Improving Mobile Database Access Over Wide-Area Networks Without Degrading Consistency

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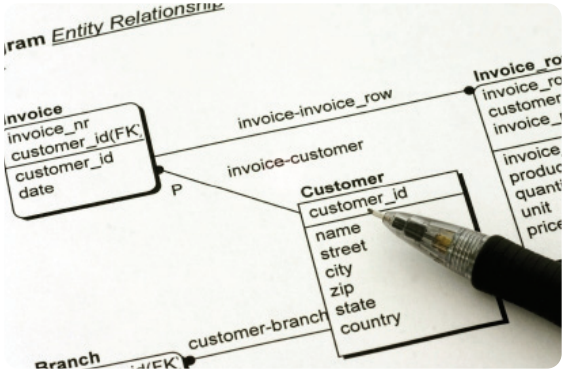
Motivation

- Increased database use over wireless WANs
  - CRM, Sales, Insurance, etc…
- Providing performance and consistency is hard
  - Bandwidth problem acute for wireless networks
  - Previous solutions tend to use:
    - weaken consistency [Bayou, Mariposa, DBCache, Barbara99, …]
    - per-application consistency model [Gao03, Ganymed, …]

Cedar: Mobile Database Access



Mobility

Database Systems

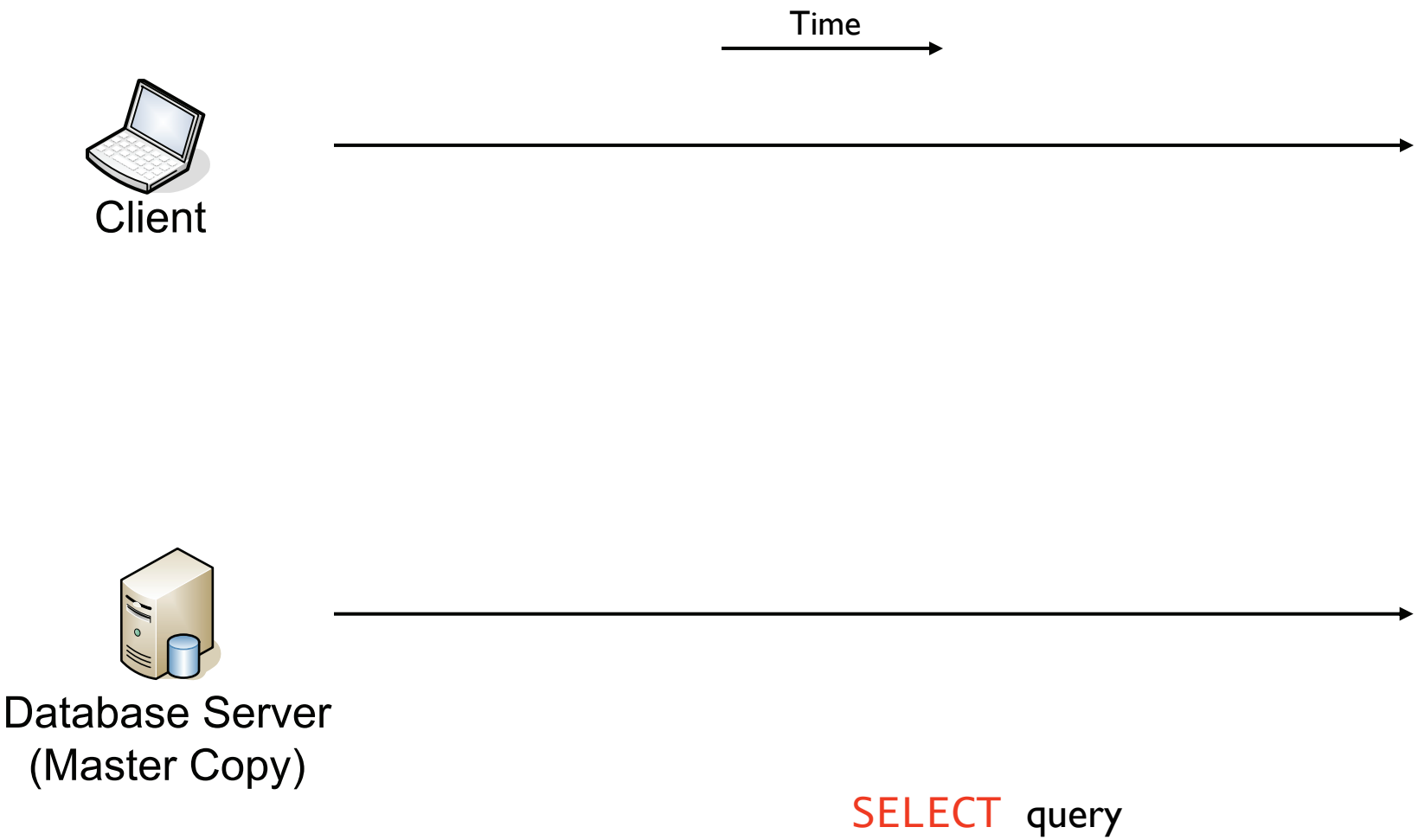
Cedar

- Cedar optimizes mobile database access
  - Improves performance under weak connectivity
  - Does not weaken consistency or modify application
- Scope
  - Mobile users and wireless WANs
  - Assume at least some weak connectivity
  - OLTP-style applications
    - Query size smaller than results
    - Will show evaluation from a TPC-based benchmark

Key Insight

- A *stale database replica* on the client can be useful
  - Optimistic use to reduce data transmission volume
- Stale replicas can be used without compromises
- Tradeoff increased computation for network savings

High-level overview



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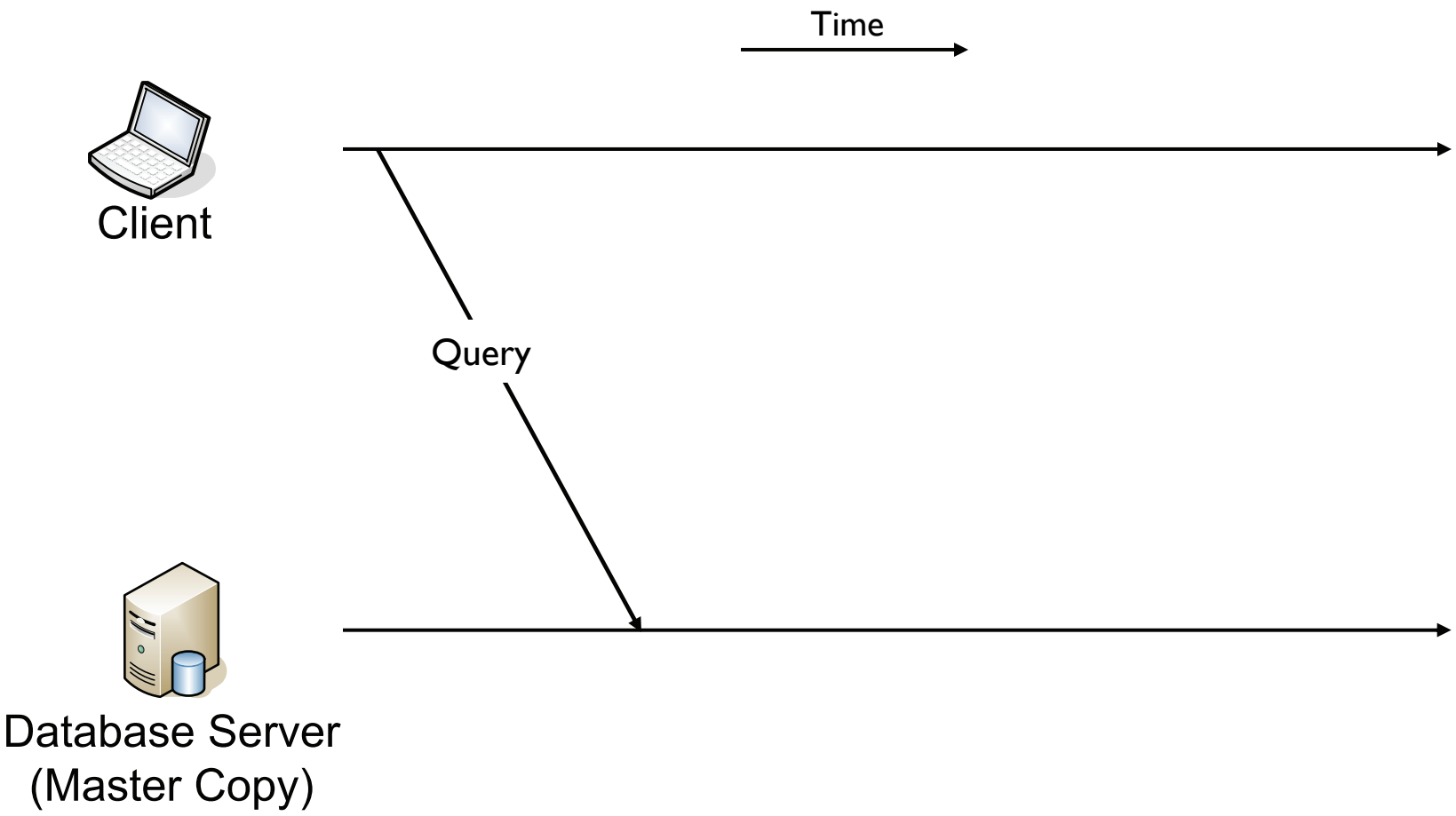

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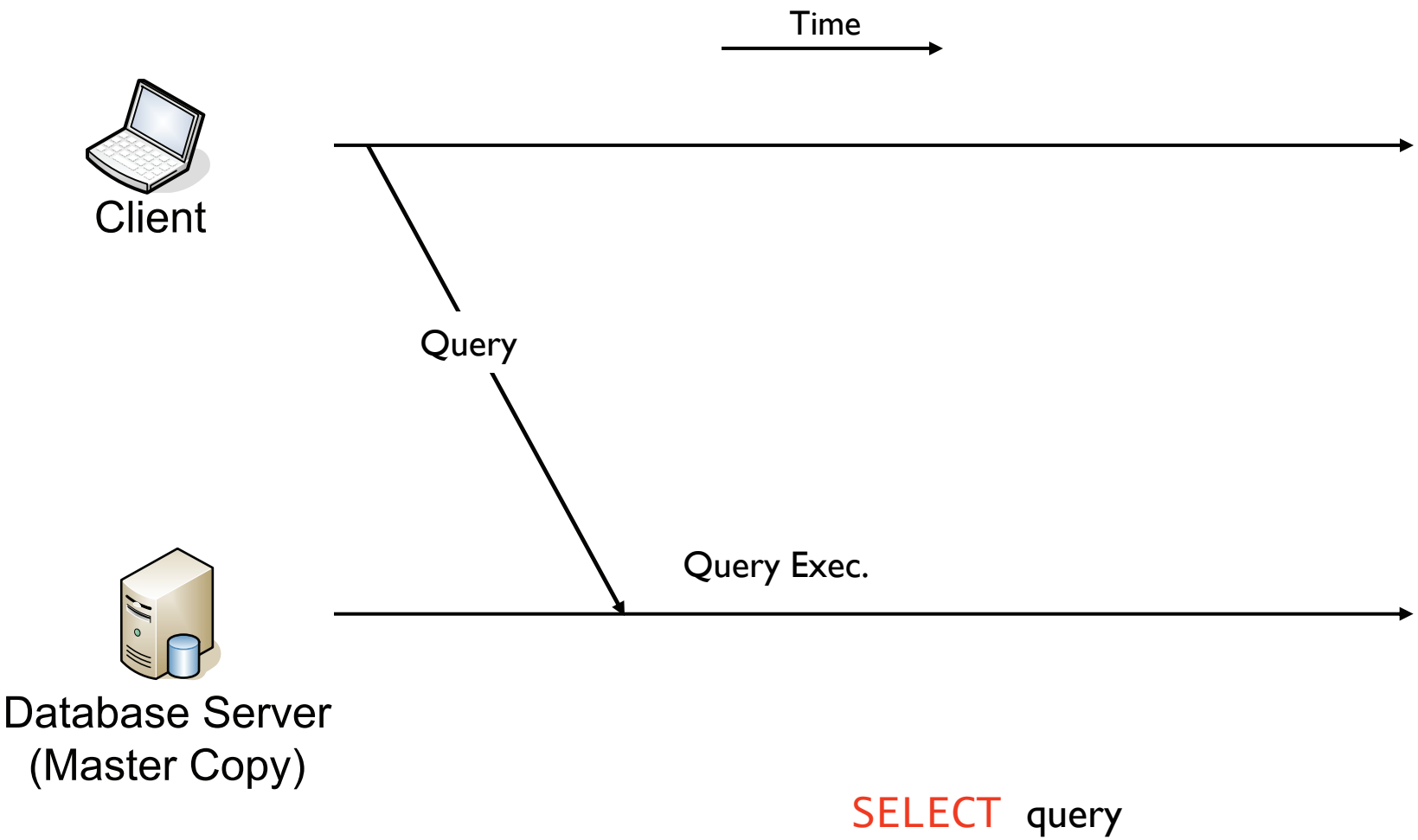

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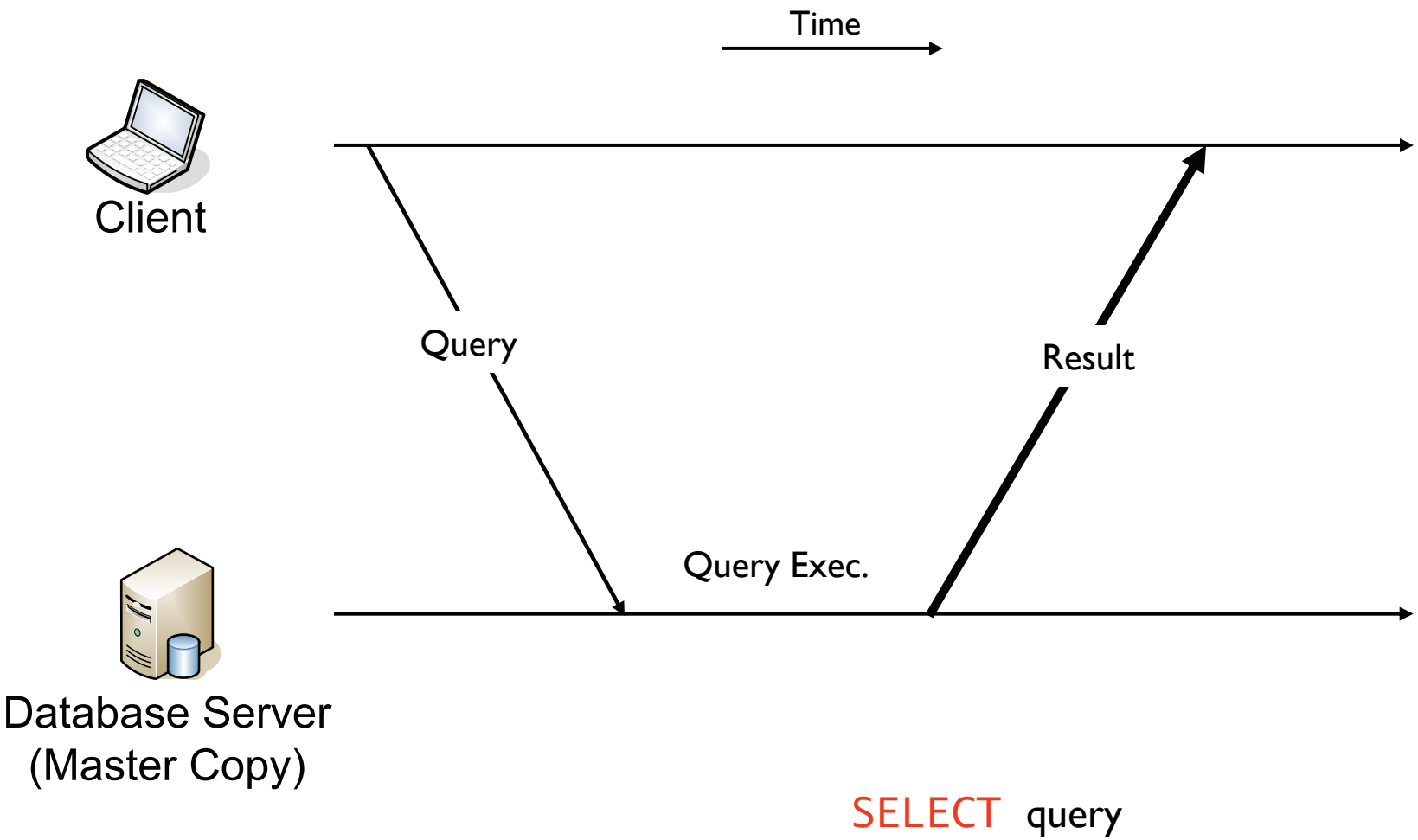

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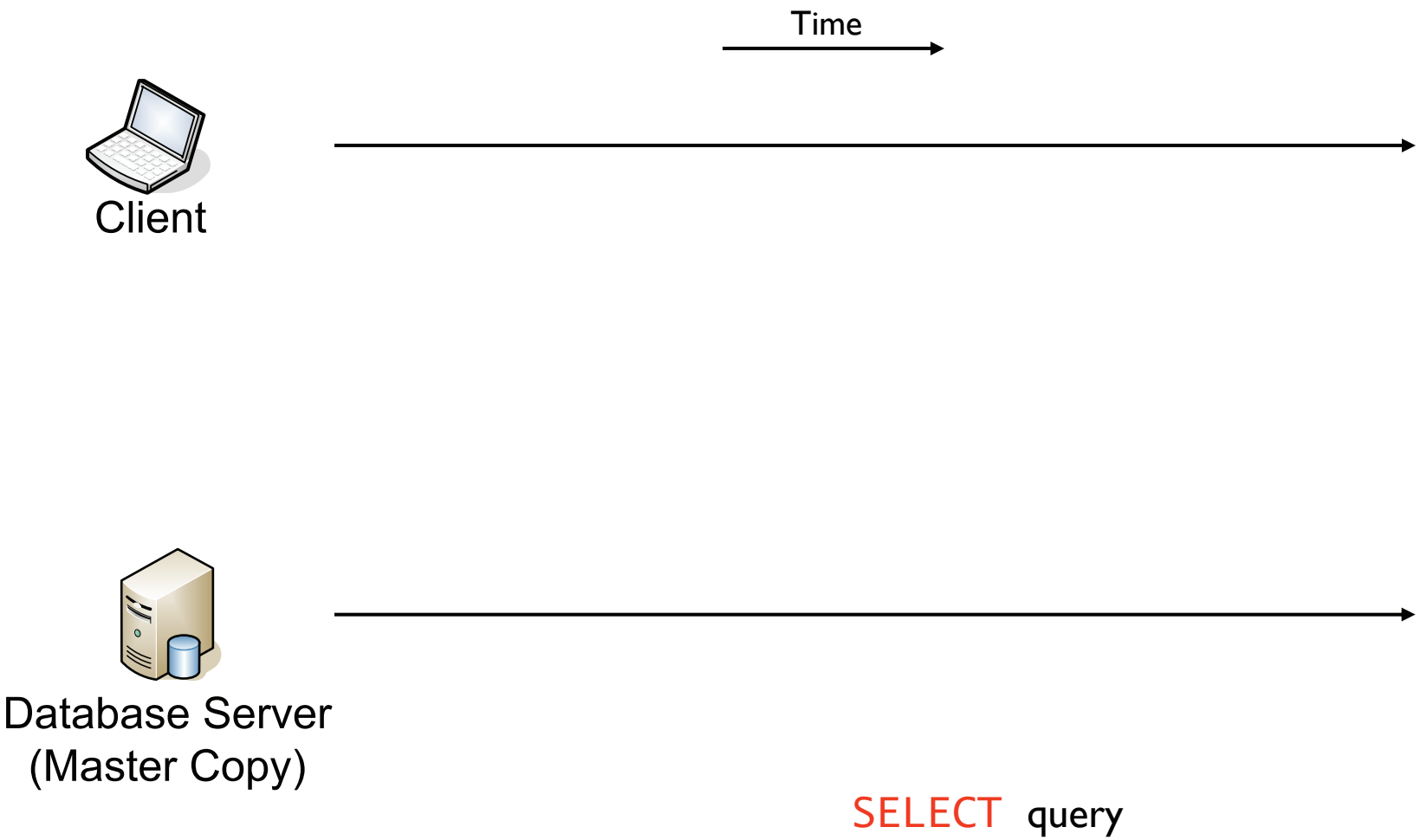

