Dynamic Scalable State Machine Replication

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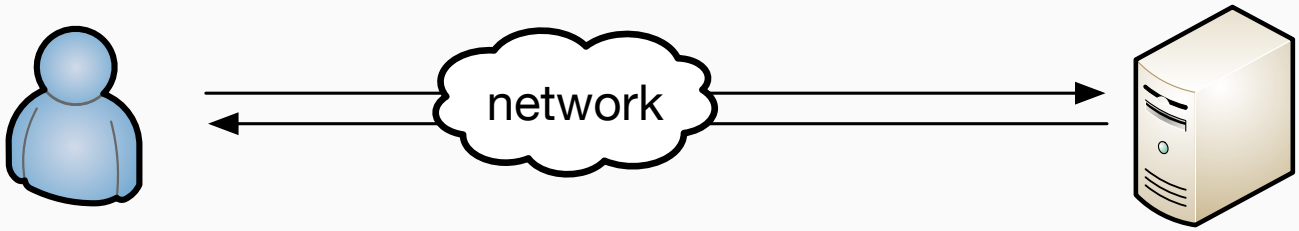
Outlines

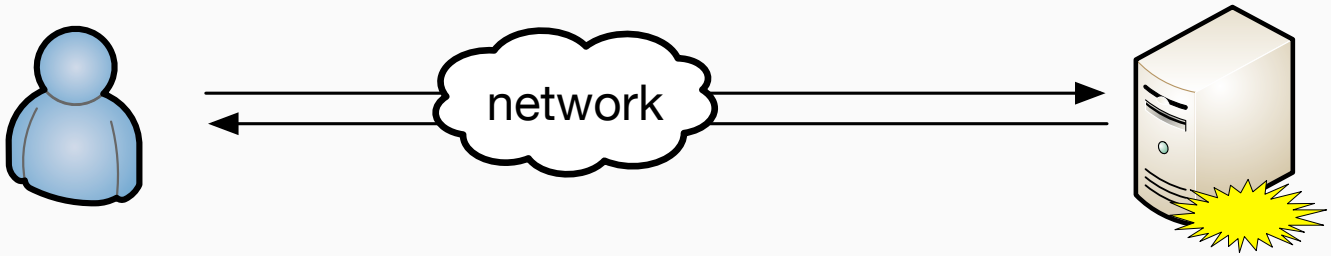
1. Motivation
2. Dynamic Scalable State Machine Replication
3. Implementation
4. Performance Evaluation
5. Conclusion

Motivation

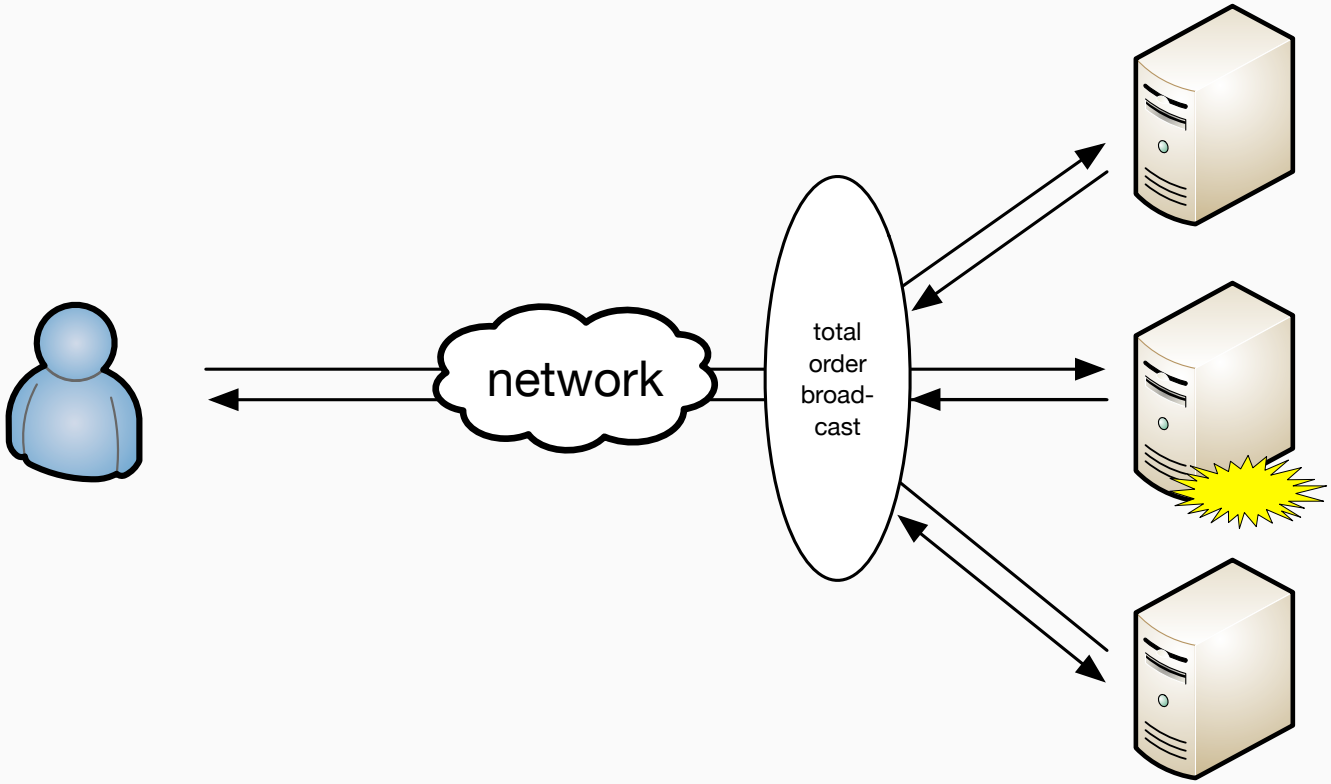
State Machine Replication



State Machine Replication



State Machine Replication



State Machine Replication

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

Production systems

- Google Spanner, Windows azure storage, CockroachDB, HydraBase, Chubby

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

Applies state partitioning

- Partitions application's state and replicates each partition
- Relies on an atomic multicast primitive

Guarantees strong consistency (ie. linearizability)

