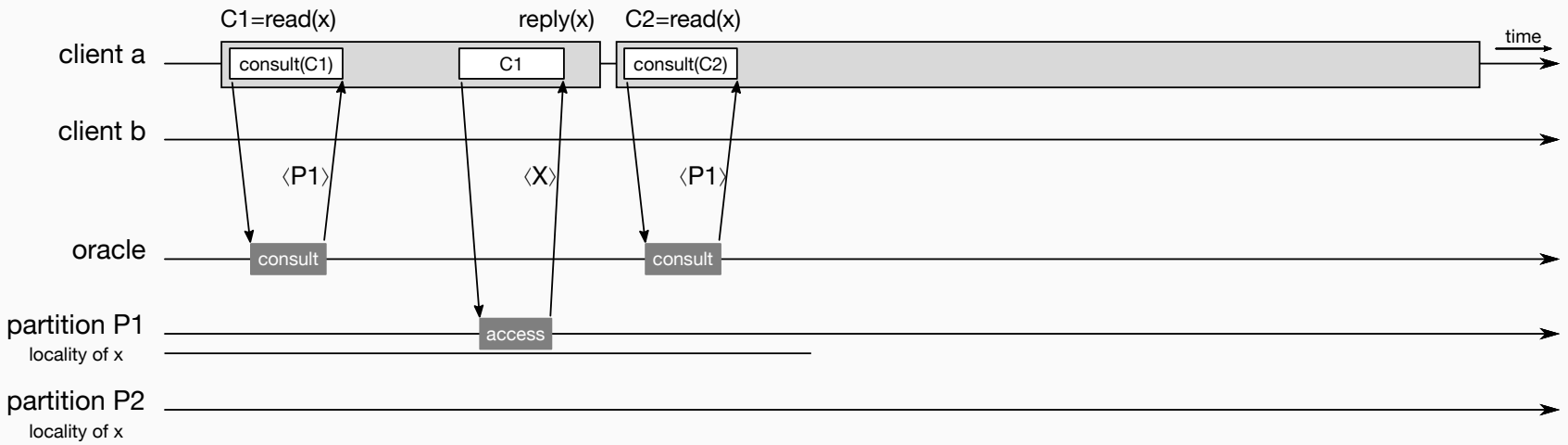

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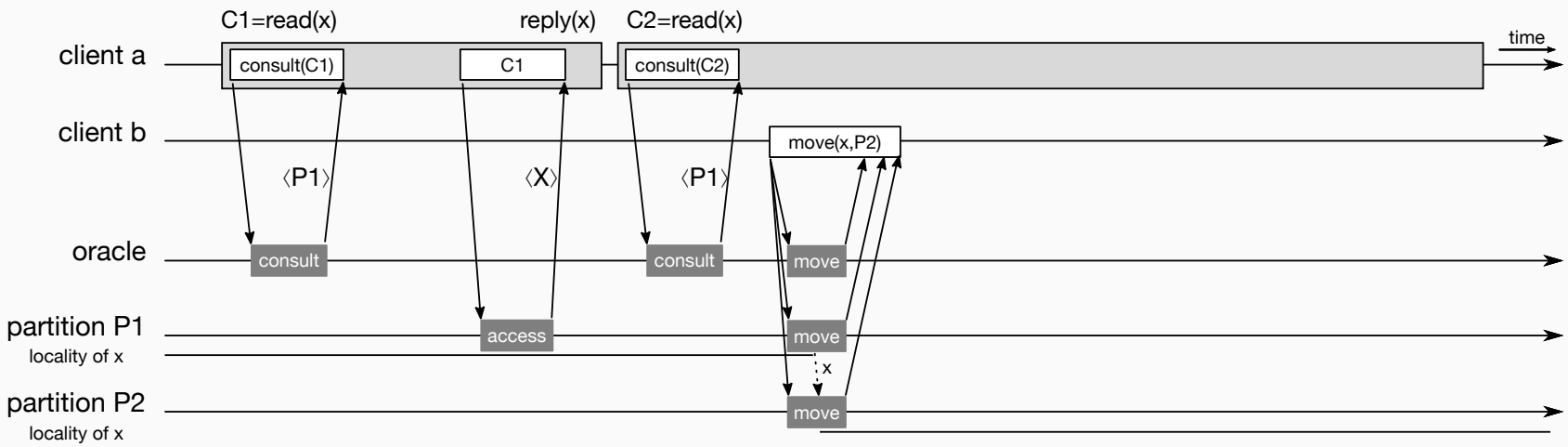