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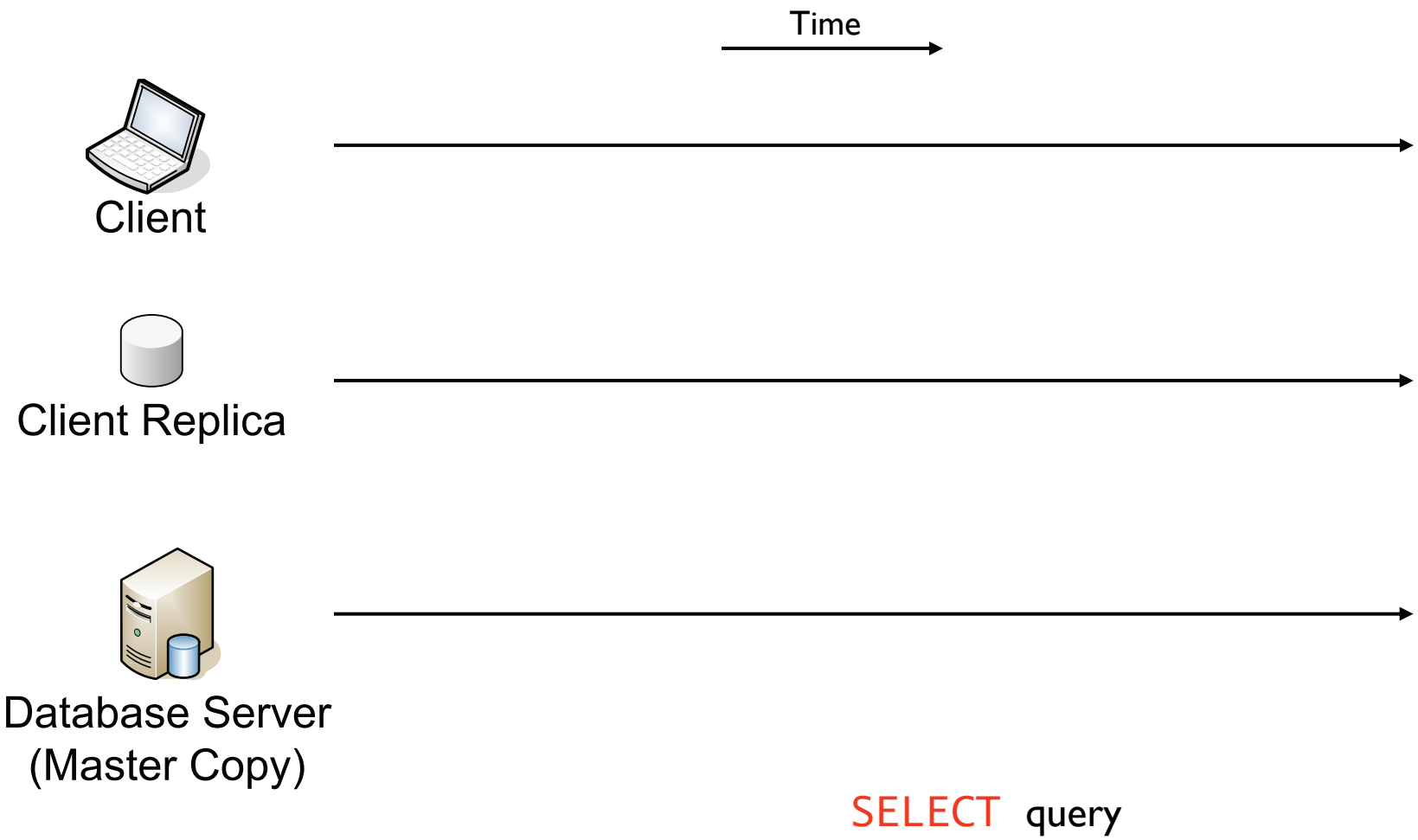

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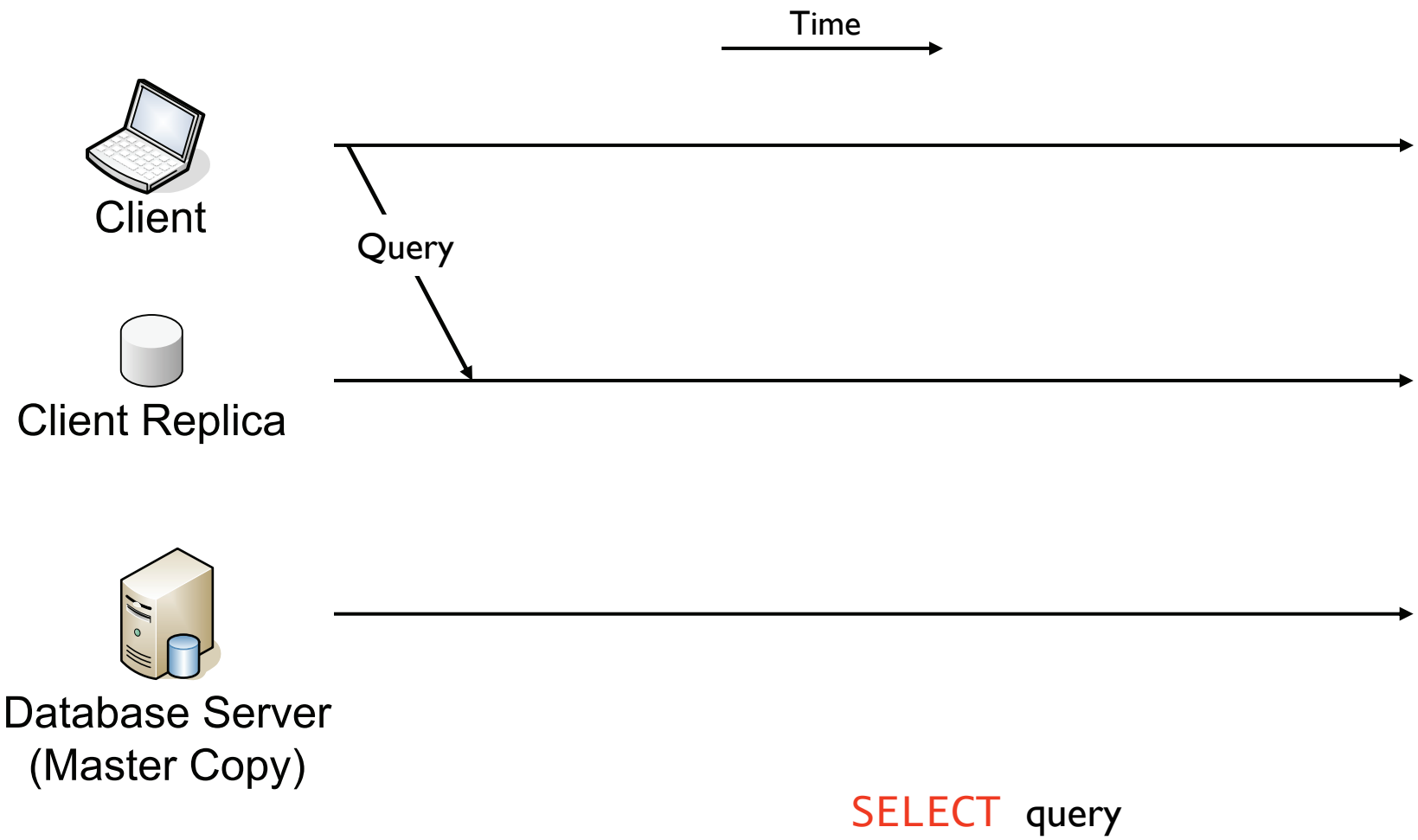

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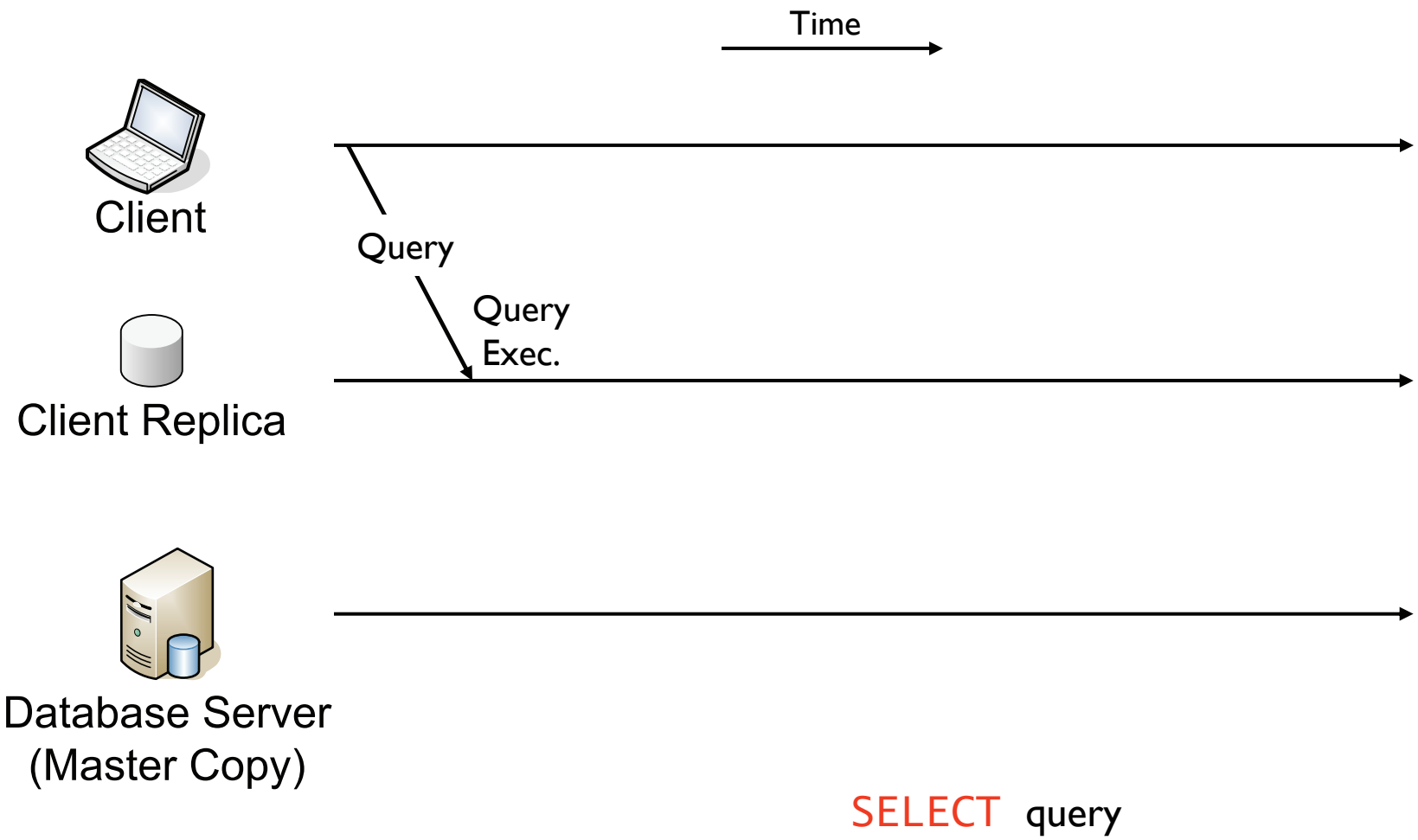

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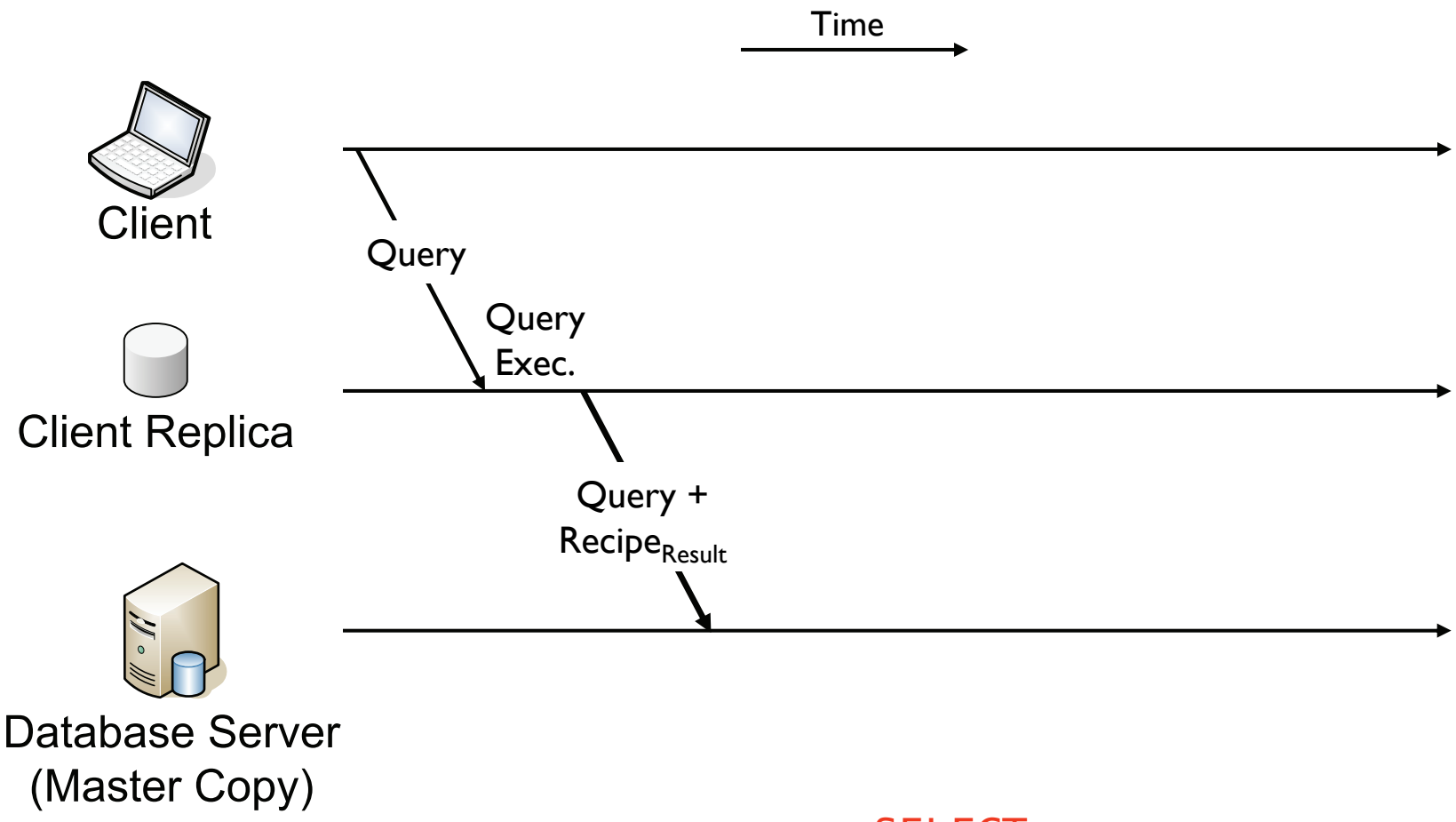

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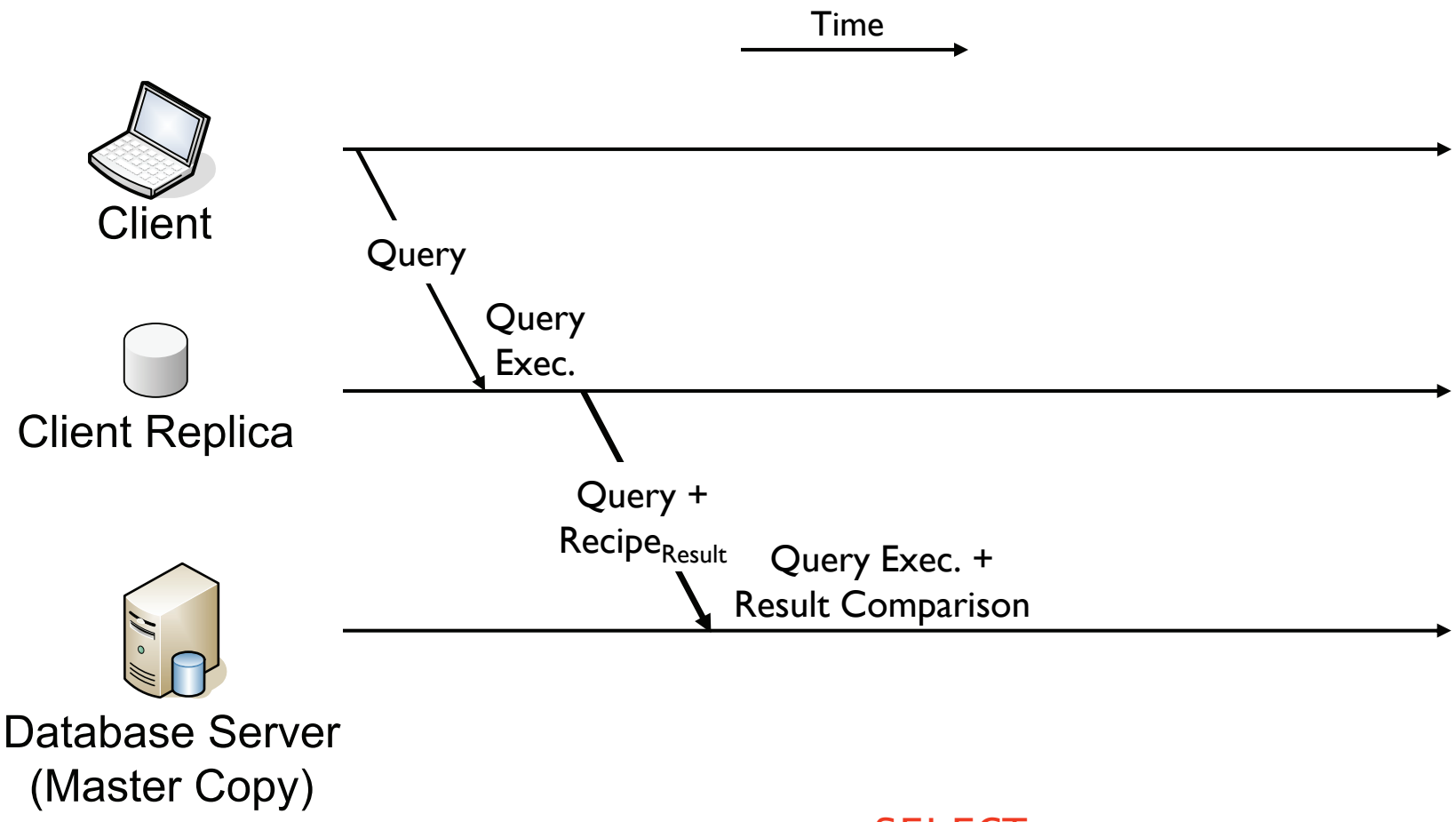