- Provides execution atomicity

Scalable State Machine Replication

Assumes a static workload partitioning

- Relies on static mapping
- Mapping does not need to be minimal

Expensive cost of multi-partition commands

- Partitions need to exchange signal
- Performance decreases when number of involved partitions increases

Dynamic Scalable State Machine Replication

System Model

Communication by message passing

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

Crash-recovery failure model

- No Byzantine behavior

System is partially synchronous

- No delay bound

Relies on atomic multicast

General idea

Dynamically changing the partitioning

- DS-SMR was designed to exploit workload locality
- Involved variables are moved to a single partition
- Command is executed against this partition
- Variable mapping managed by an Oracle partition

Distinguishes five types of commands

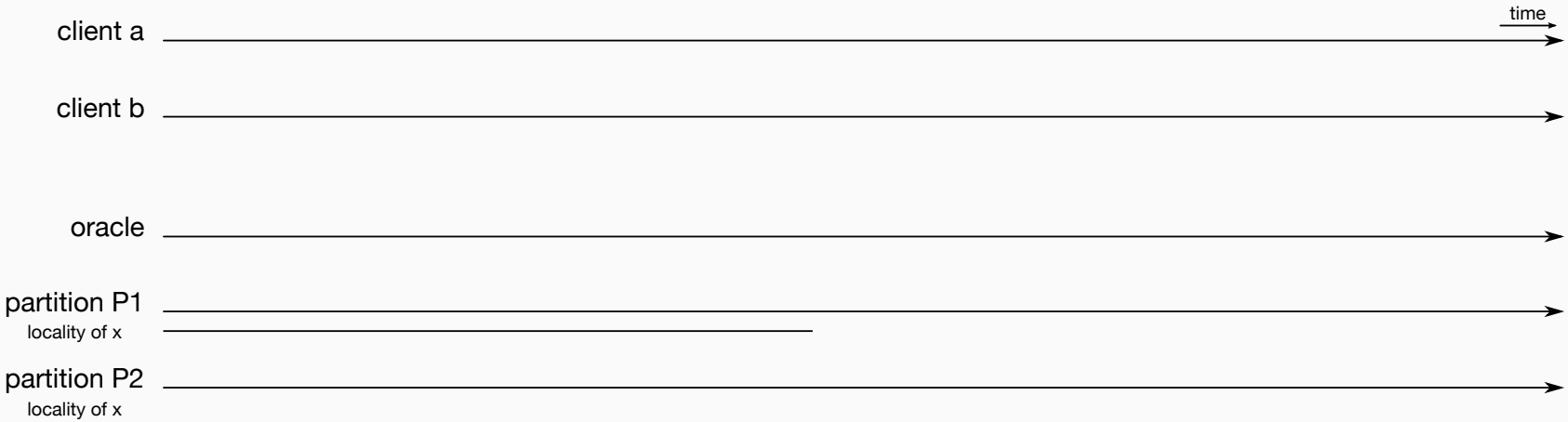
- $access(w), create(v), delete(v), move(v, Ps, Pd), consult(C)$

Clients consult the oracle to know variable's location

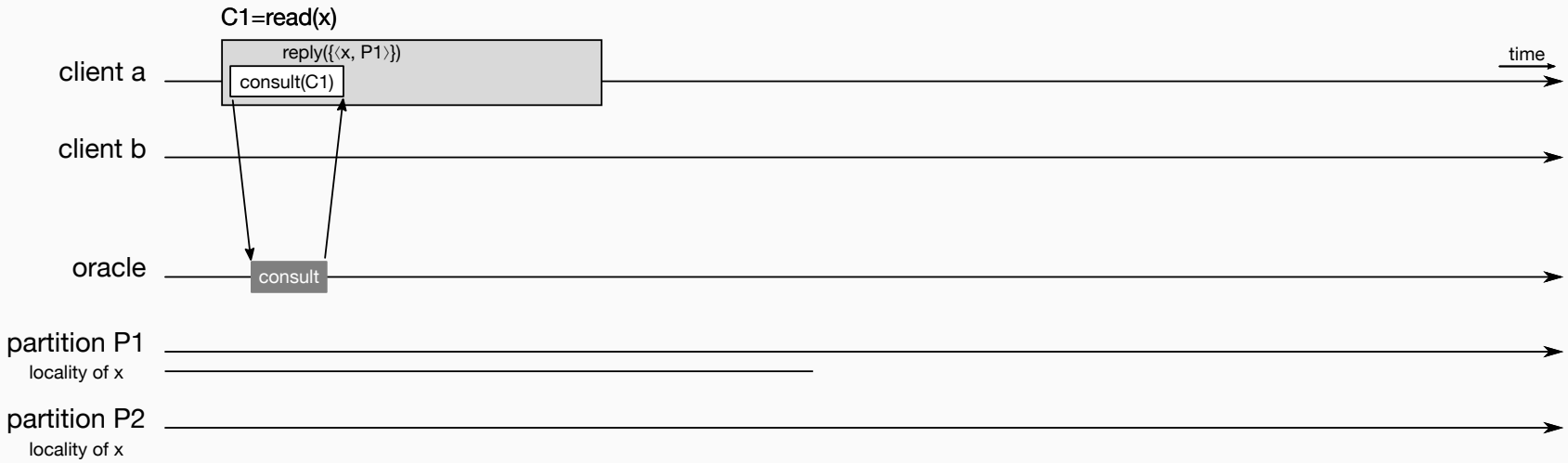
Clients *retry* if command execution is failed

Clients retry command using S-SMRs execution atomicity after a number of retries.