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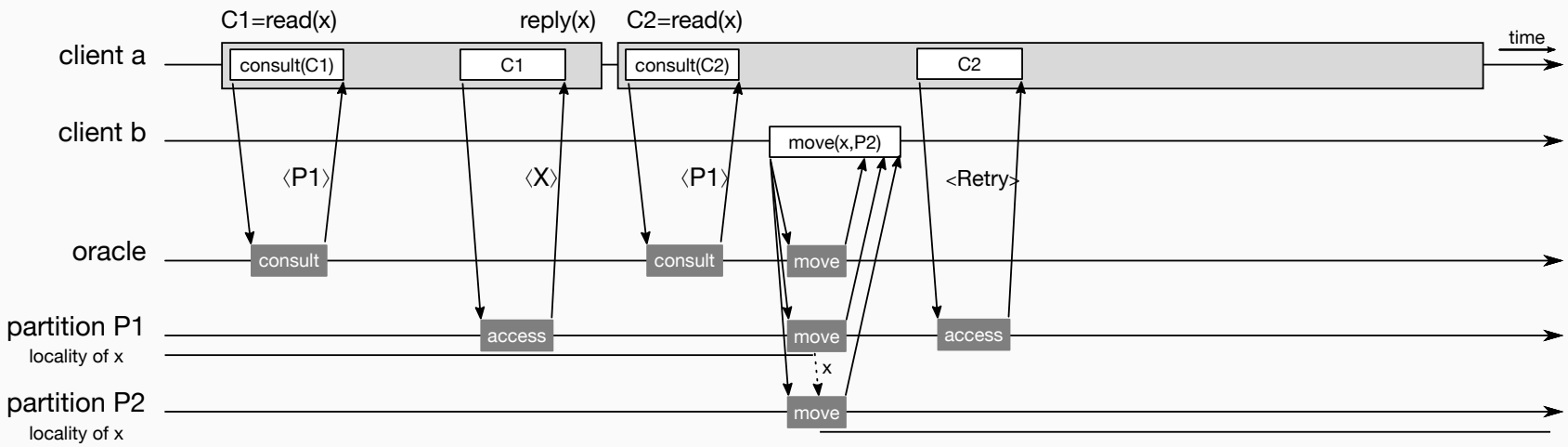