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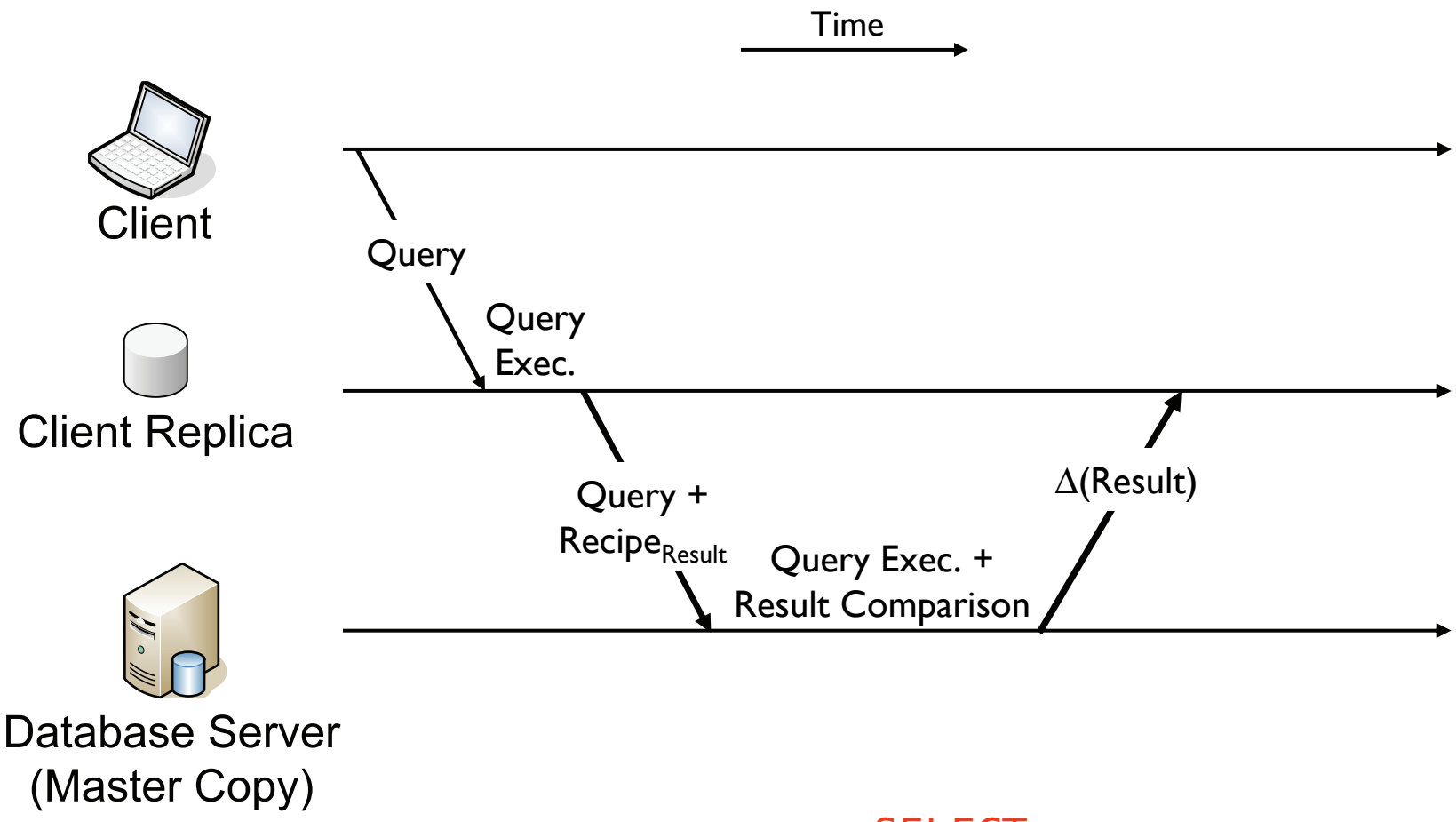

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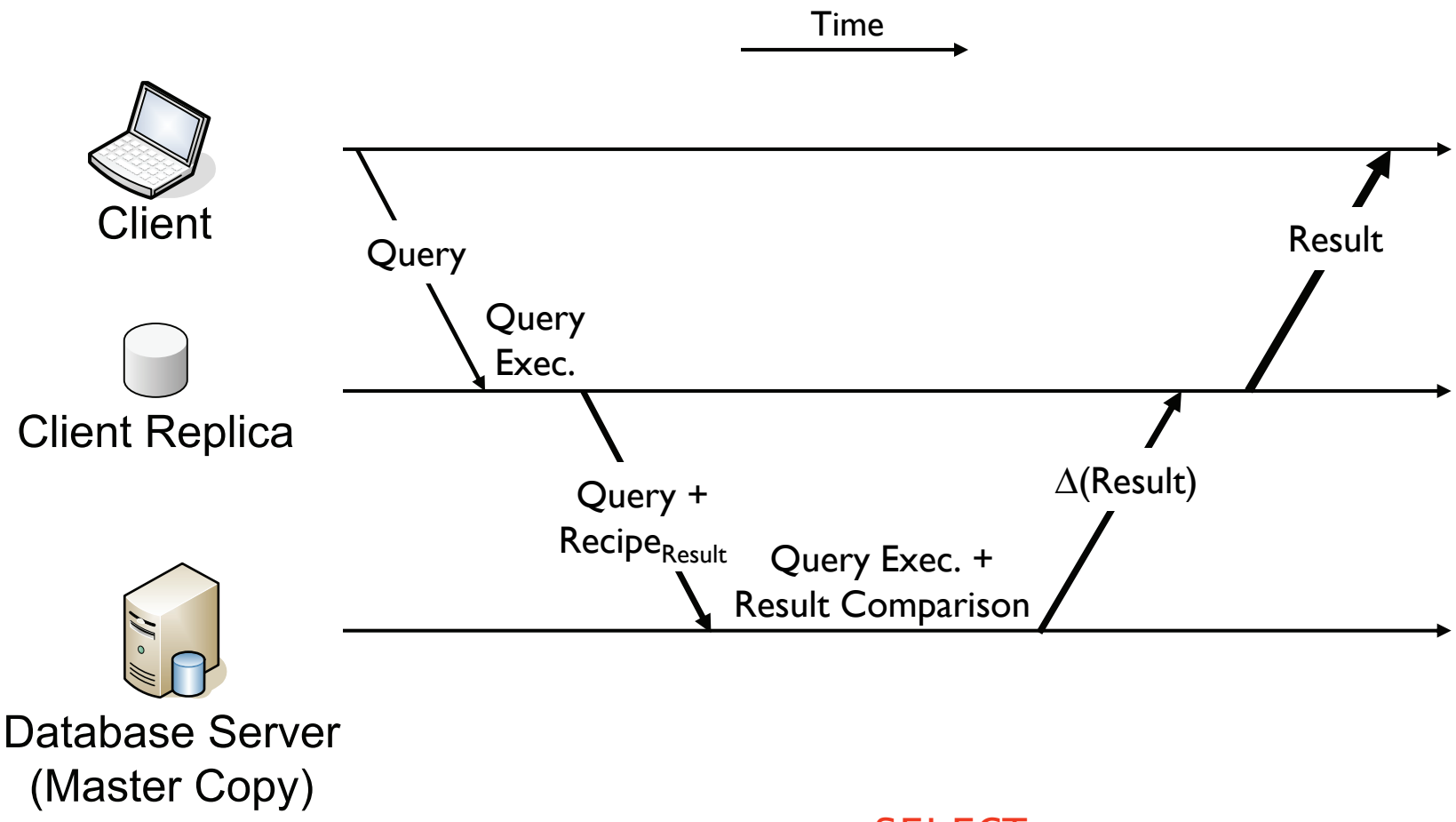

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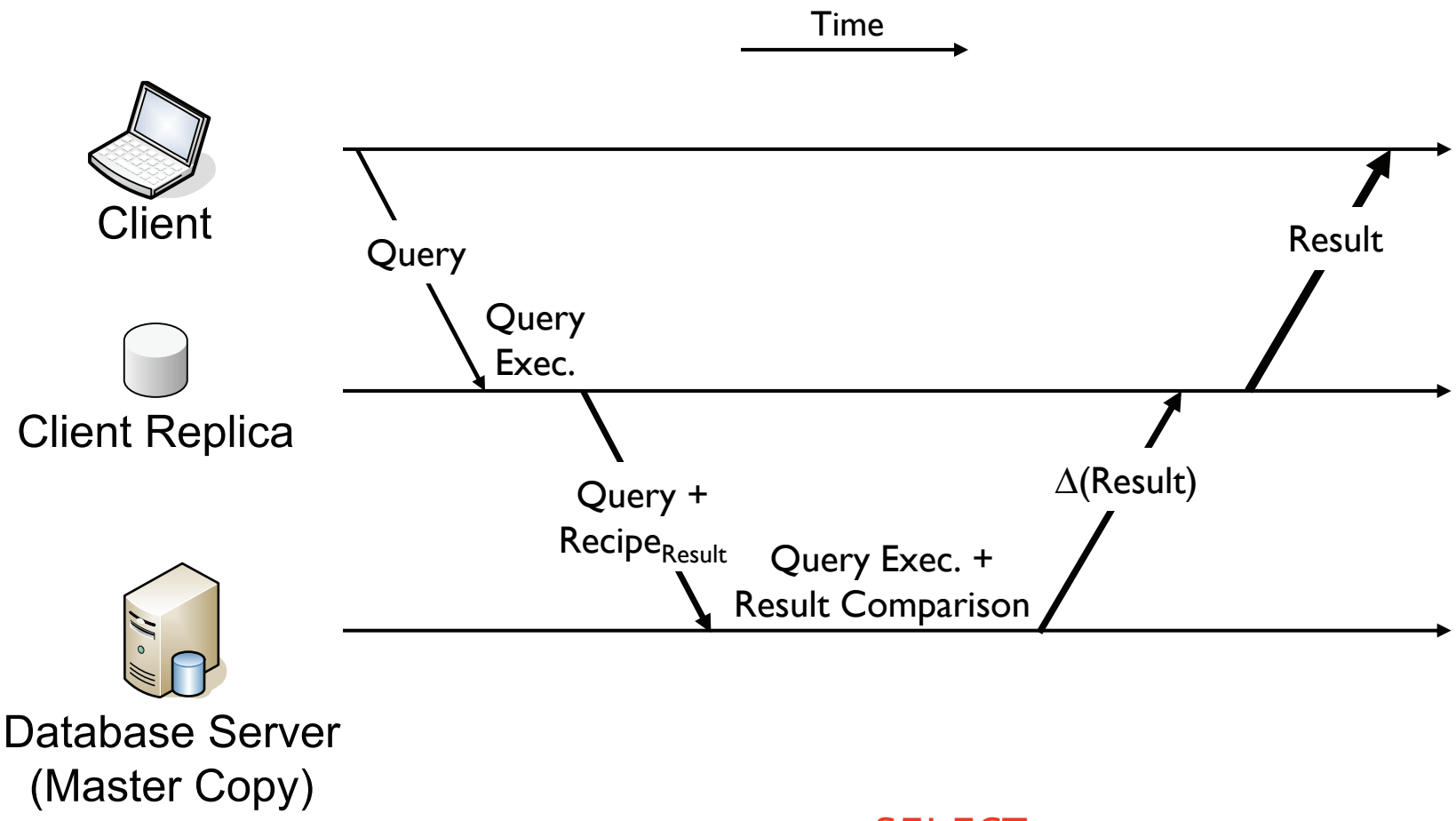

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UPDATE queries do directly to the server

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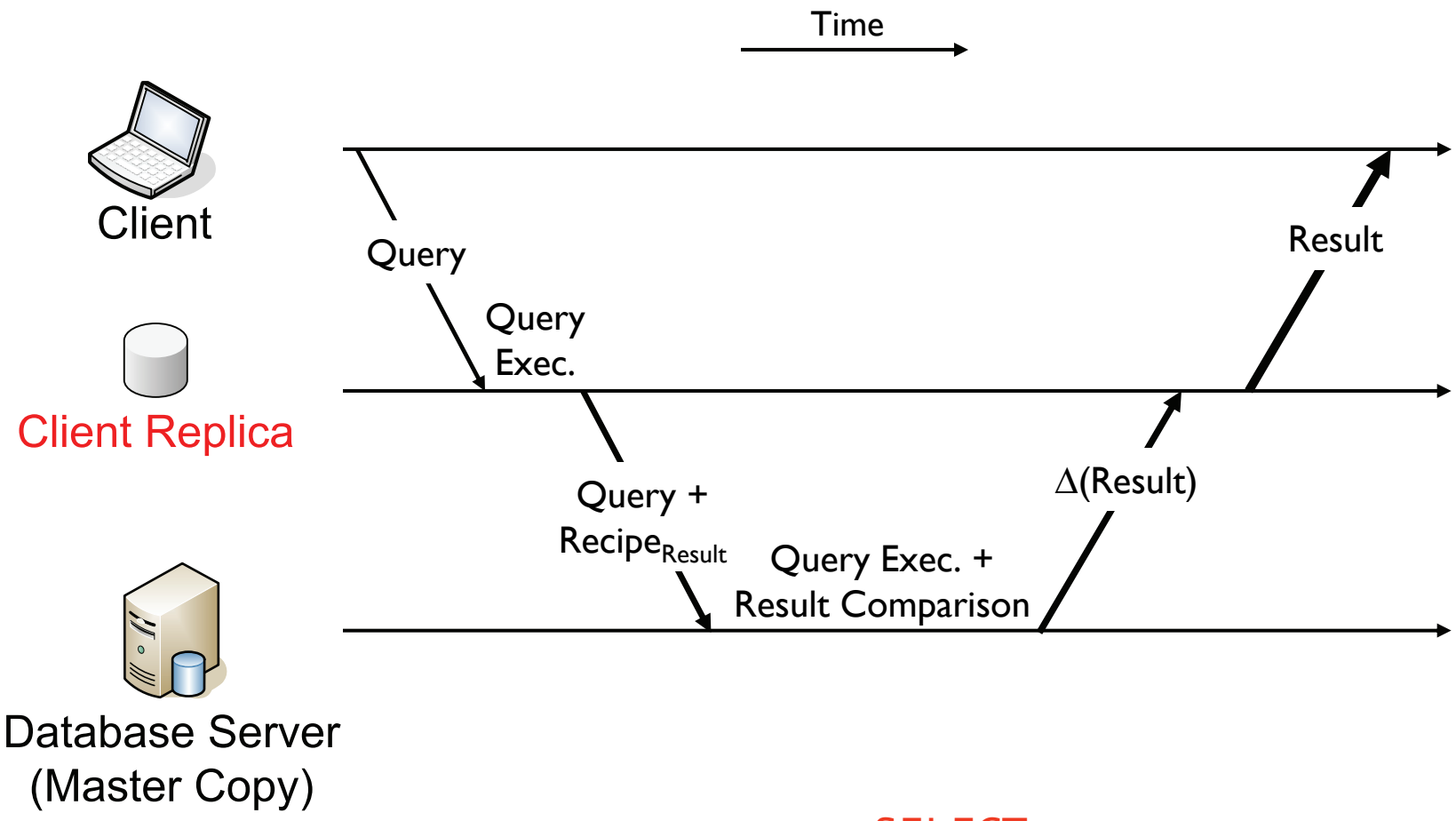

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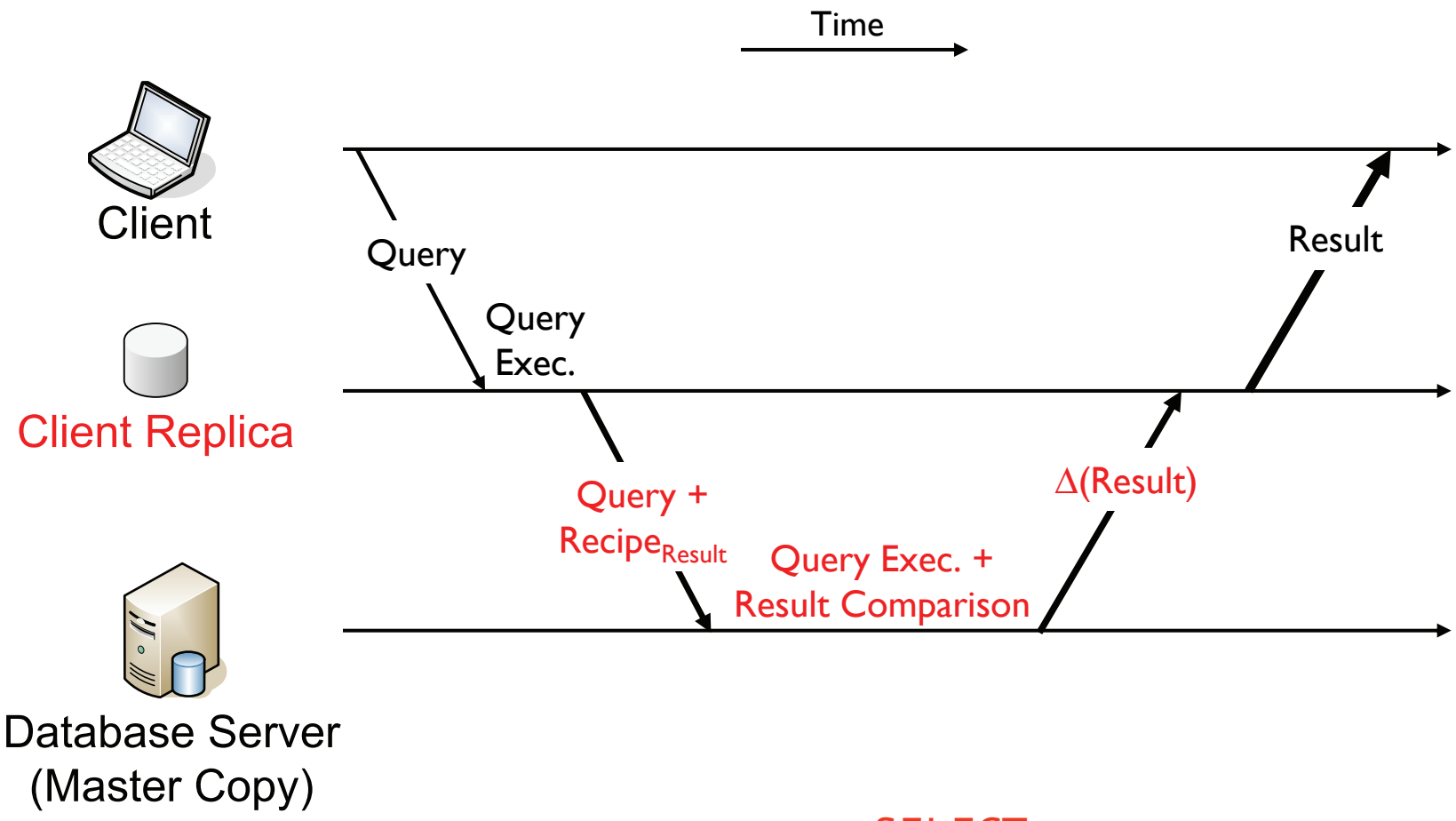

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Database Replicas

- Local storage and CPU allow for client replicas
- However, Cedar has to support partial replicas
  - Capacity, privacy, security, and regulatory concerns
- Replicas created using database *hoard profiles*