General idea



General idea



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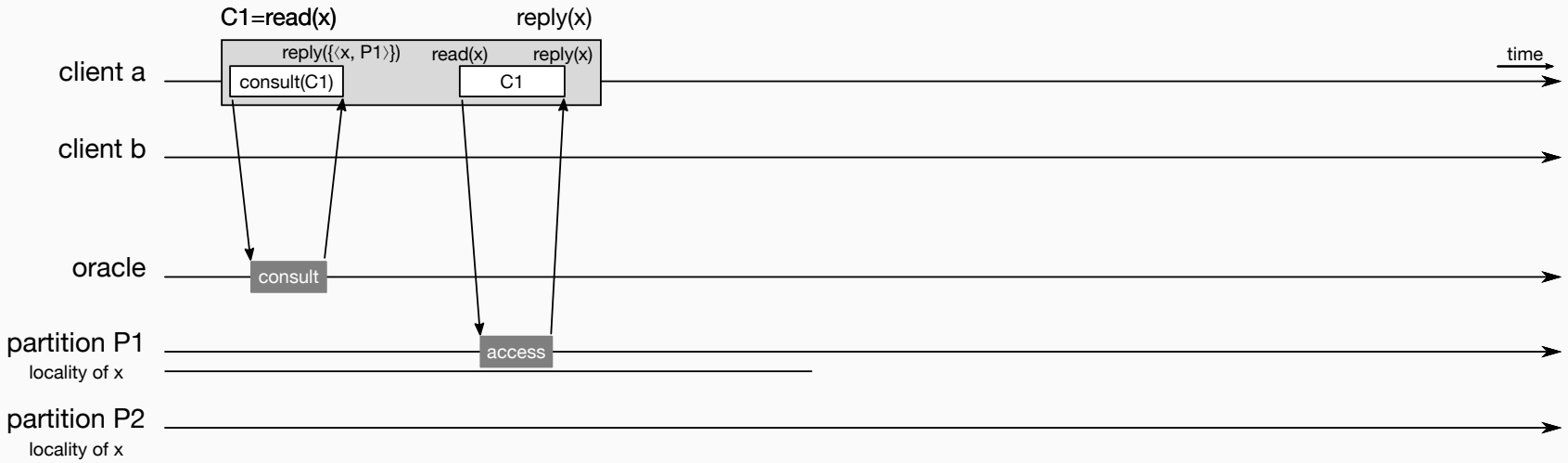

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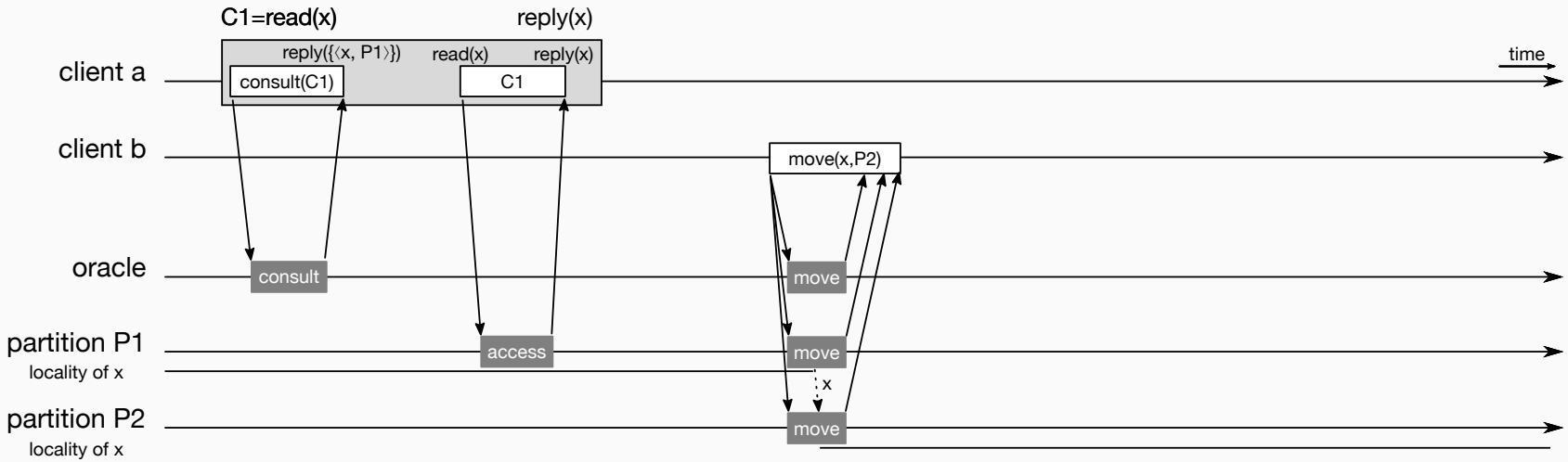

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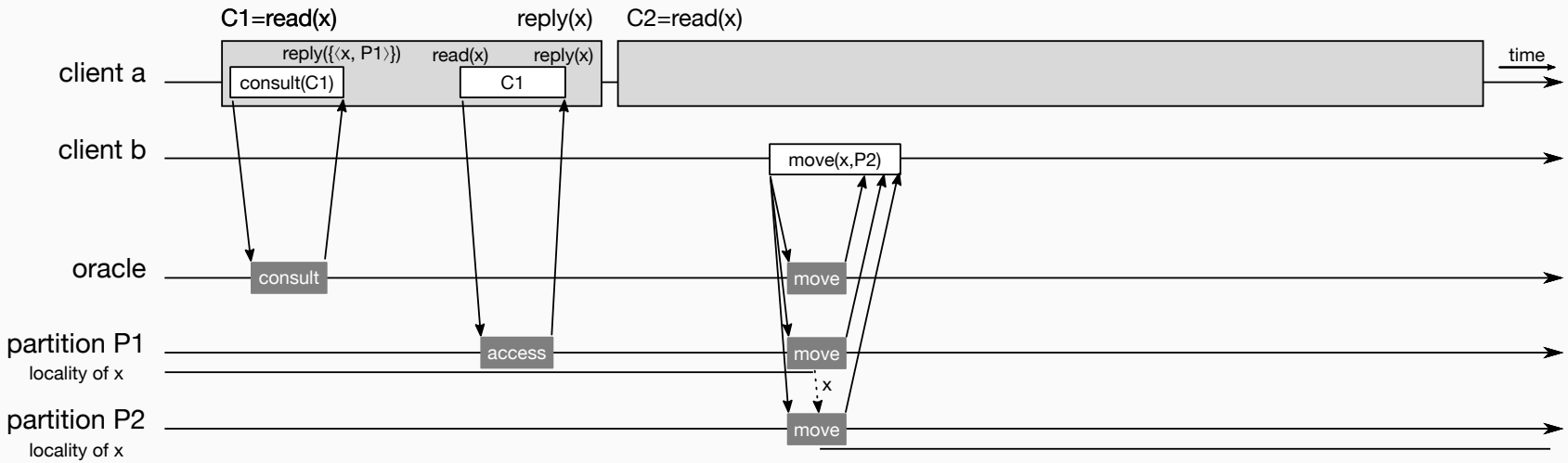