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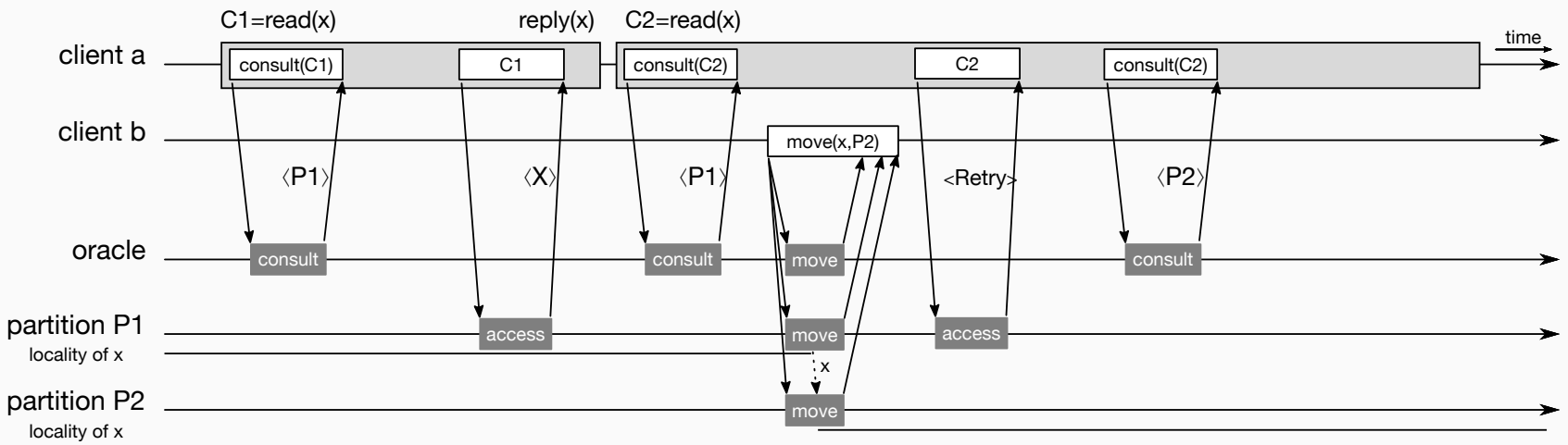