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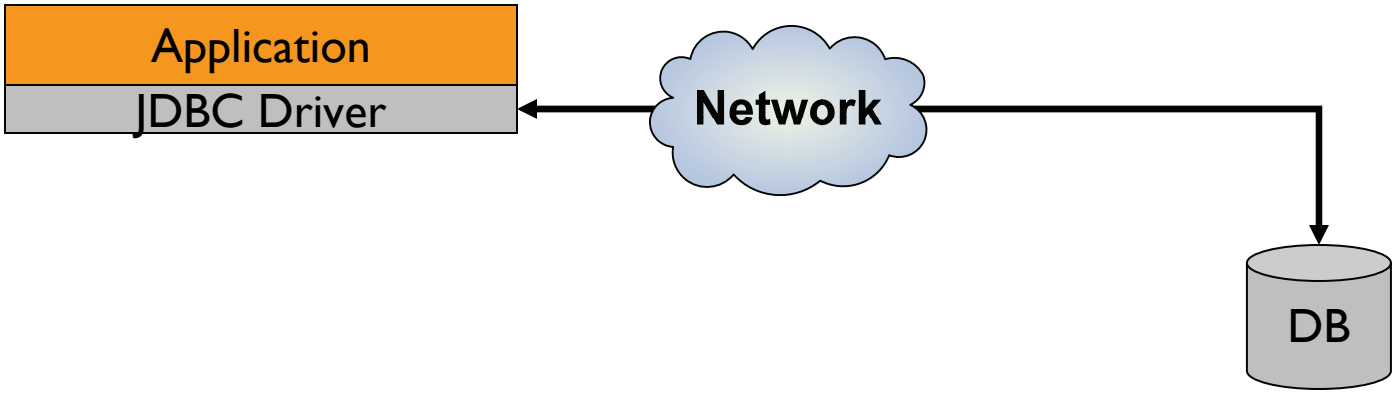
  - Hoard profiles preserve schema of the original database

Using Replicas

- Replicas are standalone database engines
- Transparent to application and database server



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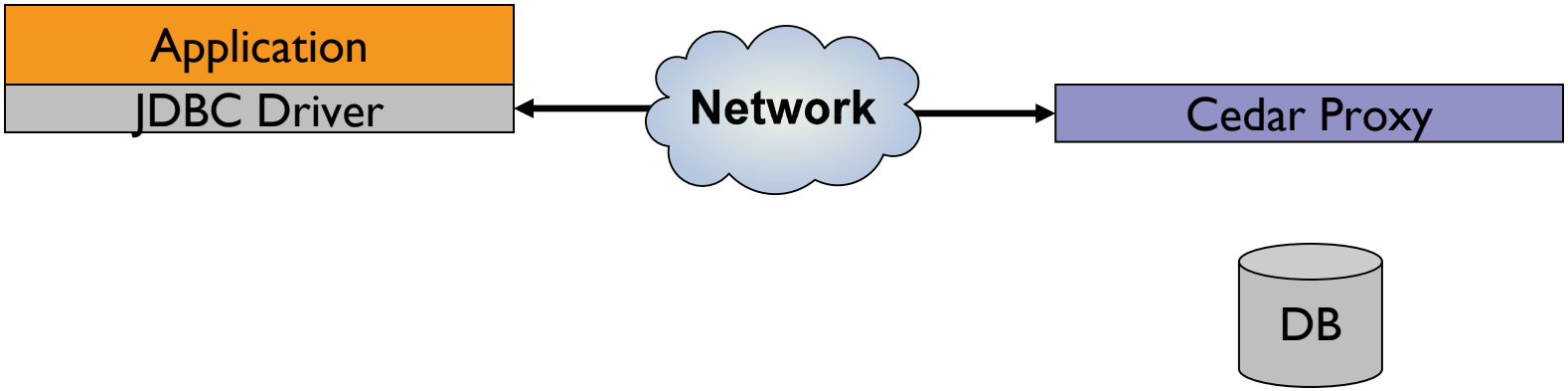

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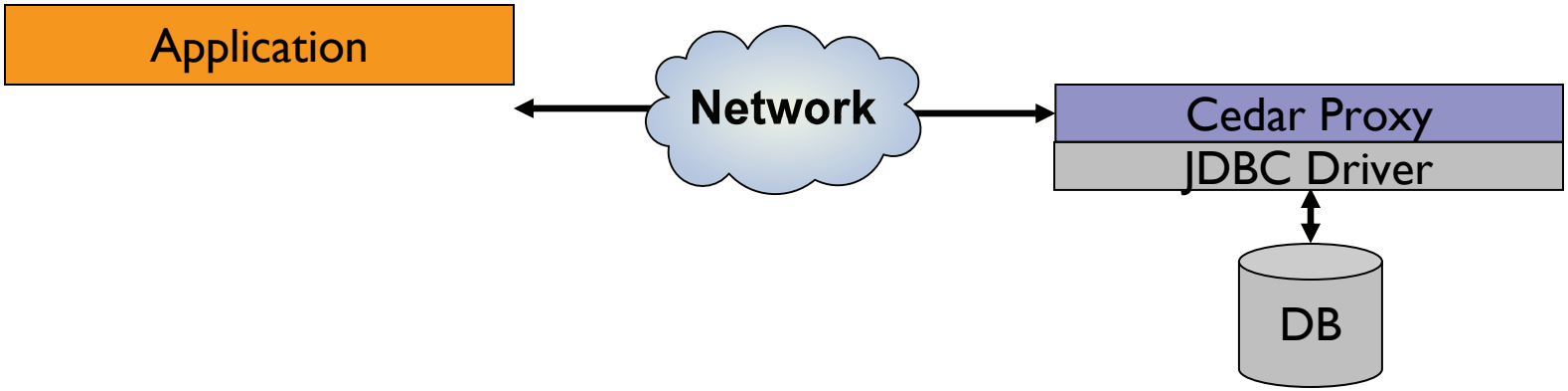

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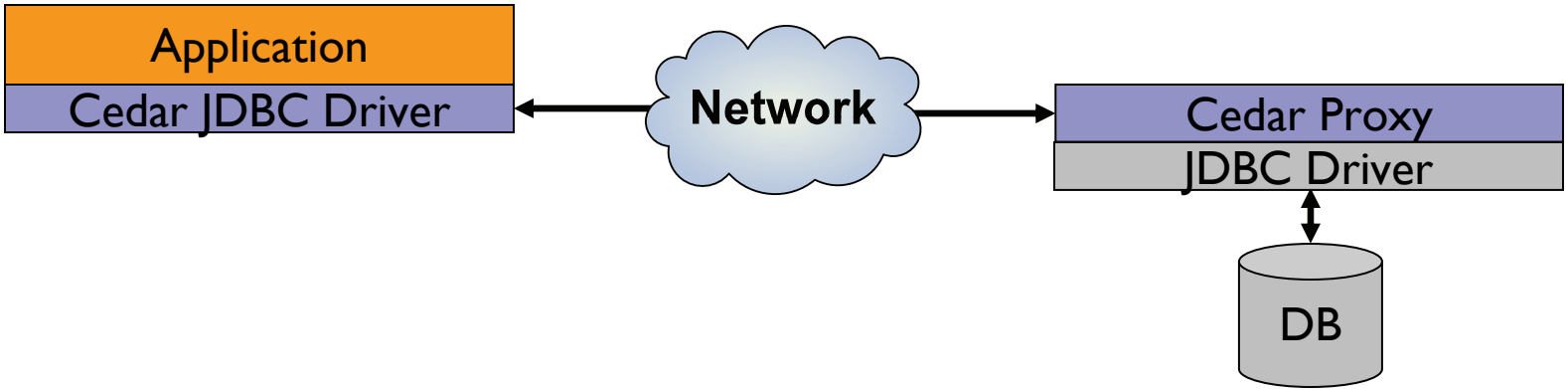

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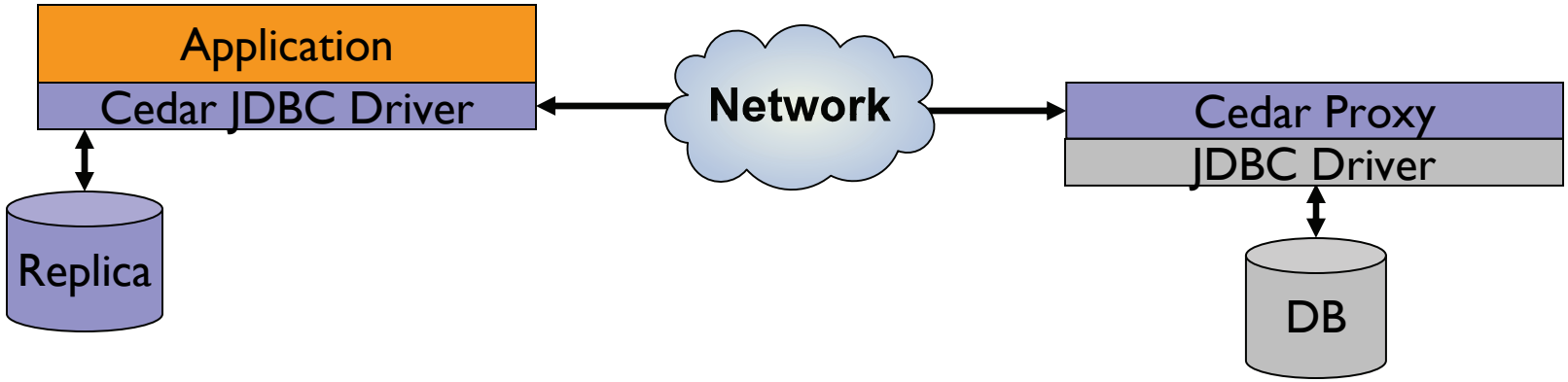

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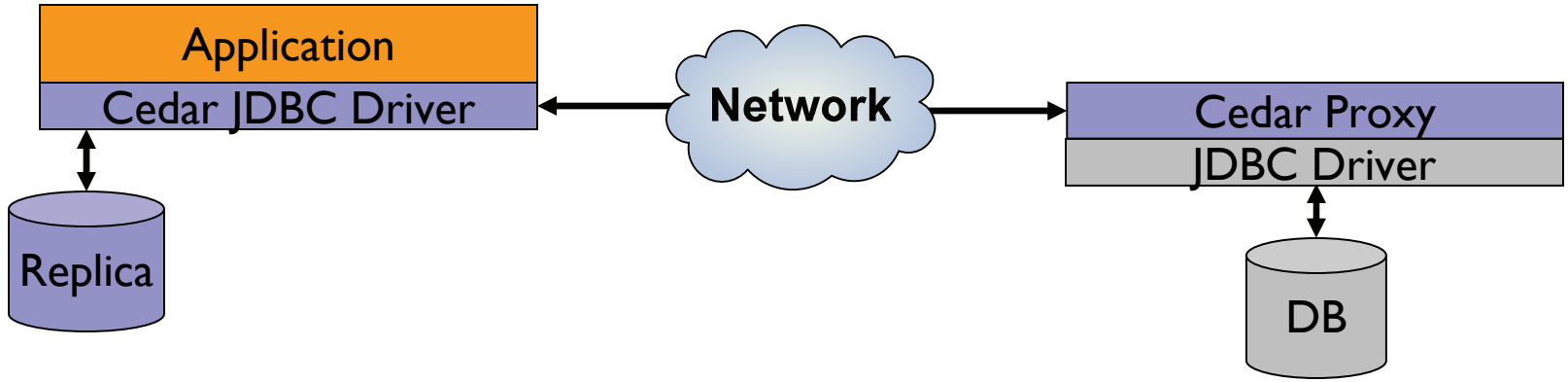
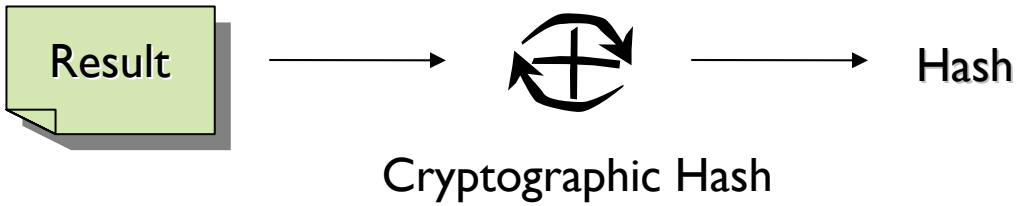


- Assuming staleness simplifies replica control
  - No overhead of callback-based mechanisms
  - Replicas can be updated lazily at runtime

Commonality Detection

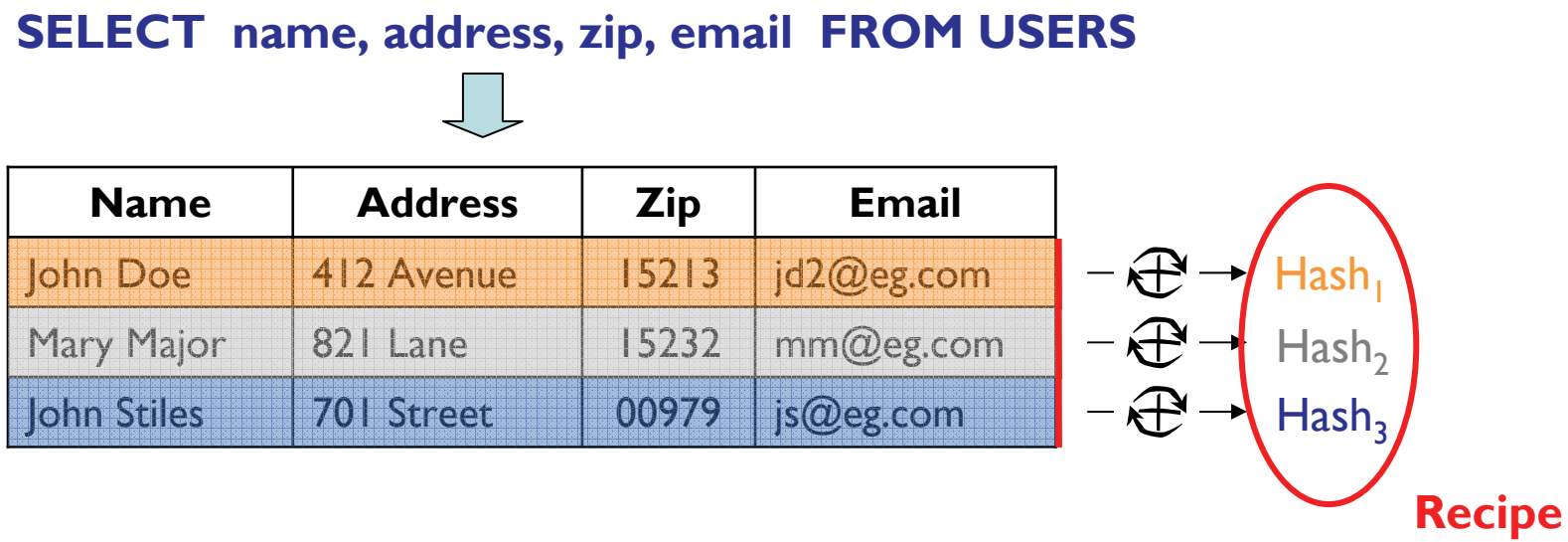
- Cedar uses Content Addressability



- Hash value is a globally unique identifier
  - Independent of any particular system
  - Infeasible to find another object with same hash
  - If hash values are equal, so are the source objects
- Any small change in source completely changes hash

Commonality Detection

- Exploit structure in results – they look like tables



- Recipes are a compact representation of the result
  - A convenient method of comparing two results