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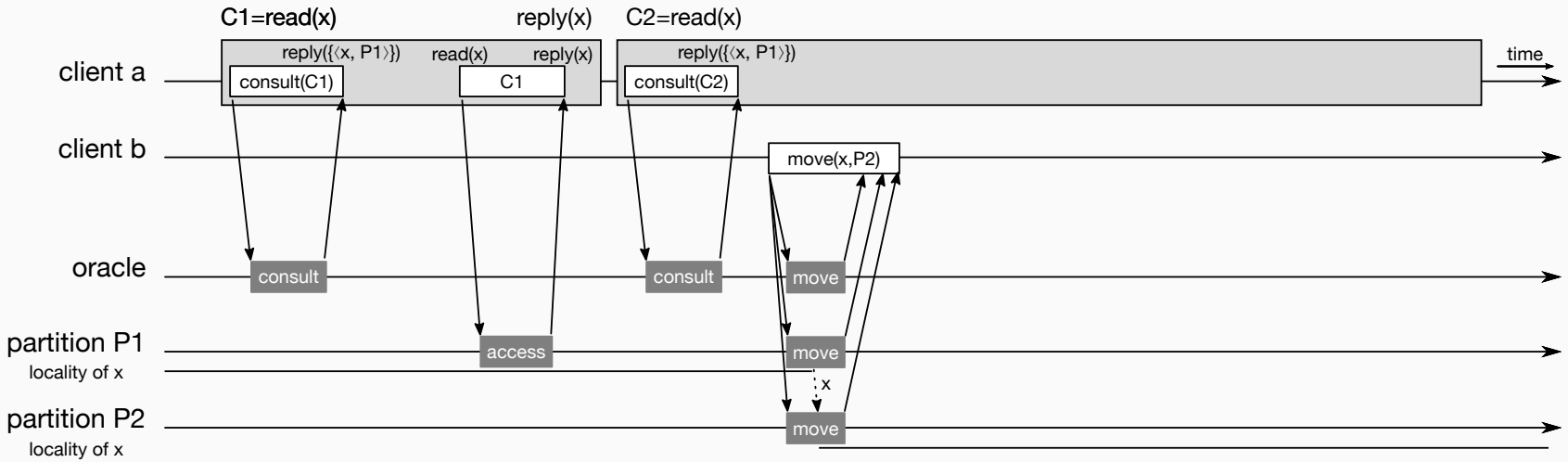

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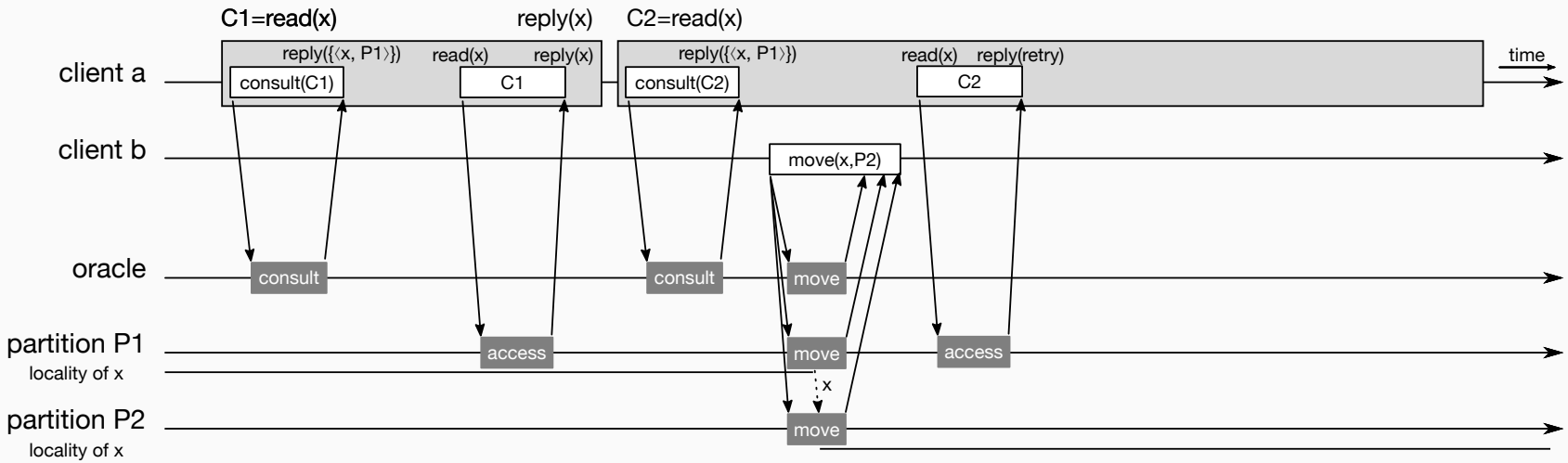