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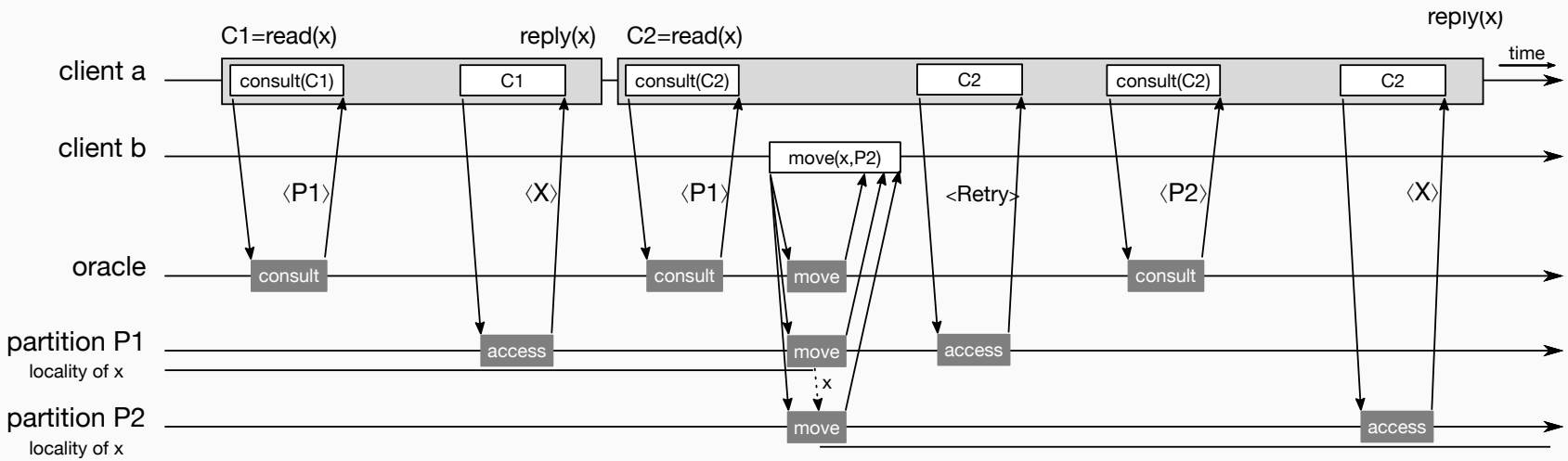