Paring down the recipe

- Recipes can be large, esp. for results with small rows
  - Each hash is 20 bytes for SHA-1, 32 bytes for SHA-256

```
0x 2fd4e1c6 7a2d28fc ed849ee1 bb76e739 1b93eb12
0x de9f2c7f d25e1b3a fad3e85a 0bd17d9b 100db4b3
0x da39a3ee 5e6b4b0d 3255bfef 95601890 afd80709
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```

Solution: Only use 4 bytes as the row identifier

- How can this ensure correctness?
  - Only compares results from same query: reduced key space
  - Therefore, a reduced probability of hash collisions
  - With 4 bytes and 10,000 hash values, $Pr\{collision\} = 2.3 \times 10^{-6}$
  - However, much lower than SHA-1, where $Pr\{collision\} = 2^{-160}$
  - A hash over the entire result provides an end-to-end check

Putting it all together

Client

Database Server

Client Replica

Putting it all together

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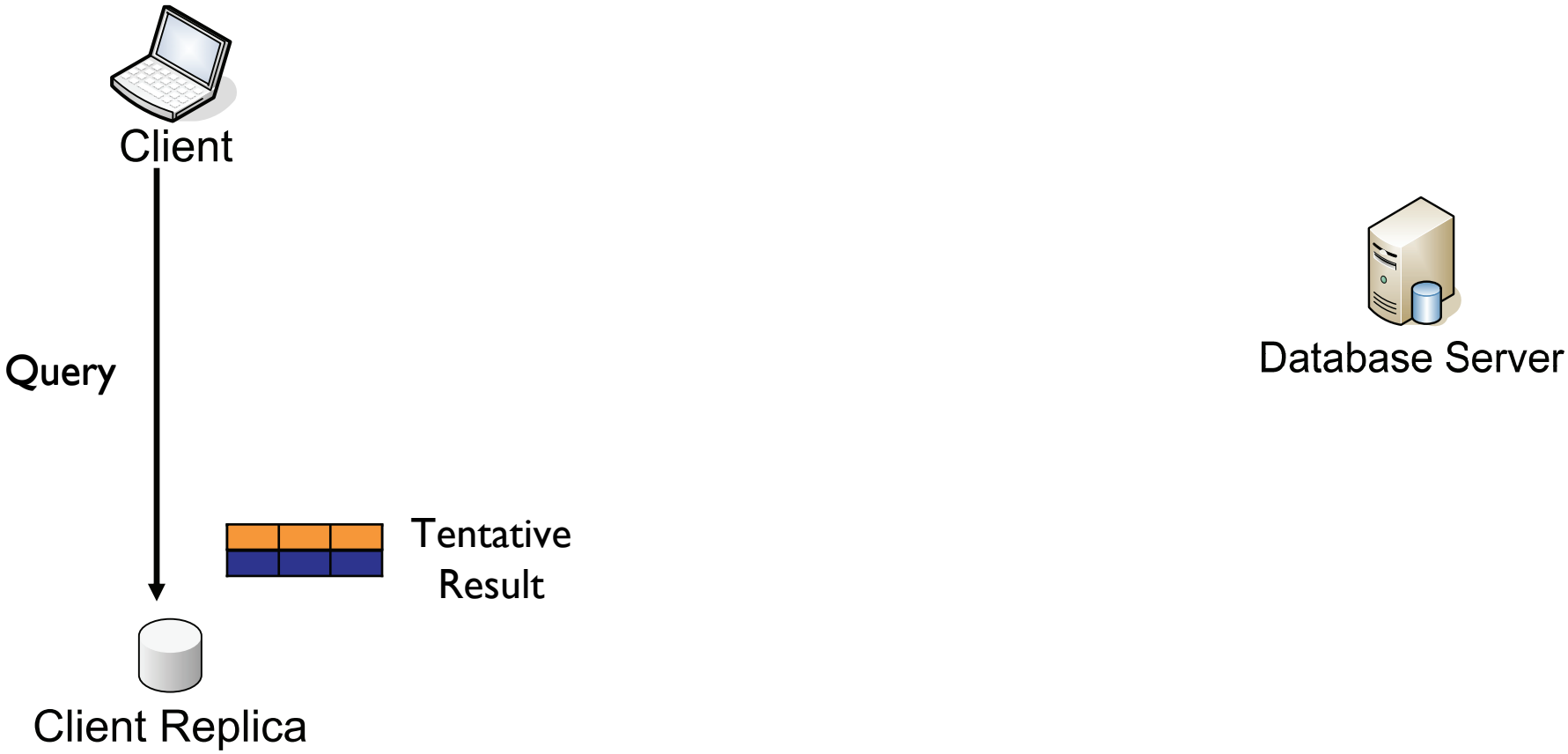

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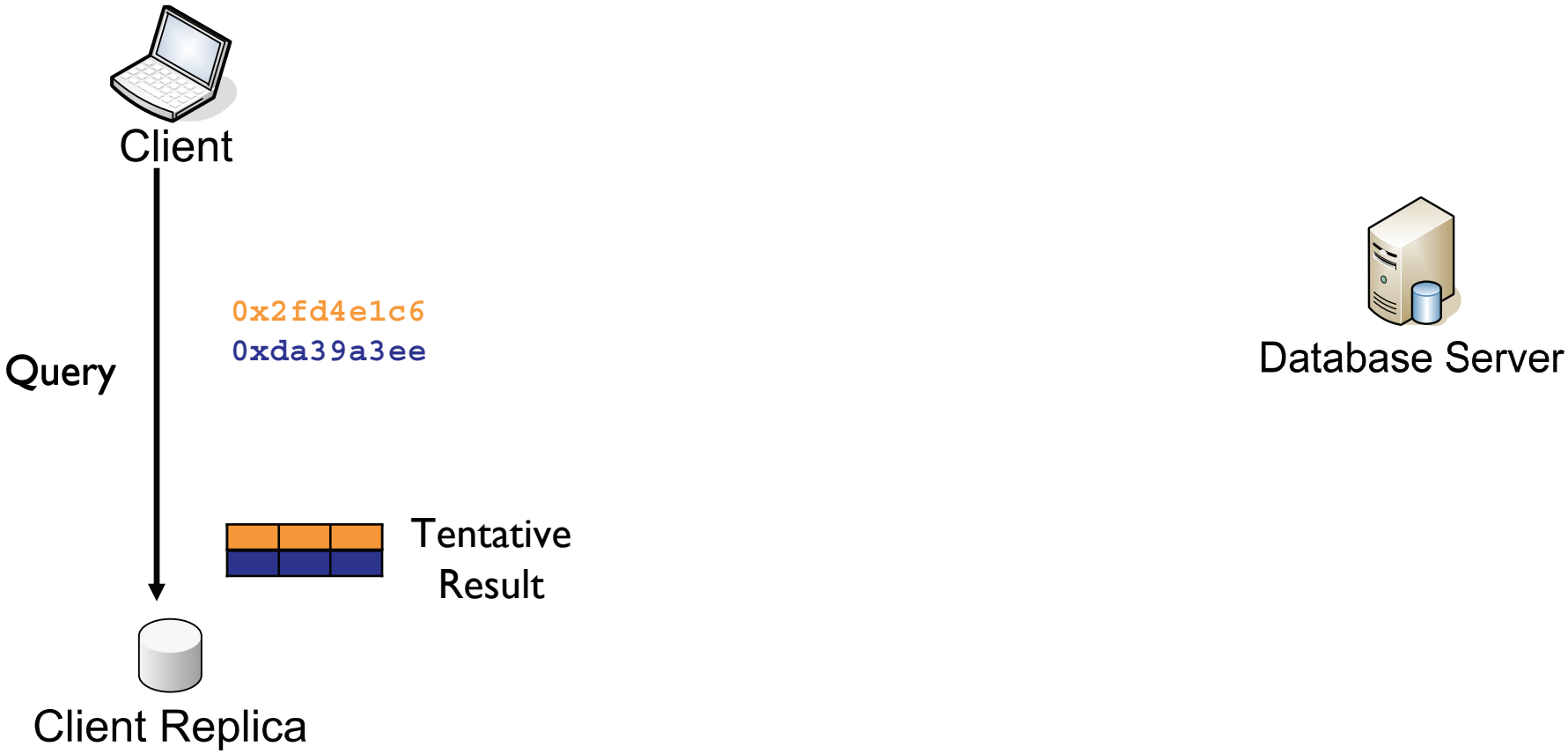

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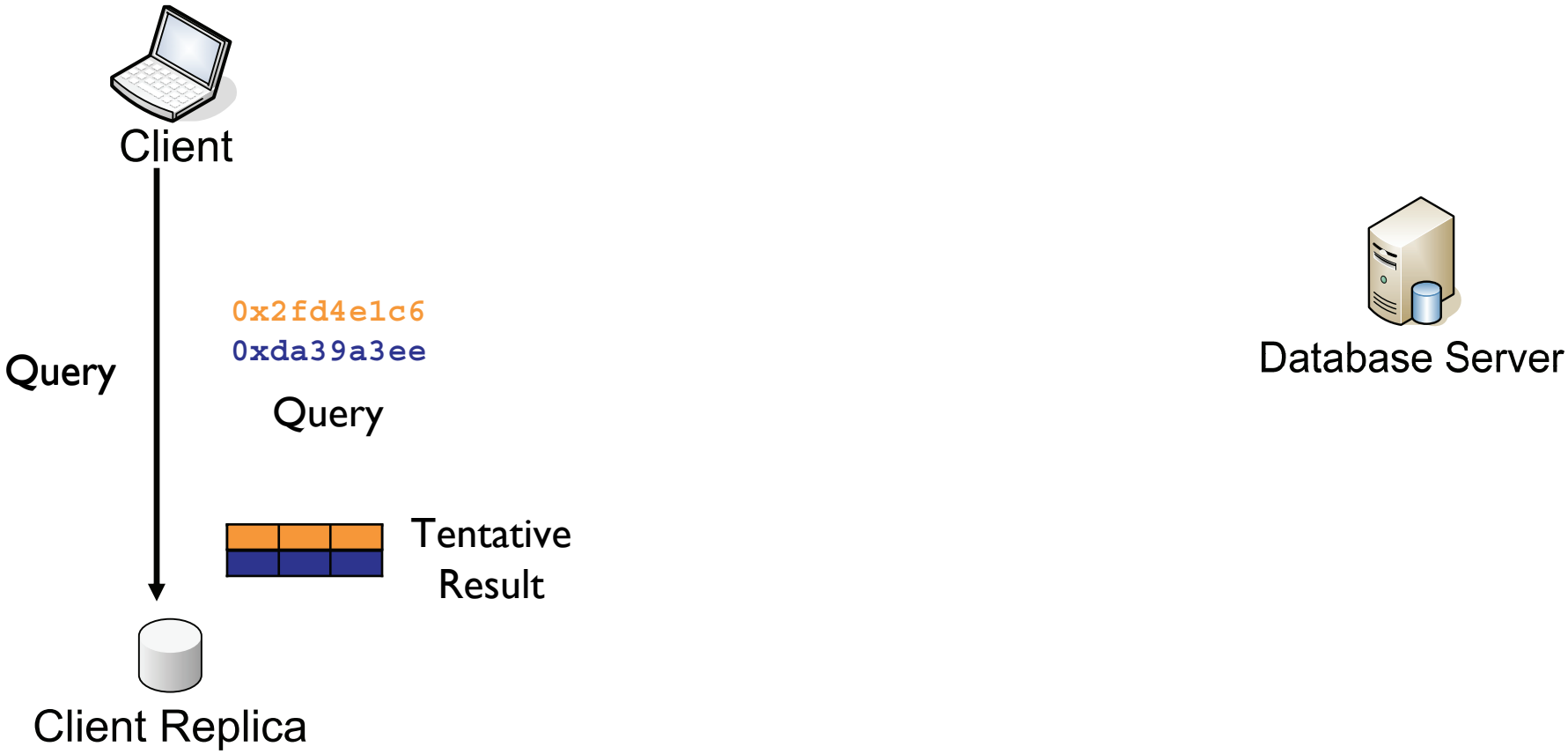

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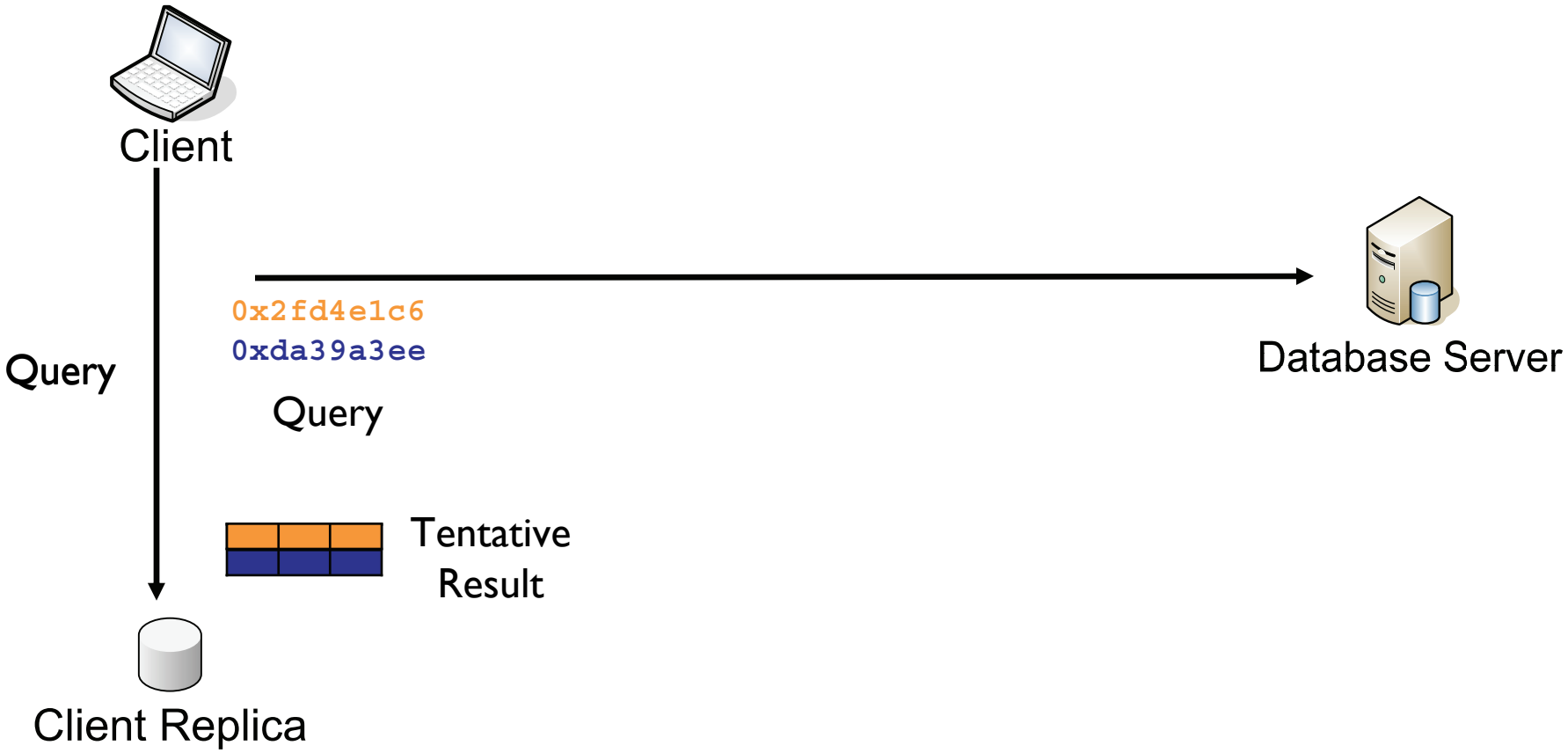

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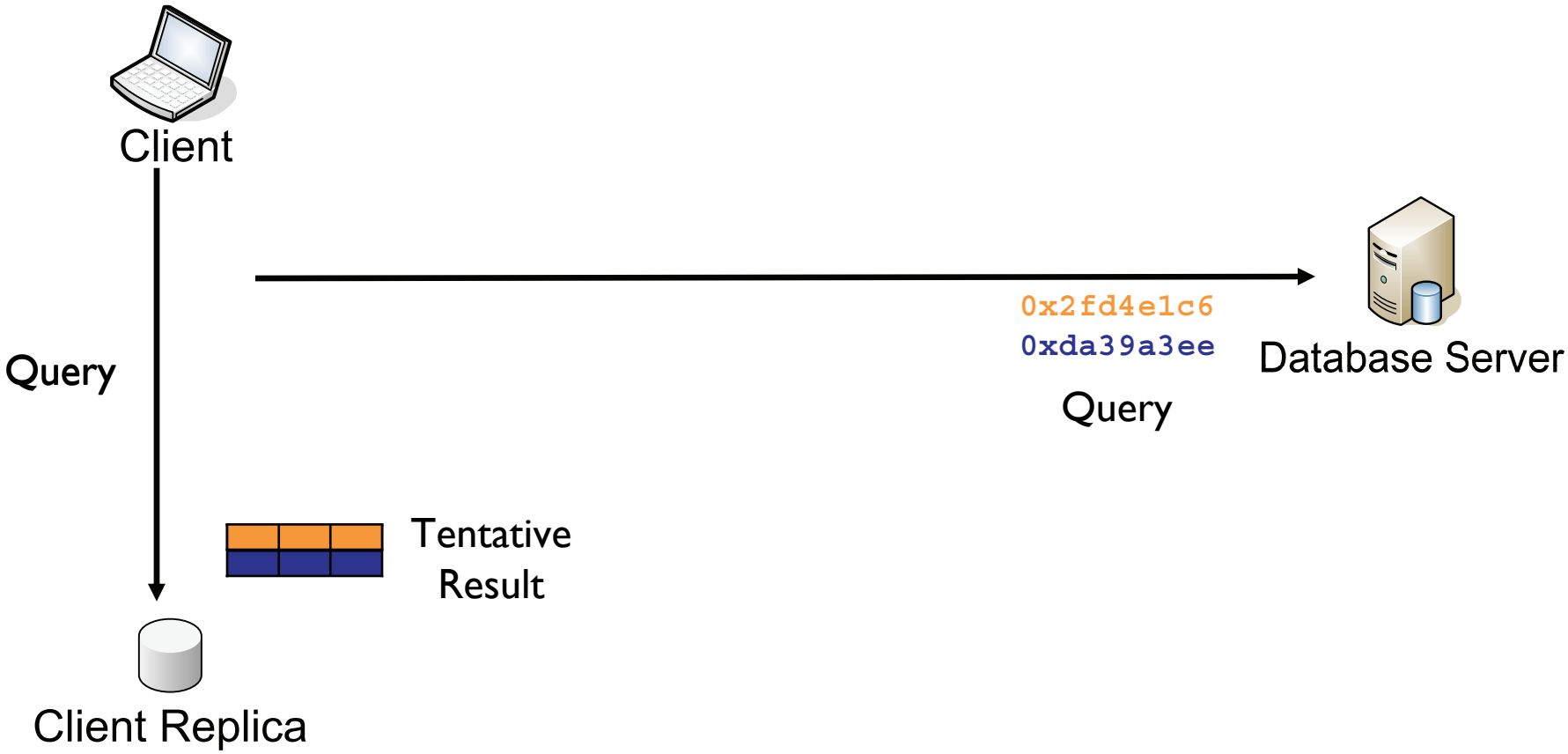

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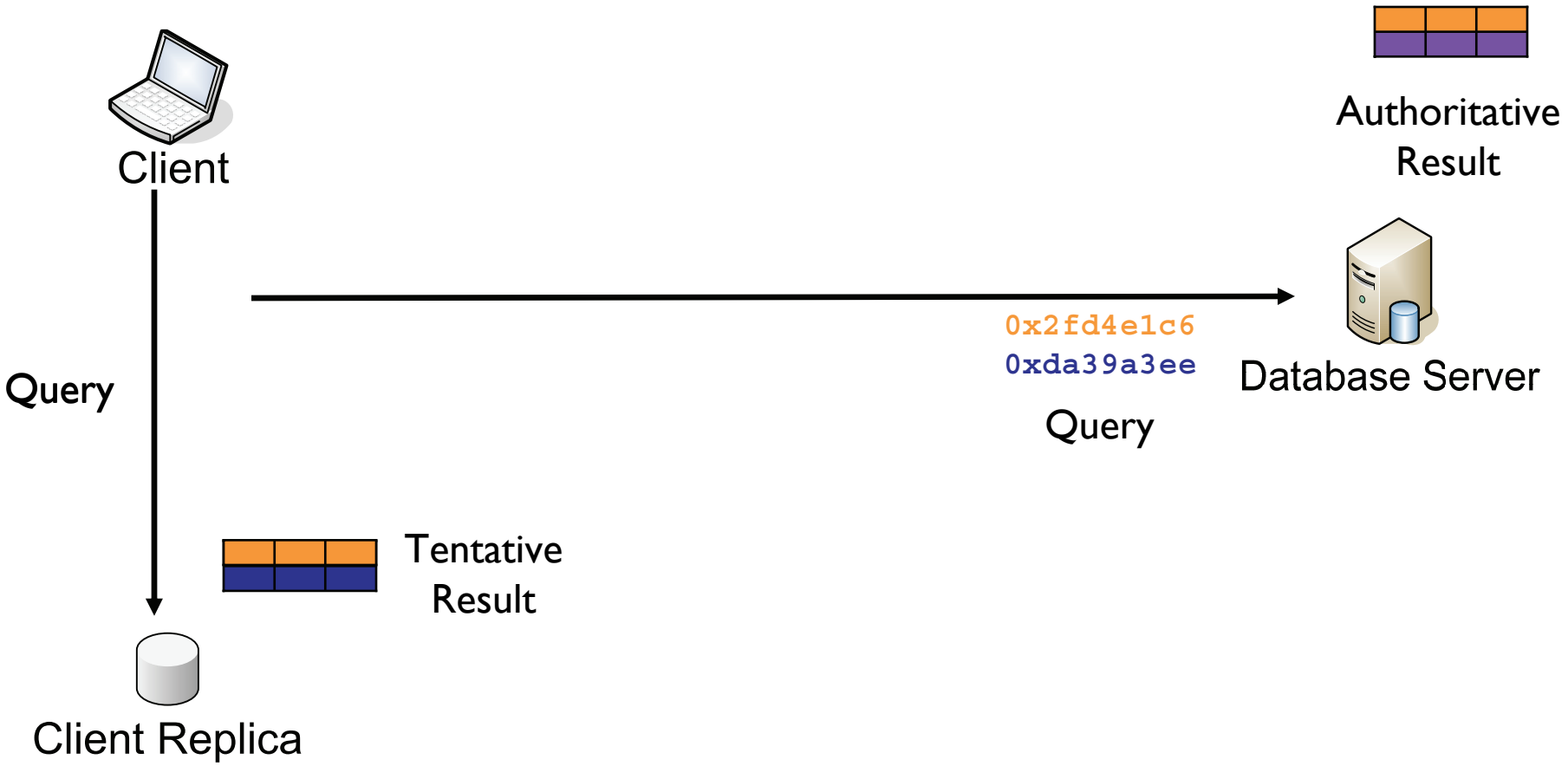

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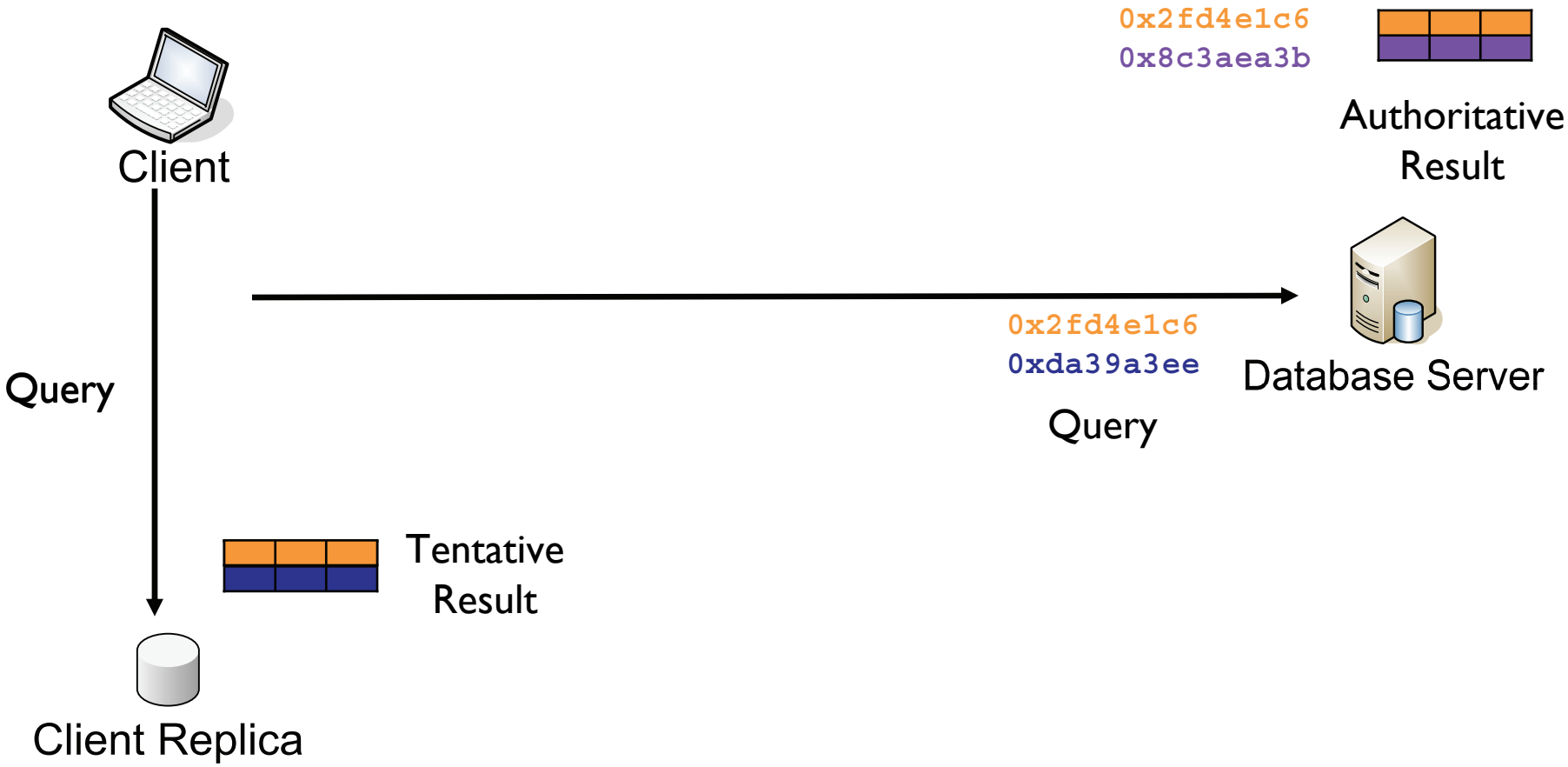

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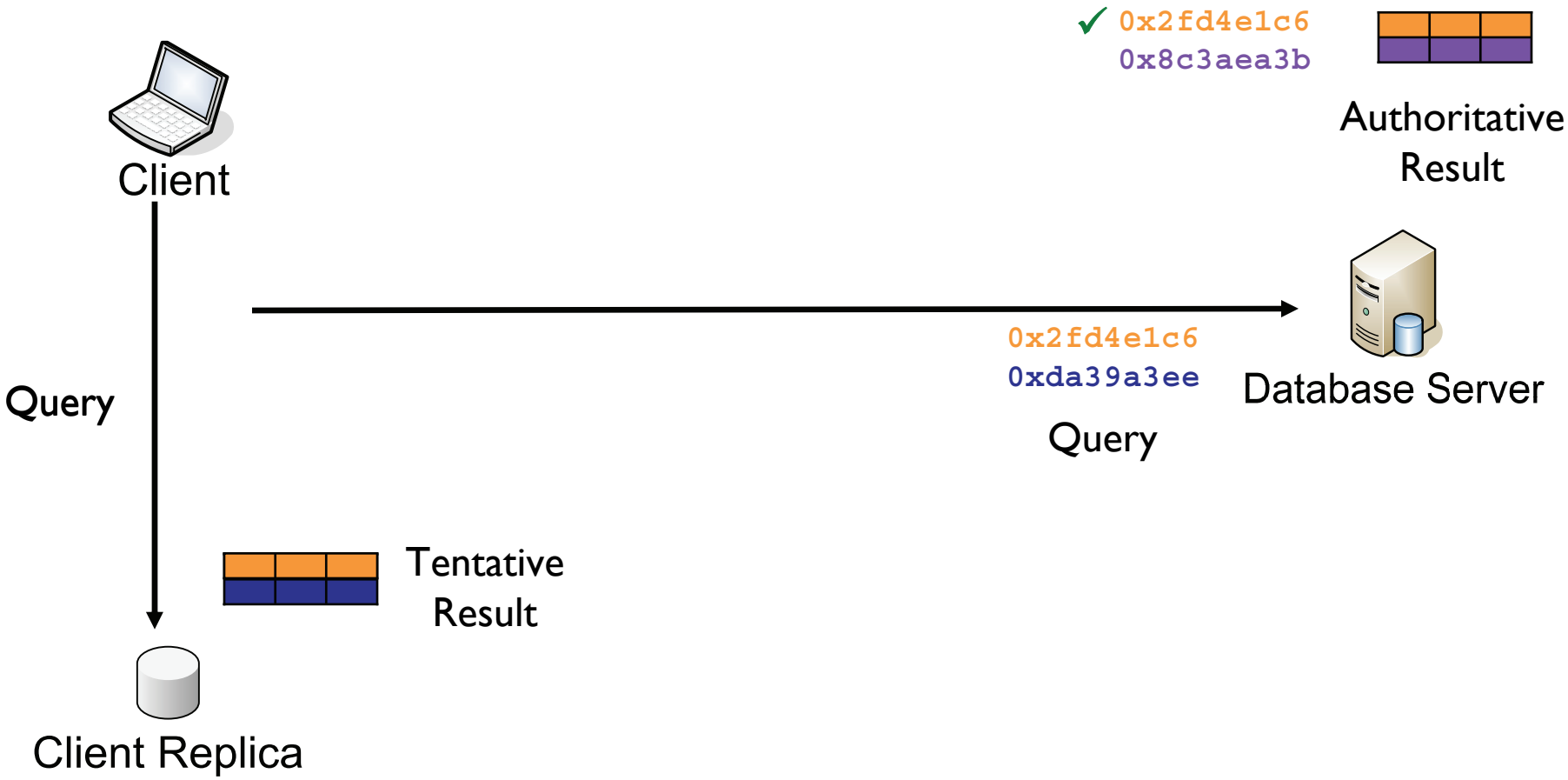

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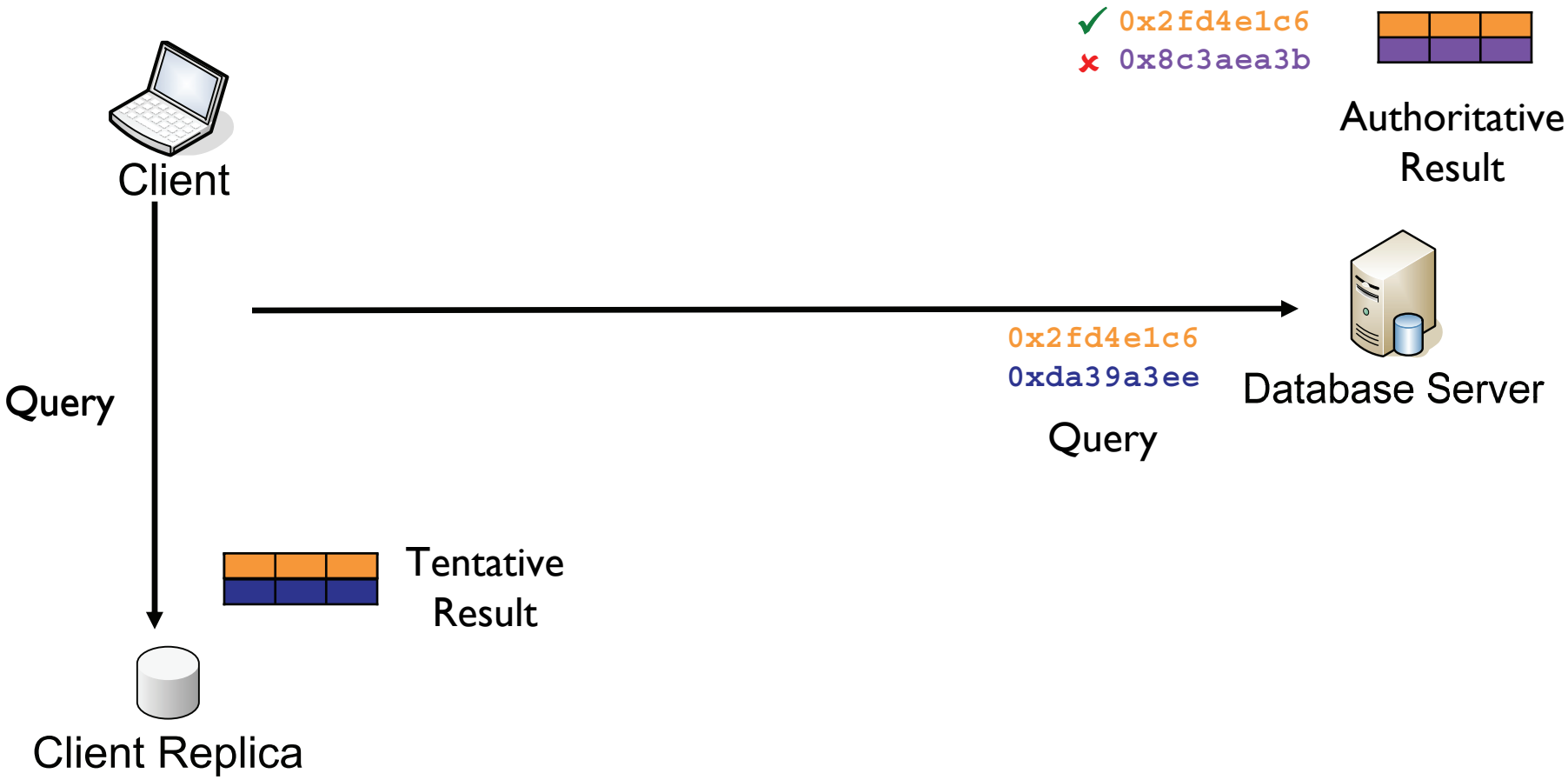