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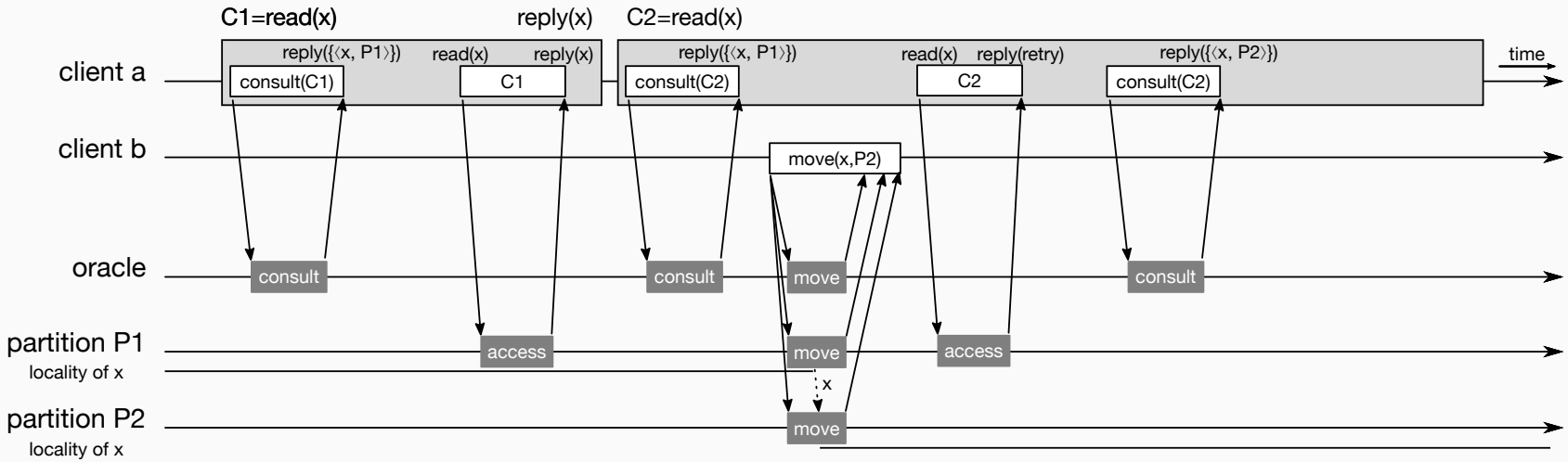

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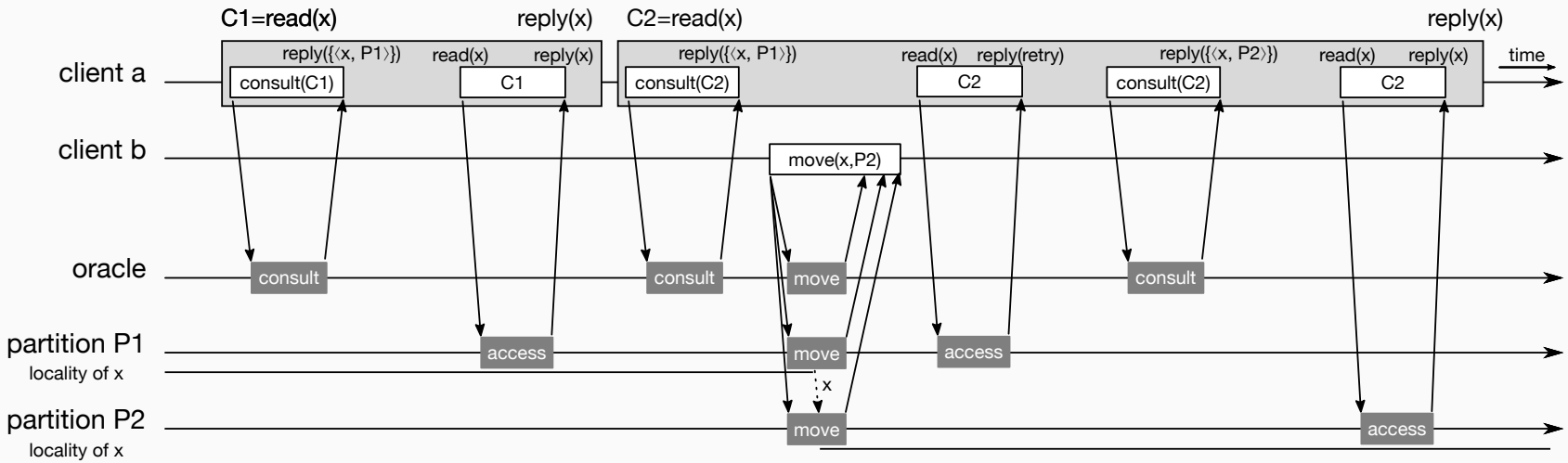
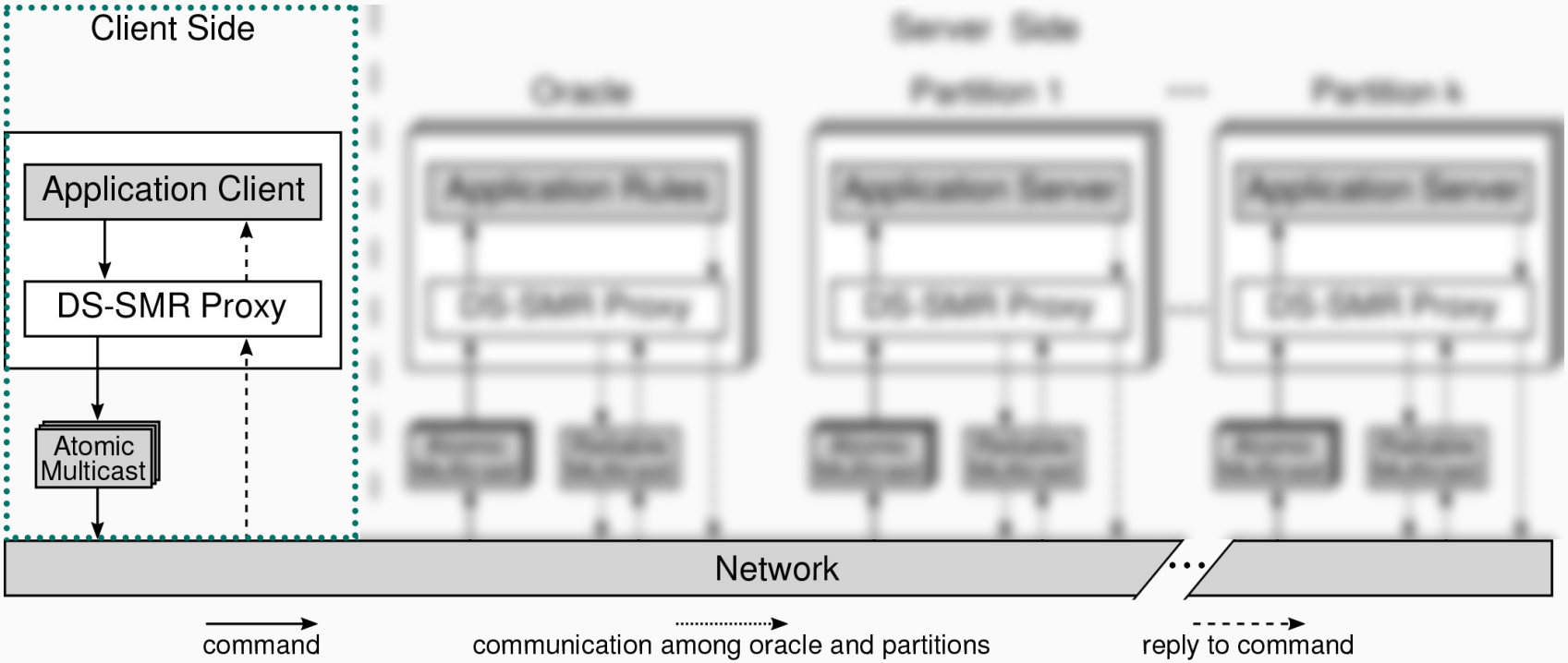