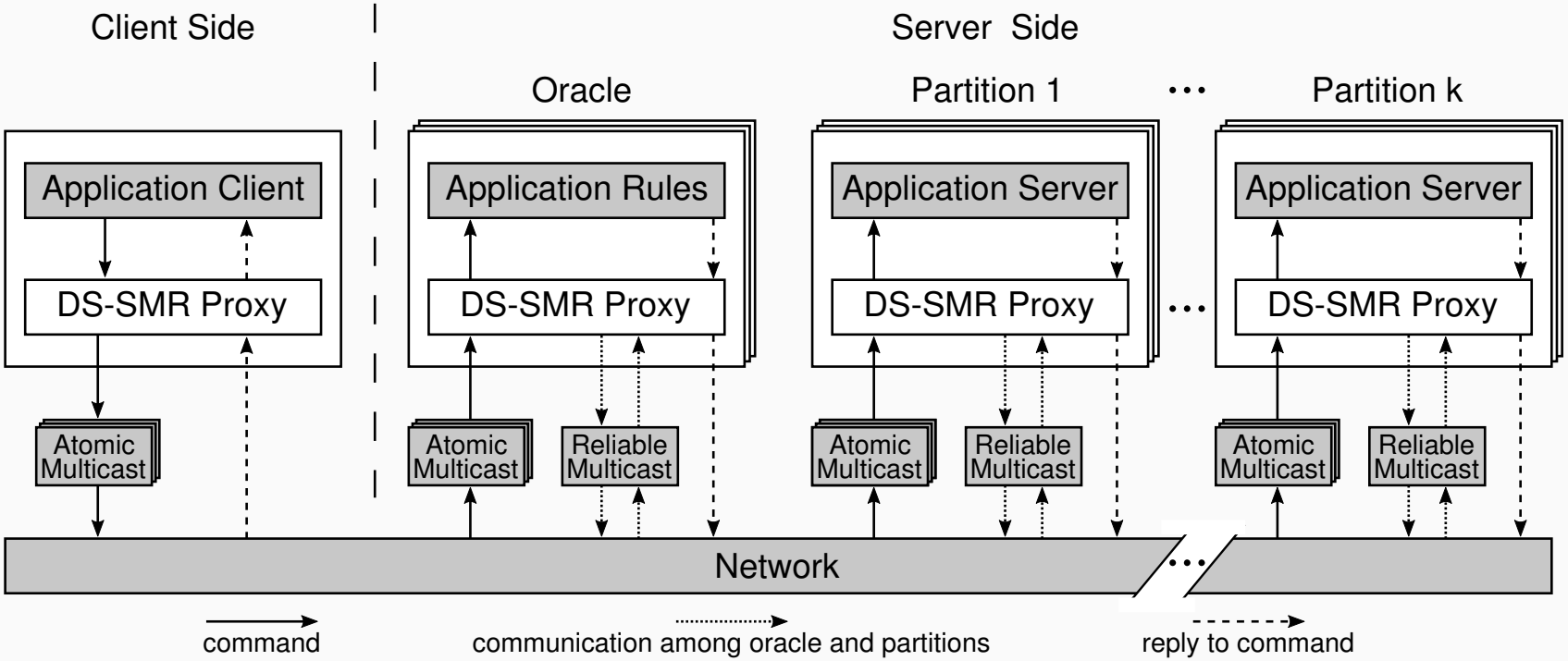
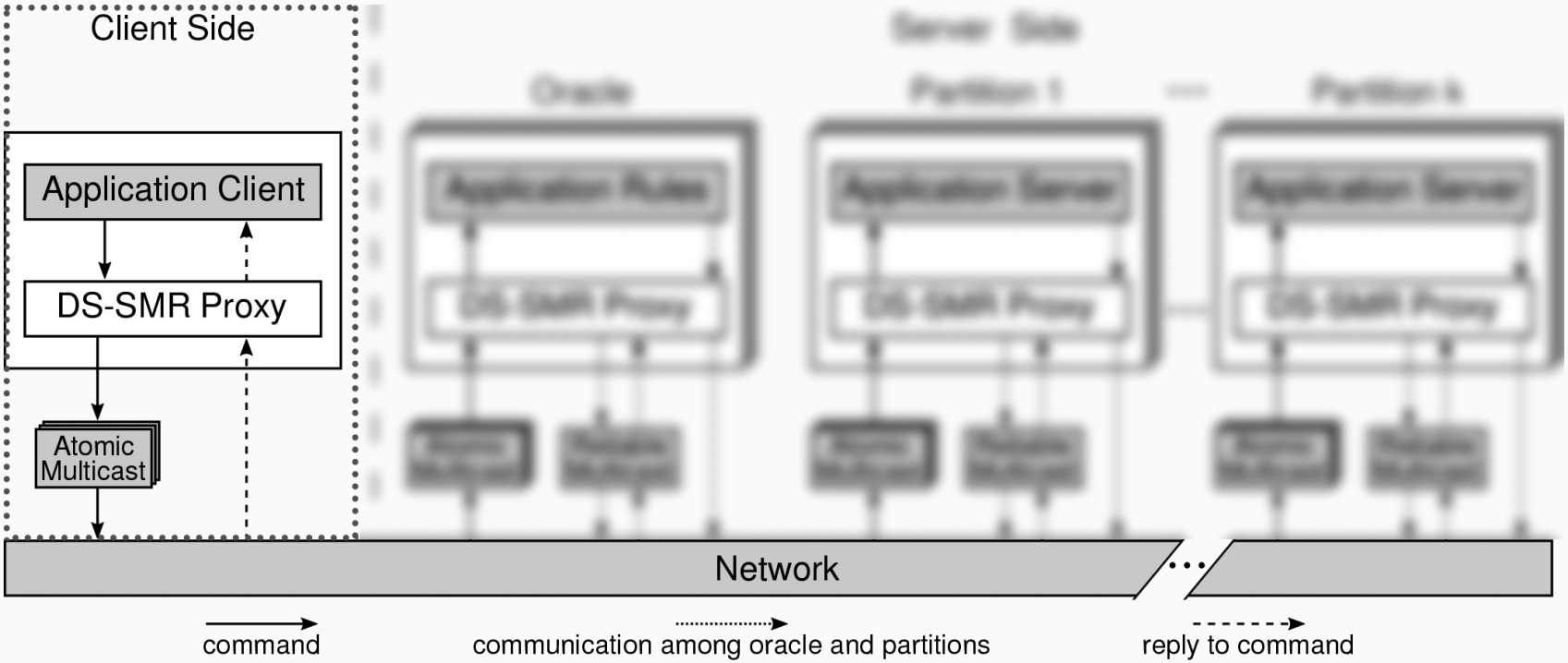