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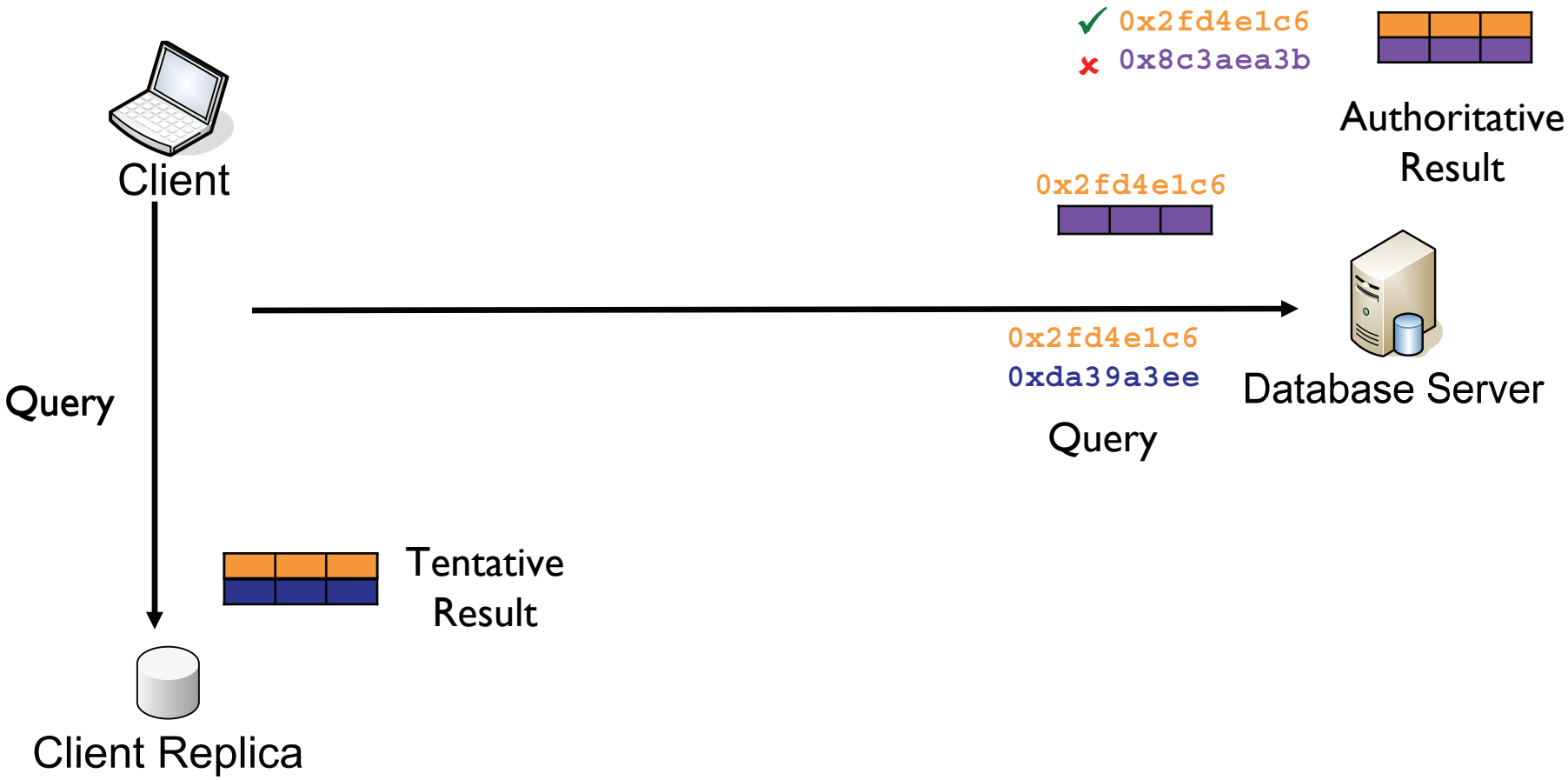

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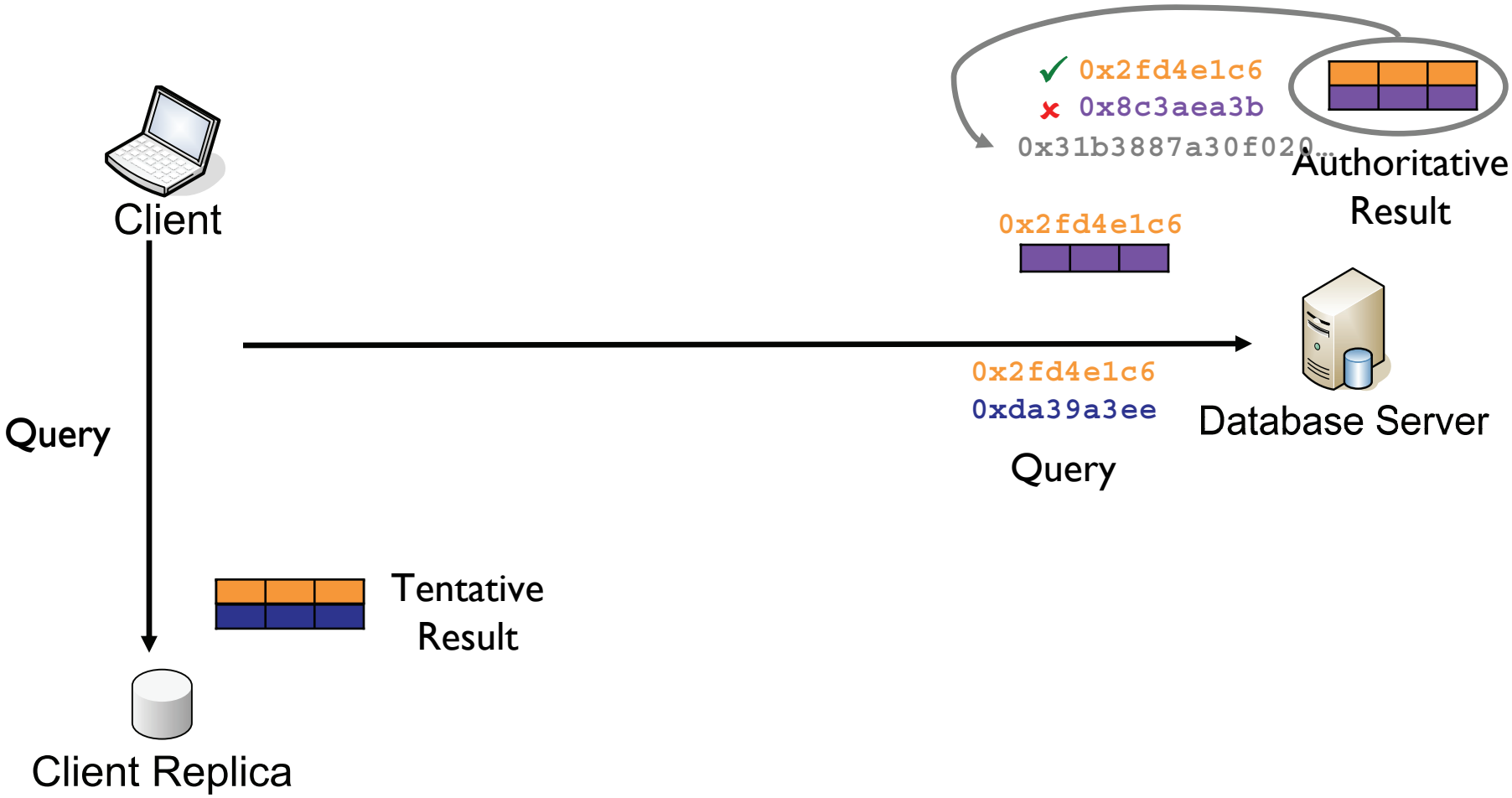

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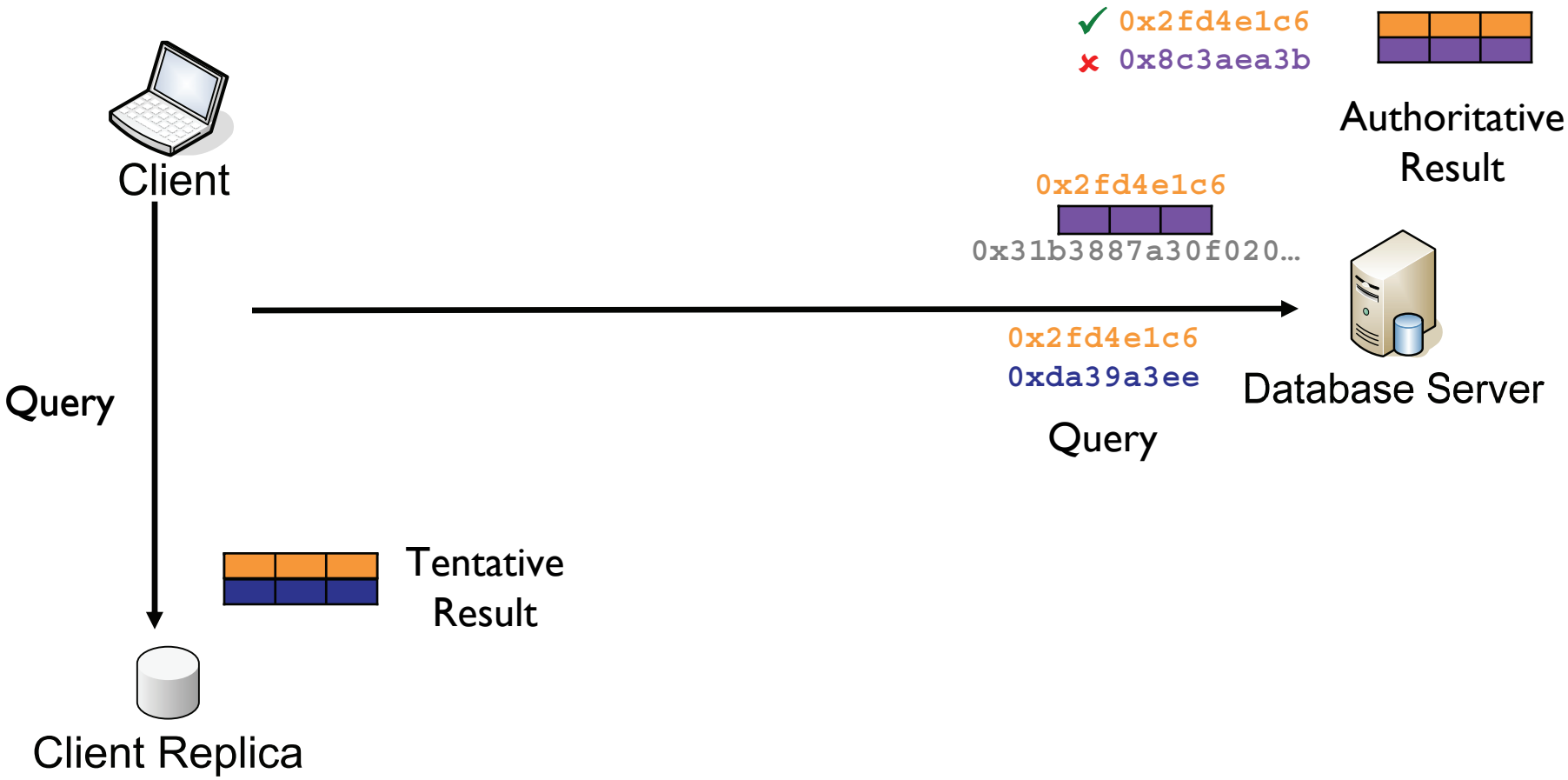

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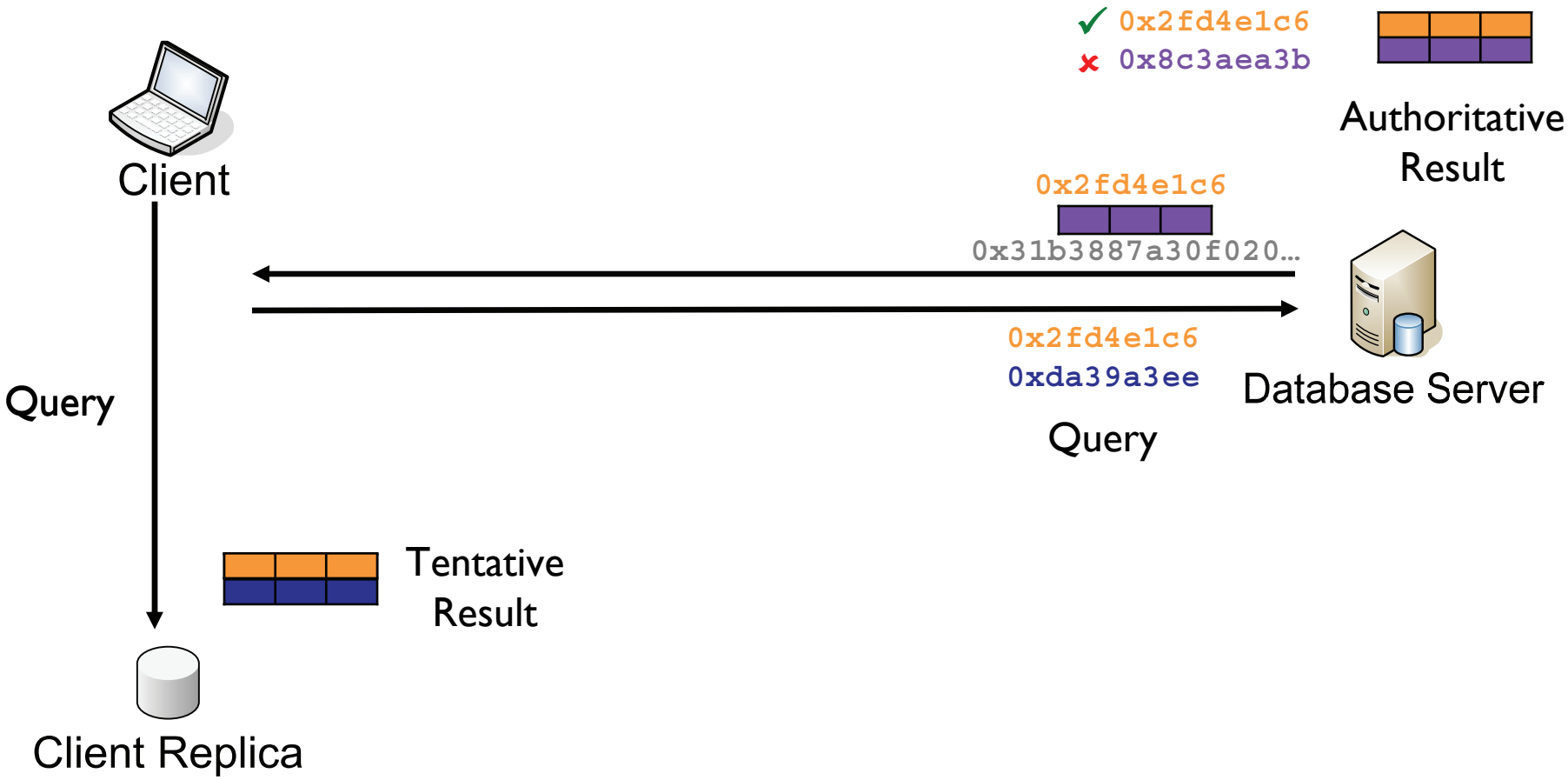

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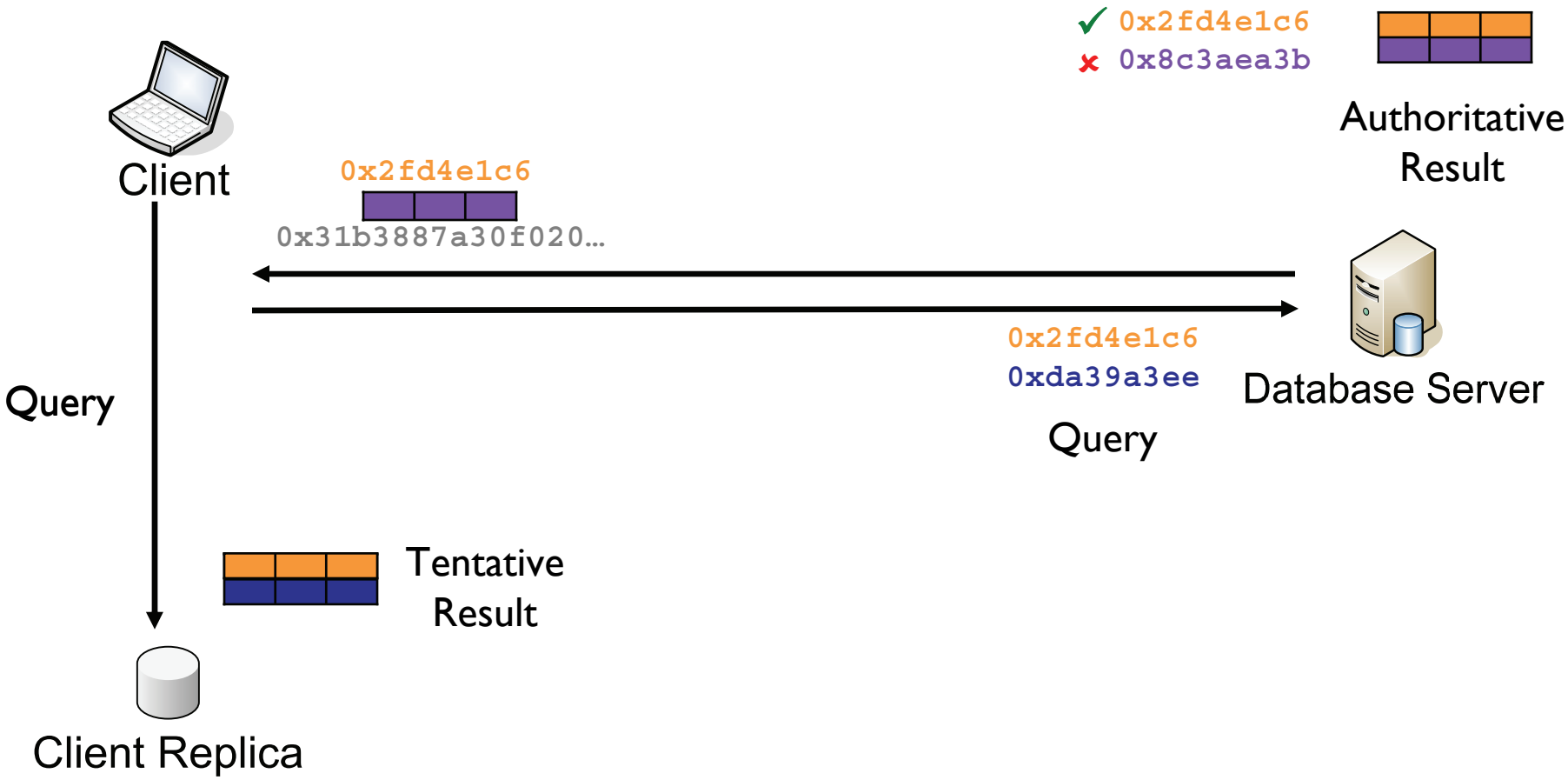

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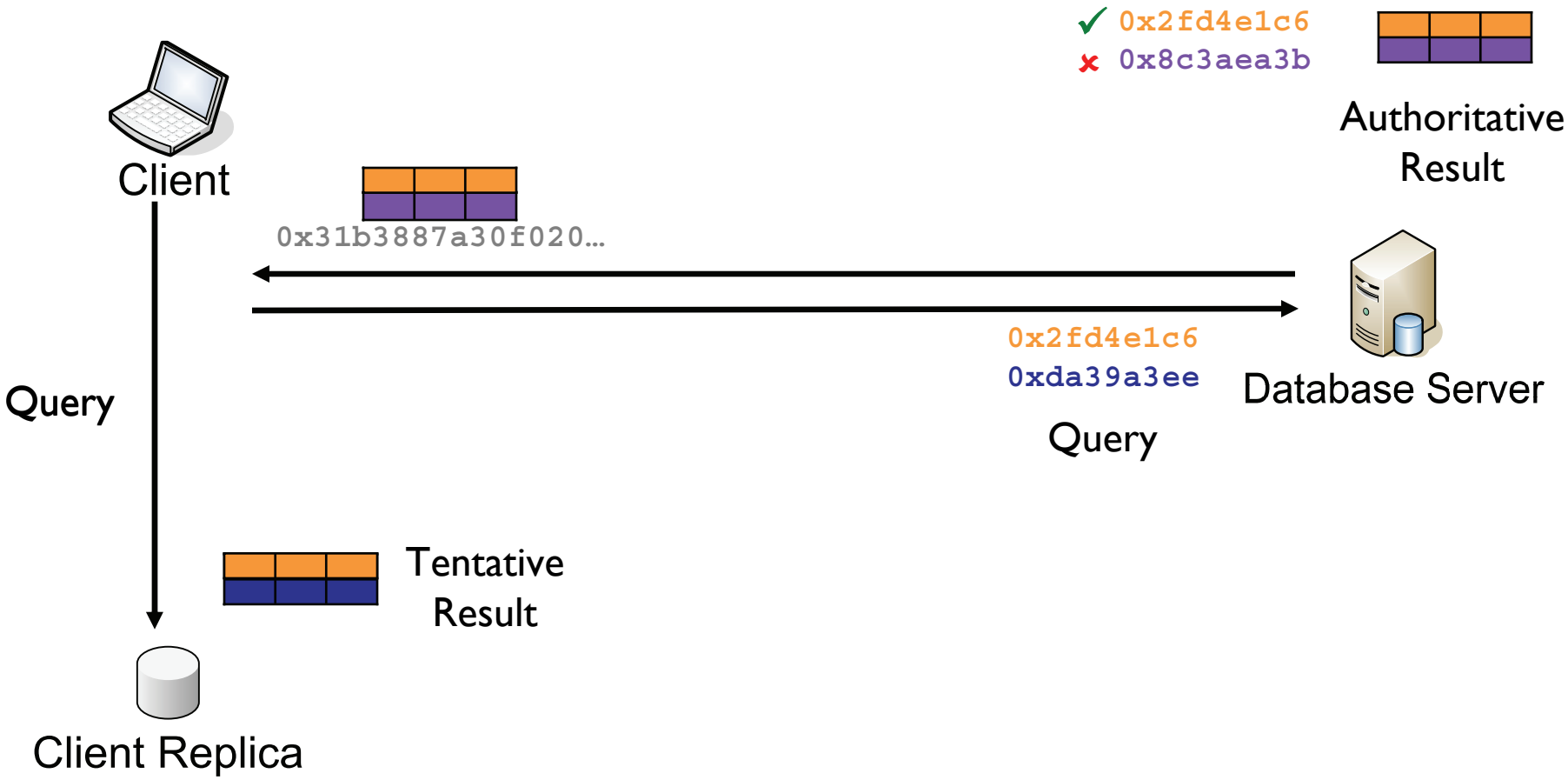

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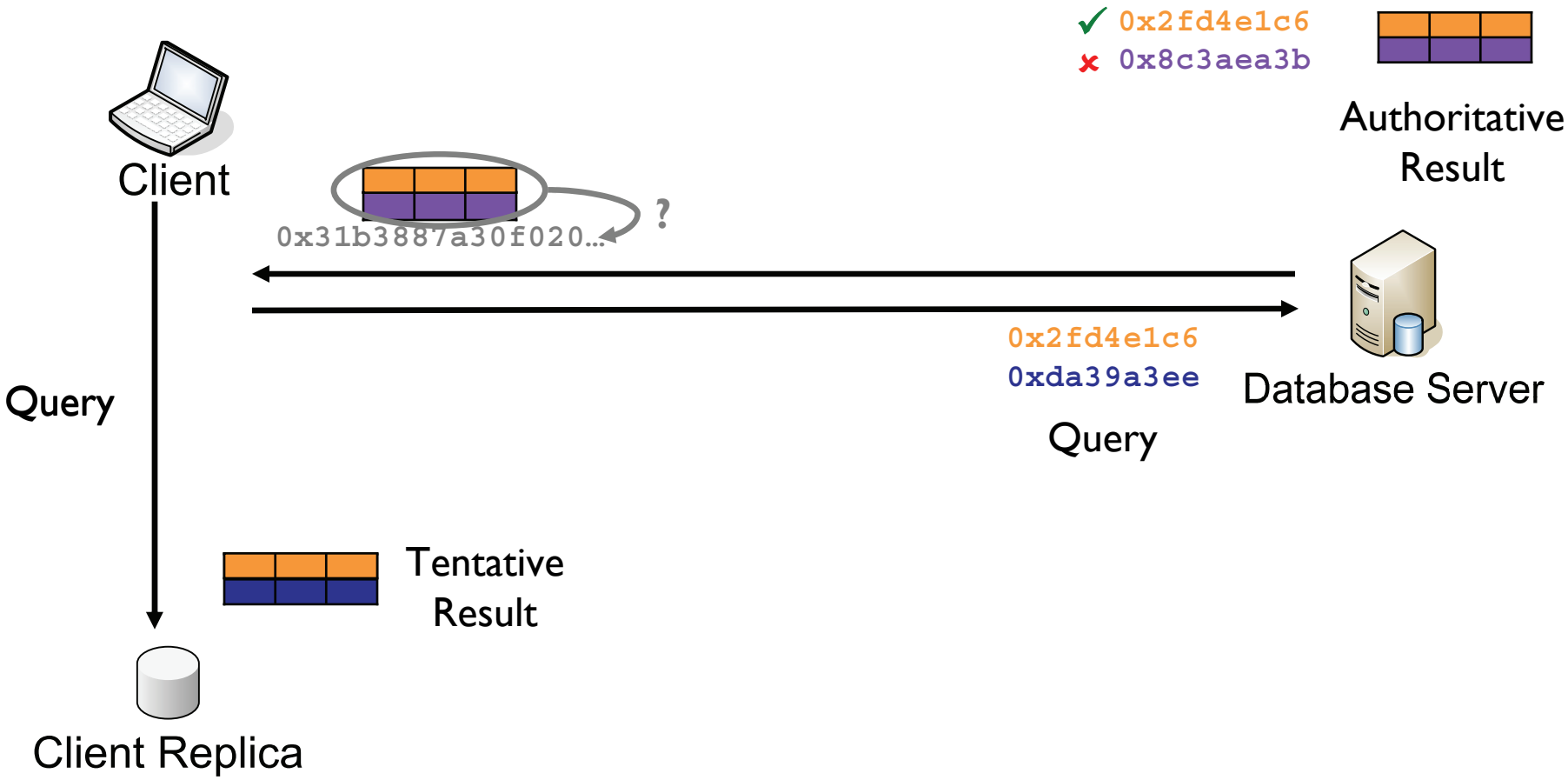

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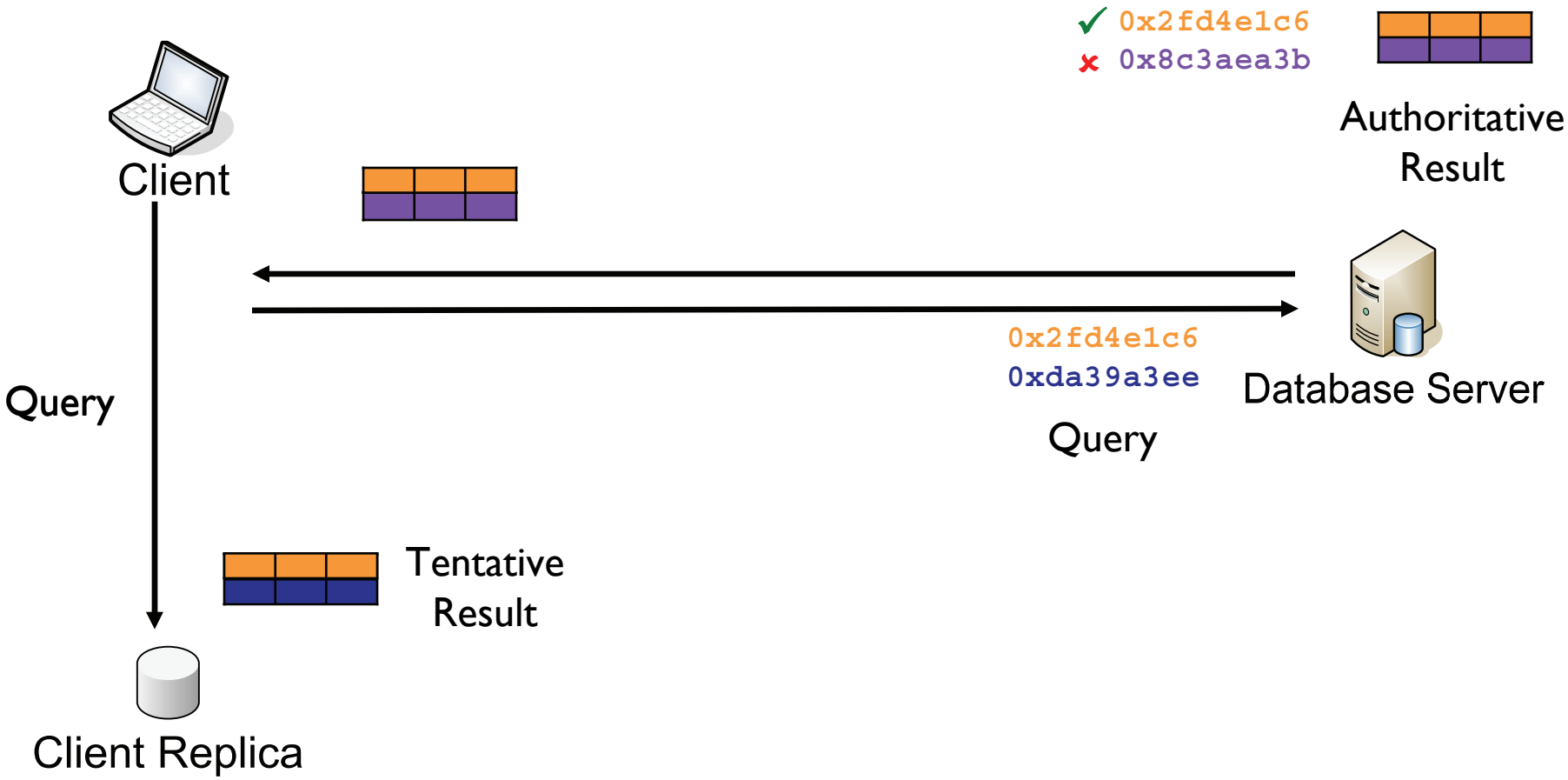

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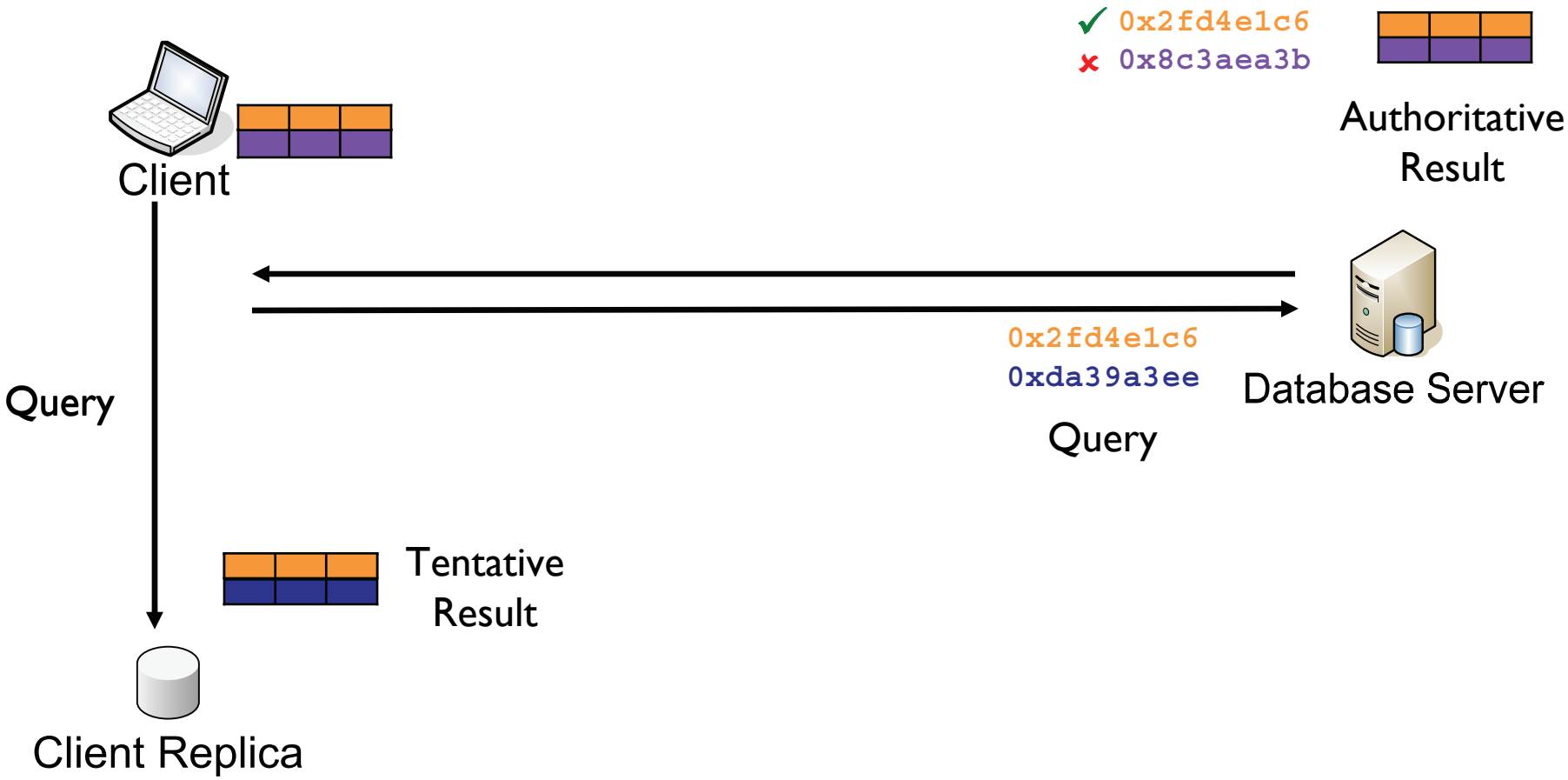