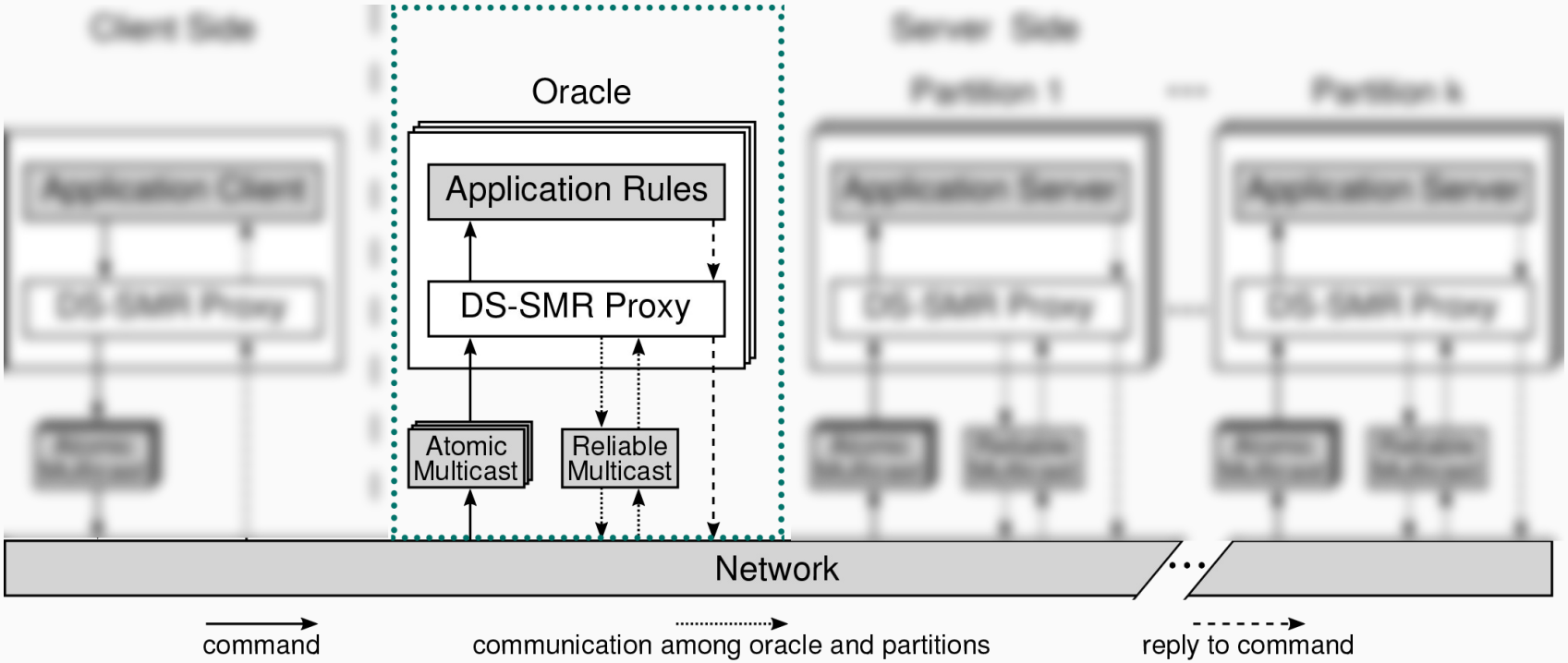
Architecture



Client

- Application Client
- DS-SMR Proxy Client

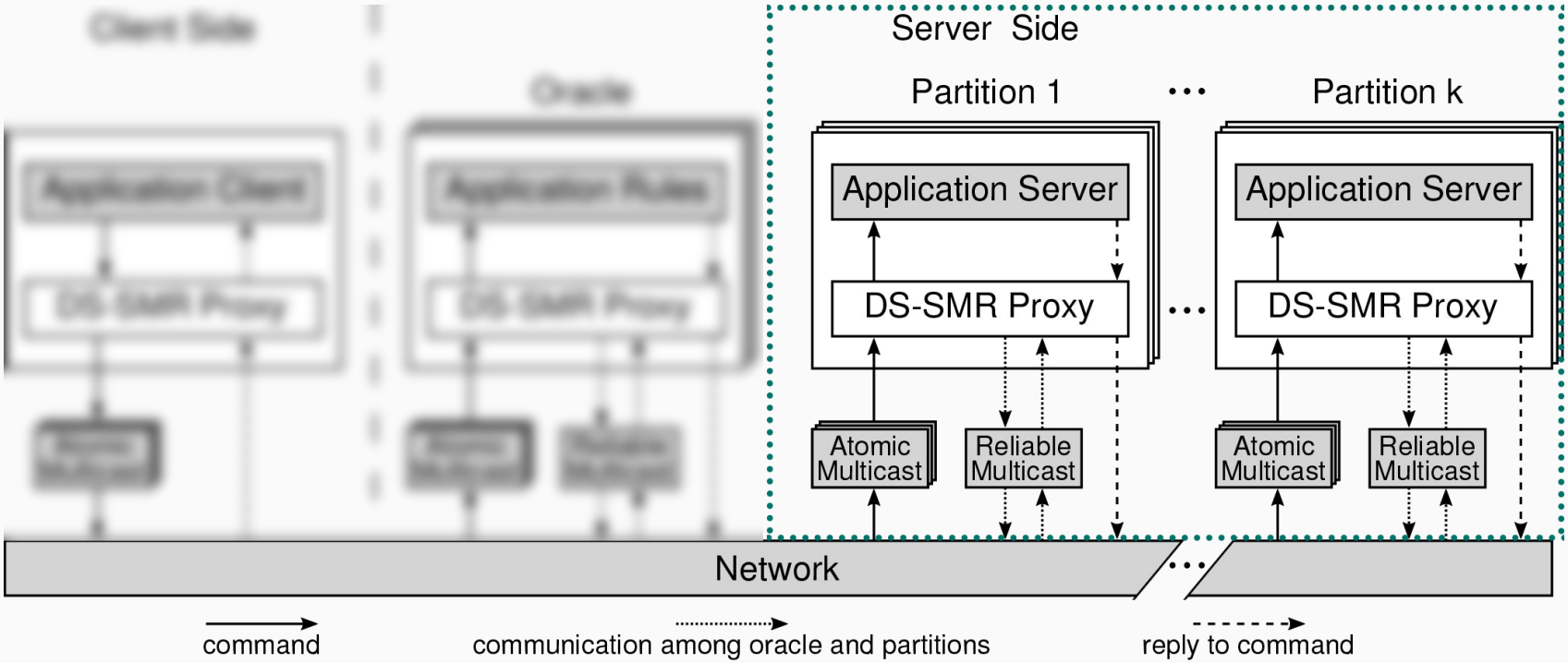
Architecture



Oracle

- Application Oracle
- DS-SMR Proxy Oracle

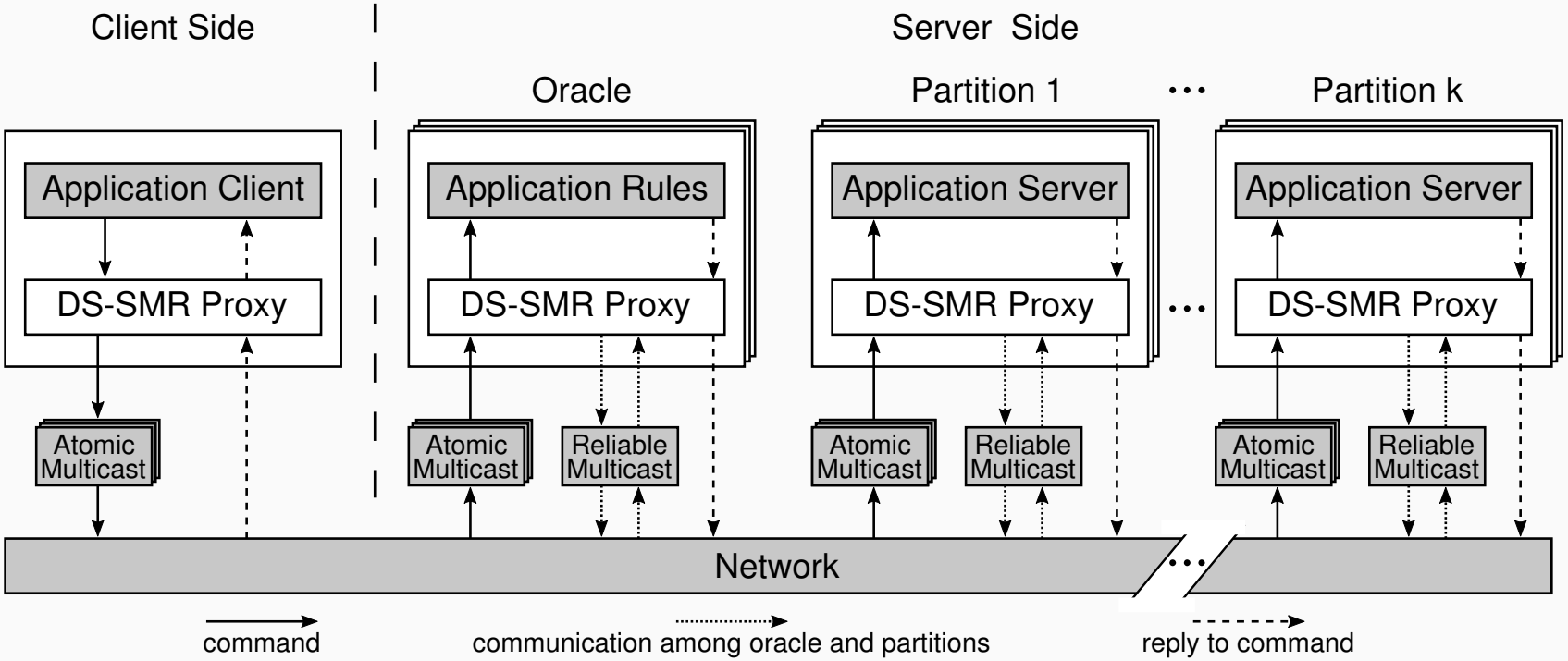
Architecture



Server

- Application Server
- DS-SMR Proxy Server

Architecture

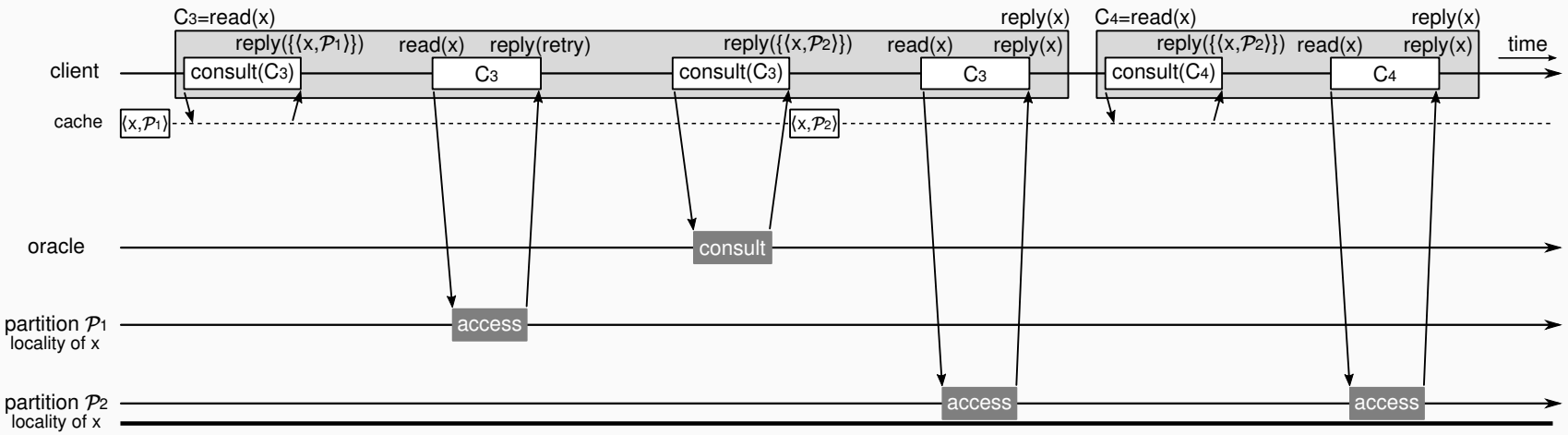


- Clients atomic multicast commands to oracle and partitions
- Oracle, partitions exchange message by reliable multicast

Performance optimizations

- Caching
  - Each client proxy has a local cache
  - Client consults local cache for determine variable's location
  - Client retry command and update invalid cache