Architecture



- Clients atomically multicast commands to oracle and partitions
- Oracle and partitions exchange messages through reliable multicast

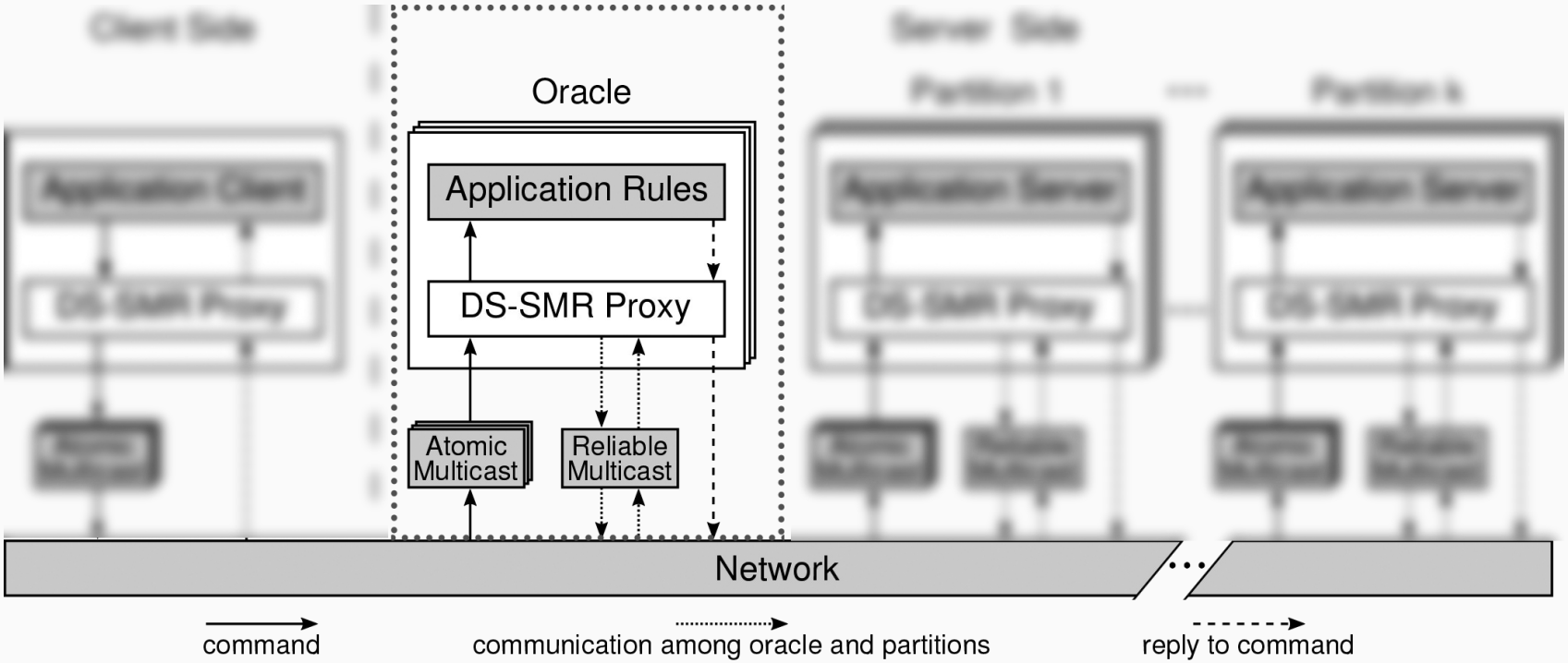
Architecture



Client

- Application Client
- DS-SMR Client Proxy

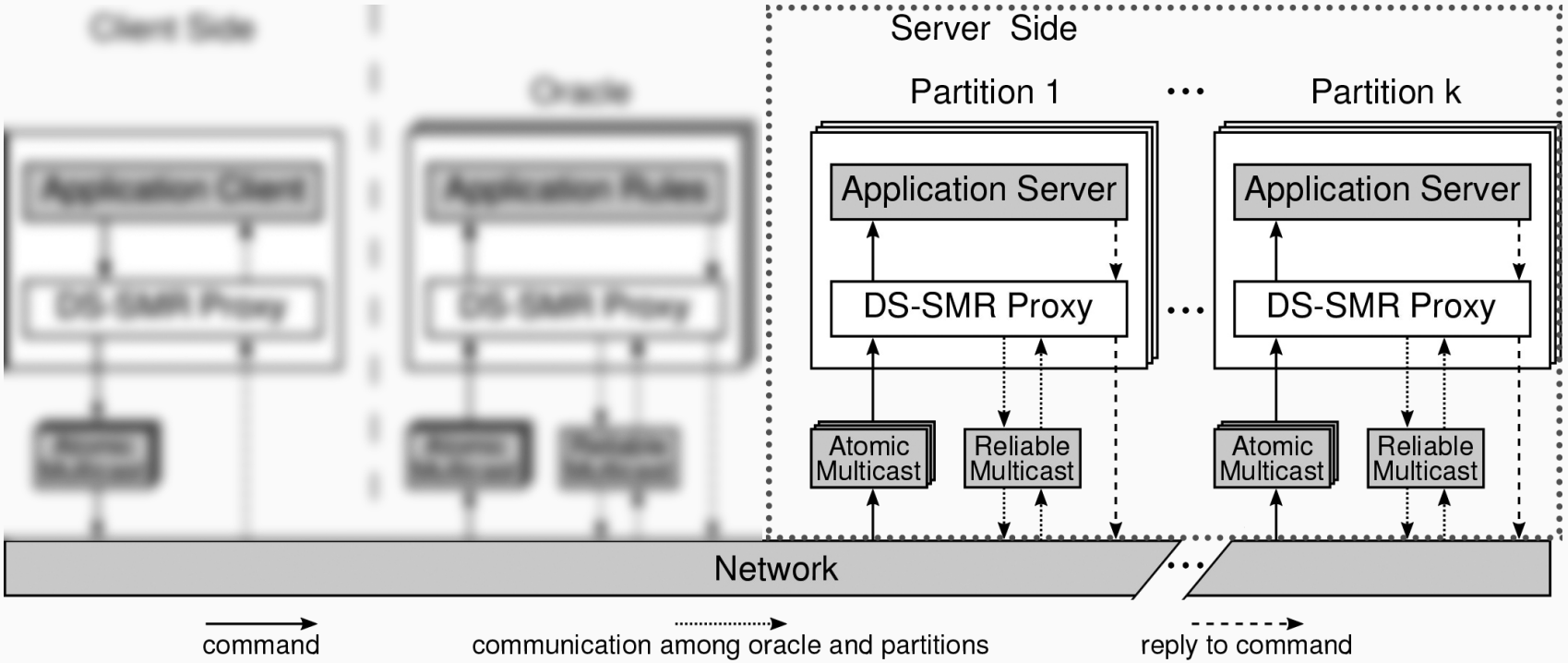
Architecture



Oracle

- Application Oracle
- DS-SMR Oracle Proxy

Architecture



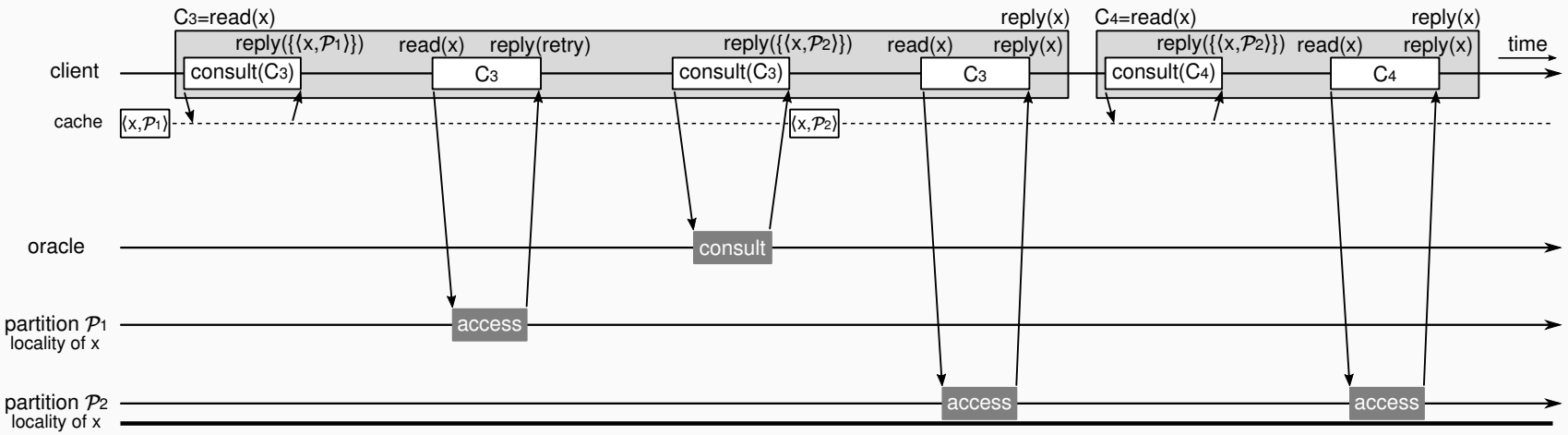
Server

- Application Server
- DS-SMR Server Proxy

Performance optimizations

- Caching
  - Each client proxy has a local cache
  - Client consults local cache to determine variable's location
  - When retrying command, clients update cache
- Client's cache could accurately resolve most query