- Under the assumption of locality, most consults queries will be accurately resolved by the clients cache

Performance optimizations



Implementation

Eyrie

Makes the implementation of services based on DS-SMR as easy as possible.

Provides proxy layers

Allows application designers to override default behaviors.

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

Chirper

Social network application similar to Twitter

State partitioning is based on users interest.

Support commands:

- post
- getTimeline
- follow, unfollow

Performance Evaluation

Environment setup and configuration parameters

Running *Chirper* under different loads and partitionings.

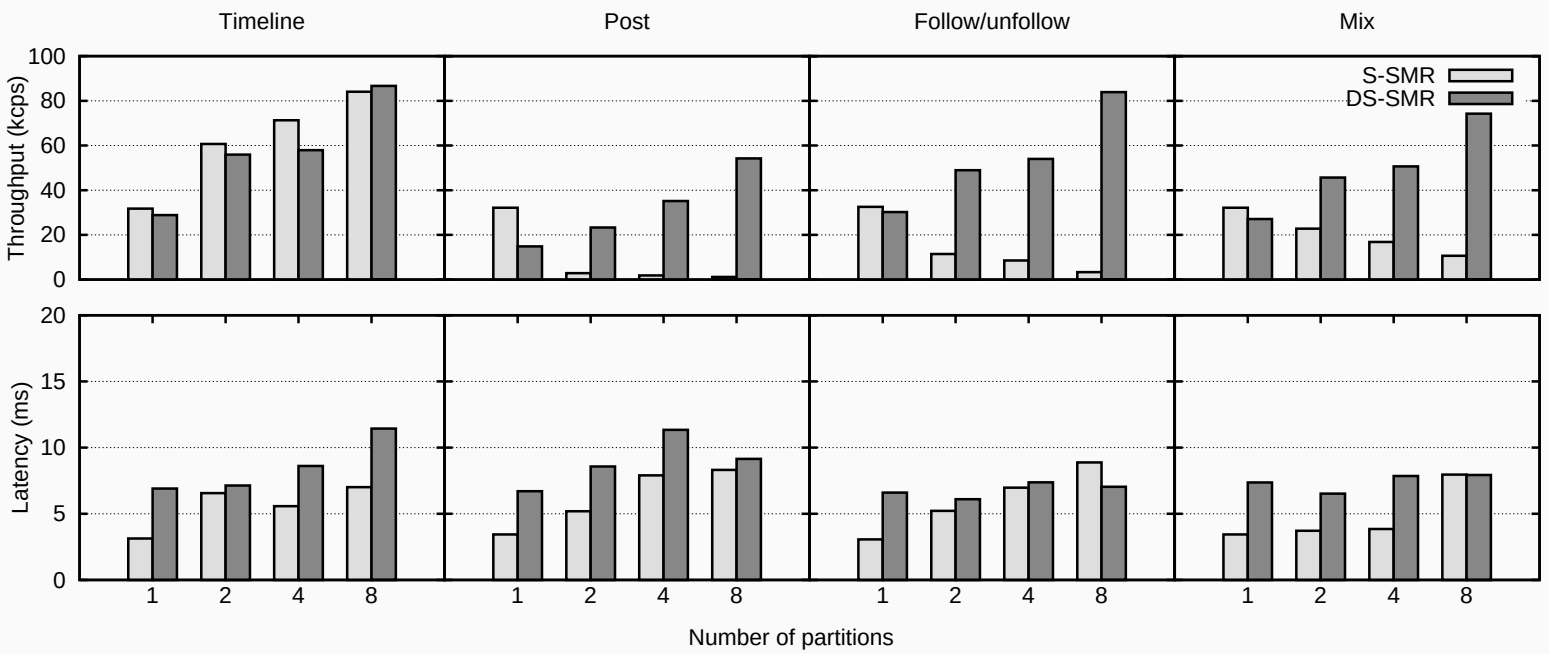
Partitioning: 2 replicas and 3 acceptors for each partition

Experiment on 2, 4, 8 partitions

Workloads:

- Get Timeline
- Post
- Follow, Unfollow
- Mix

Results


Timeline
Post
Follow/unfollow
Mix
S-SMR
DS-SMR
Throughput (kcps)
100
80
60
40
20
0
Latency (ms)
20
15
10
5
0
1
2
4
8
Number of partitions

Conclusion

Summary

- Introduces Dynamic Scalable State Machine Replication (DS-SMR)
- Details Eyrie, a Java library to simplify the design of services based on DS-SMR
- Describes Chirper to demonstrate how Eyrie can be used.
- Presents a detailed experimental evaluation of Chirper to compare the performance of the two replication techniques.

Questions?