Performance optimizations



Implementation & Evaluation

Eyrie

Eyrie simplifies implementing services based on DS-SMR

Provides proxy layers

Allows application designers to override default behaviors

- The PRObject class
- The Client class
- The StateMachine class
- The OracleStateMachine class

Chirper

Social network application similar to Twitter

Supports commands:

- post
- getTimeline
- follow, unfollow

State partitioning is based on users' interest

Environment setup and configuration parameters

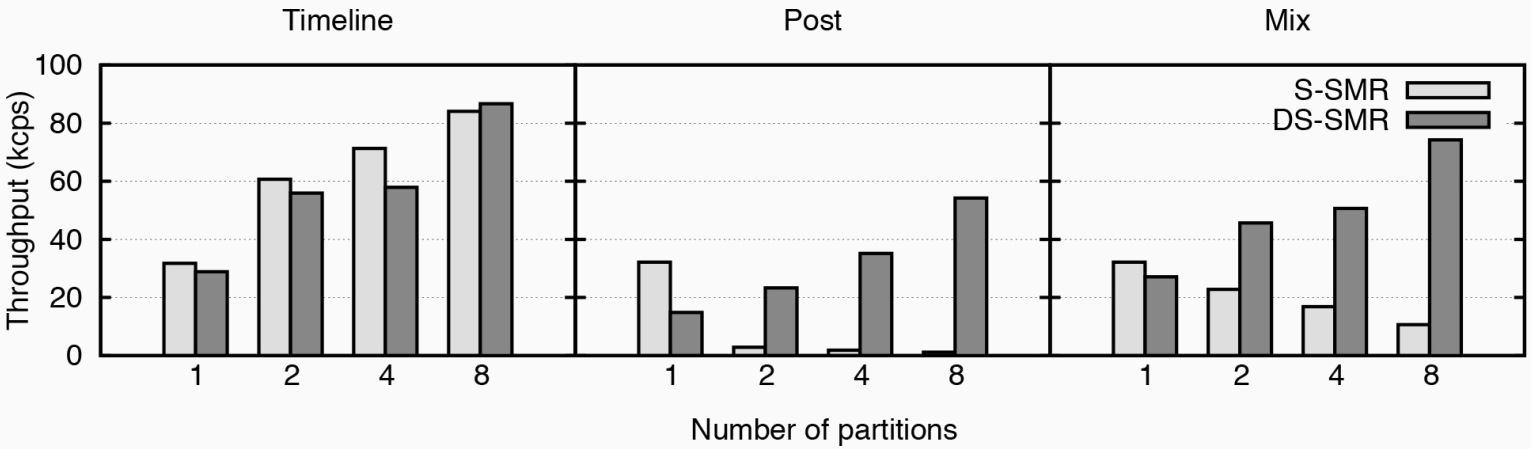
Running *Chirper* under different loads and partitionings

Number of partitions: 2, 4, and 8

Workloads:

- Timeline
- Post
- Follow/Unfollow
- Mix (Timeline: 85%, Post: 7.5%, Follow: 3.75%, Unfollow: 3.75%)

Results


Timeline
Post
Mix
Throughput (kcps)
100
80
60
40
20
0
S-SMR
DS-SMR
1
2
4
8
Number of partitions

Conclusion

Summary

- S-SMR does not adapt to high rate of global command
- DS-SMR introduces dynamic repartitioning to S-SMR
- Results show that D-SSMR outperforms S-SMR when there is access locality
- Eyrie makes developing services based on DS-SMR much simpler

Q&A