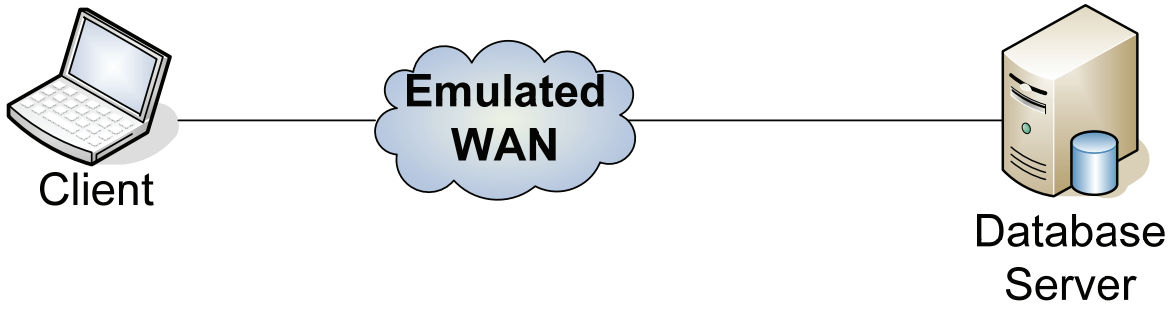


Evaluation

- Microbenchmarks
- MobileSales

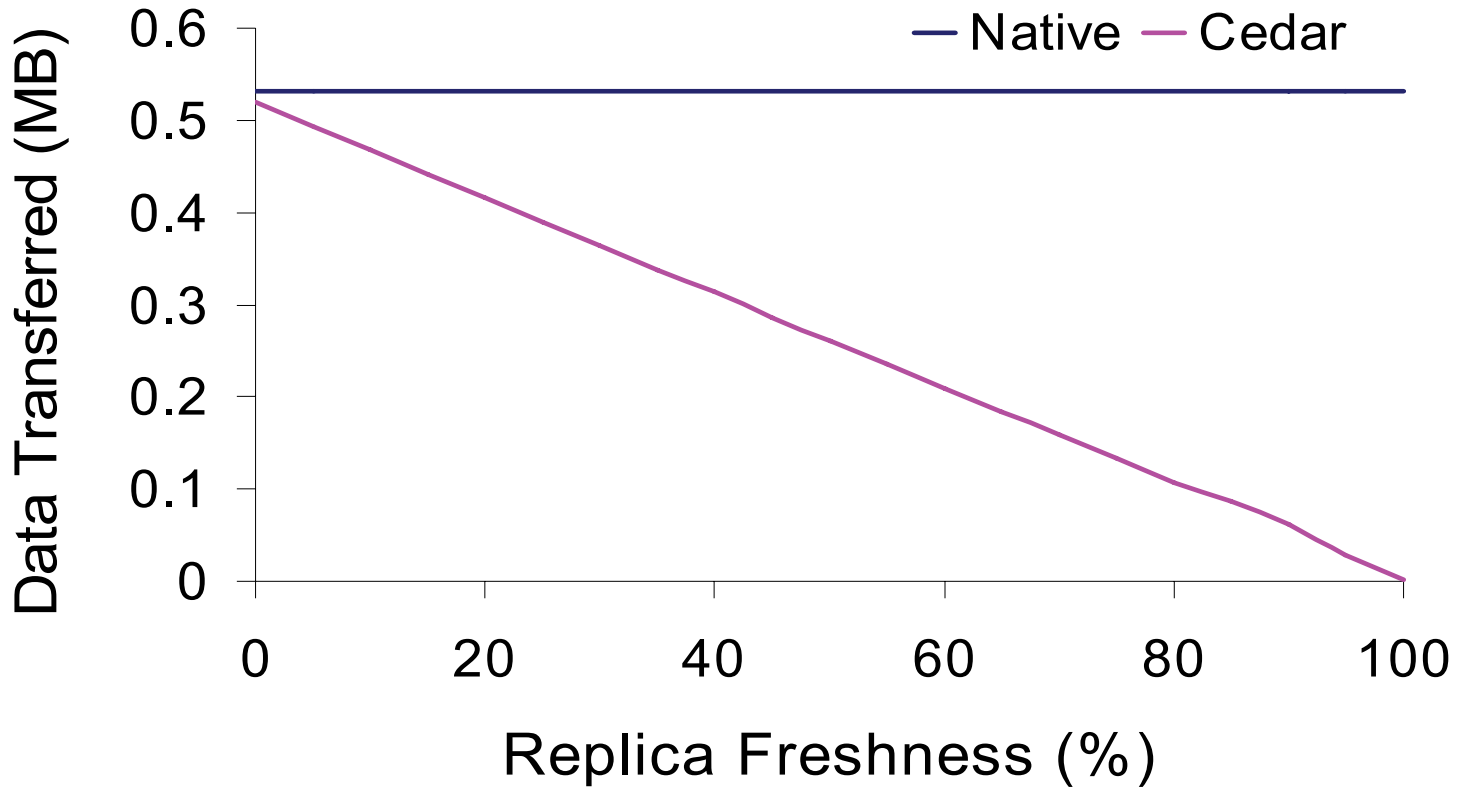
Microbenchmarks



- Single SQL Query microbenchmark
- Fetched approx. 0.1, 0.5, and 1 MB of data
  - Only presenting 0.5 MB + 1 Mbit/s @ 100 ms RTT
- Two configurations
  - Native – Benchmark uses vendor driver (MySQL)
  - Cedar – Benchmark uses Cedar driver
- Measured data transferred and response time

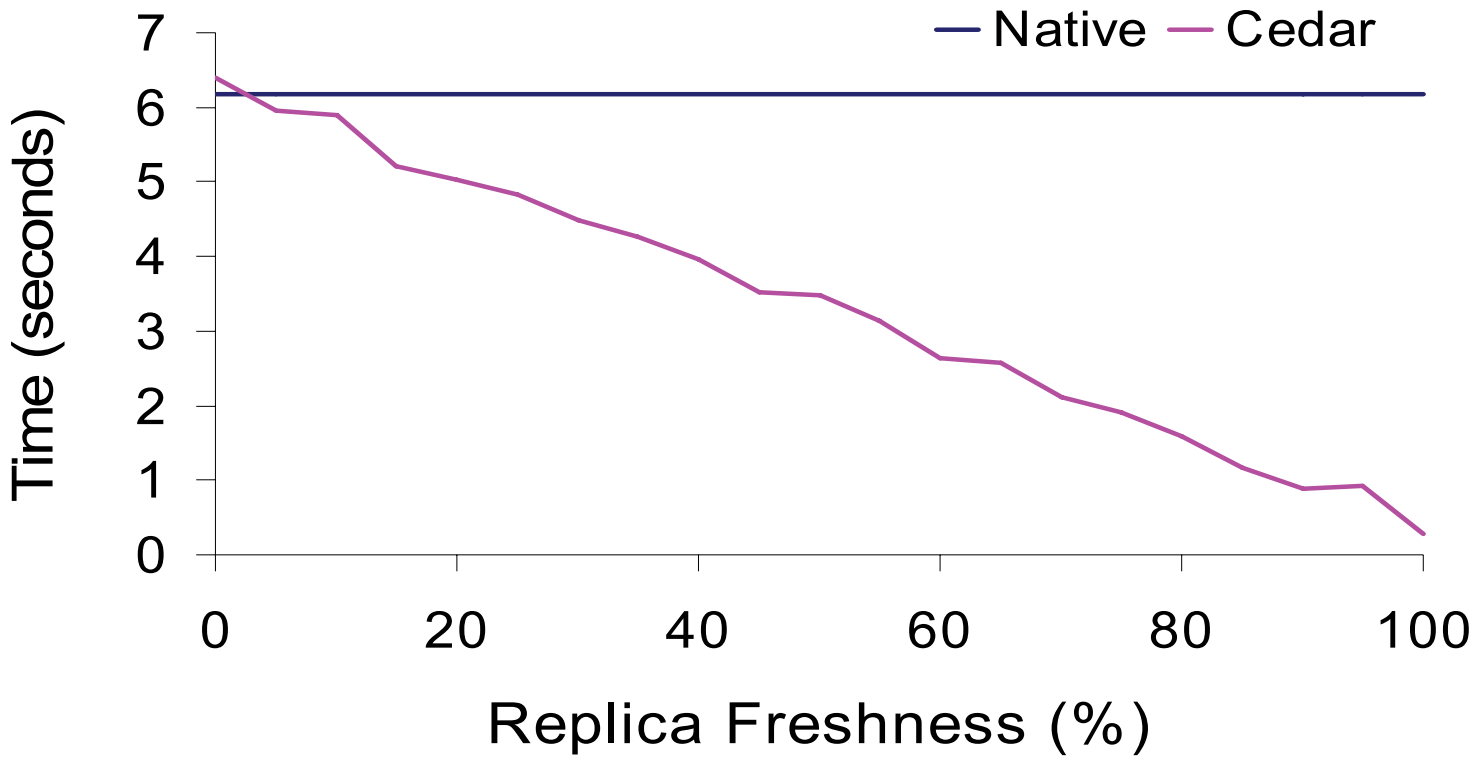
Data Transferred

1 Mbit/s – 100 ms RTT



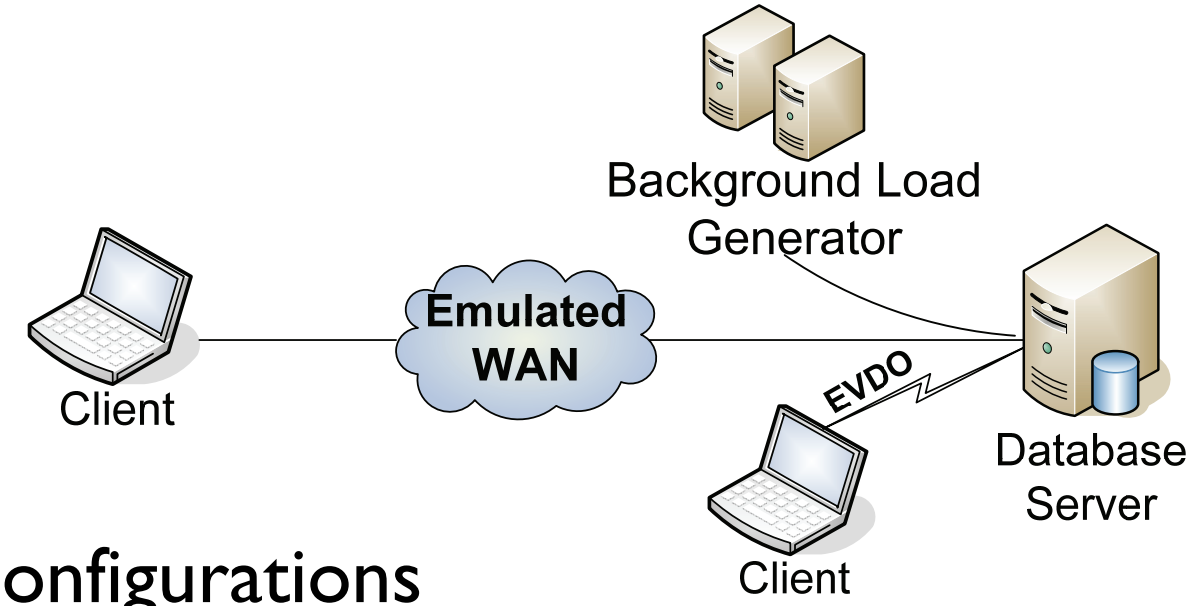
Response Time

1 Mbit/s – 100 ms RTT



MobileSales

- MobileSales (based on TPC-App)



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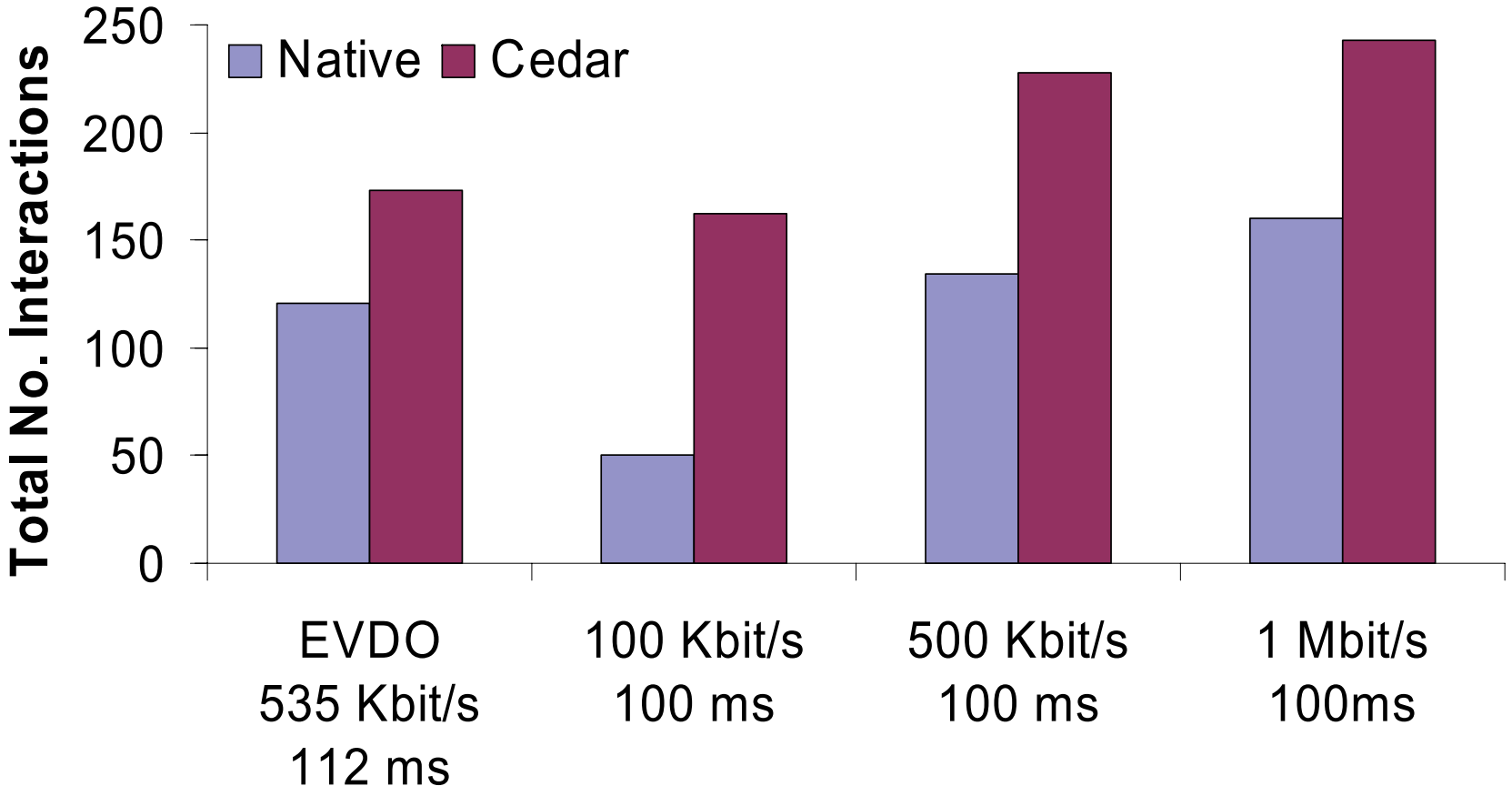
  - Cedar – Benchmark uses Cedar driver
- "Full" hoard profile used

MobileSales Benchmark

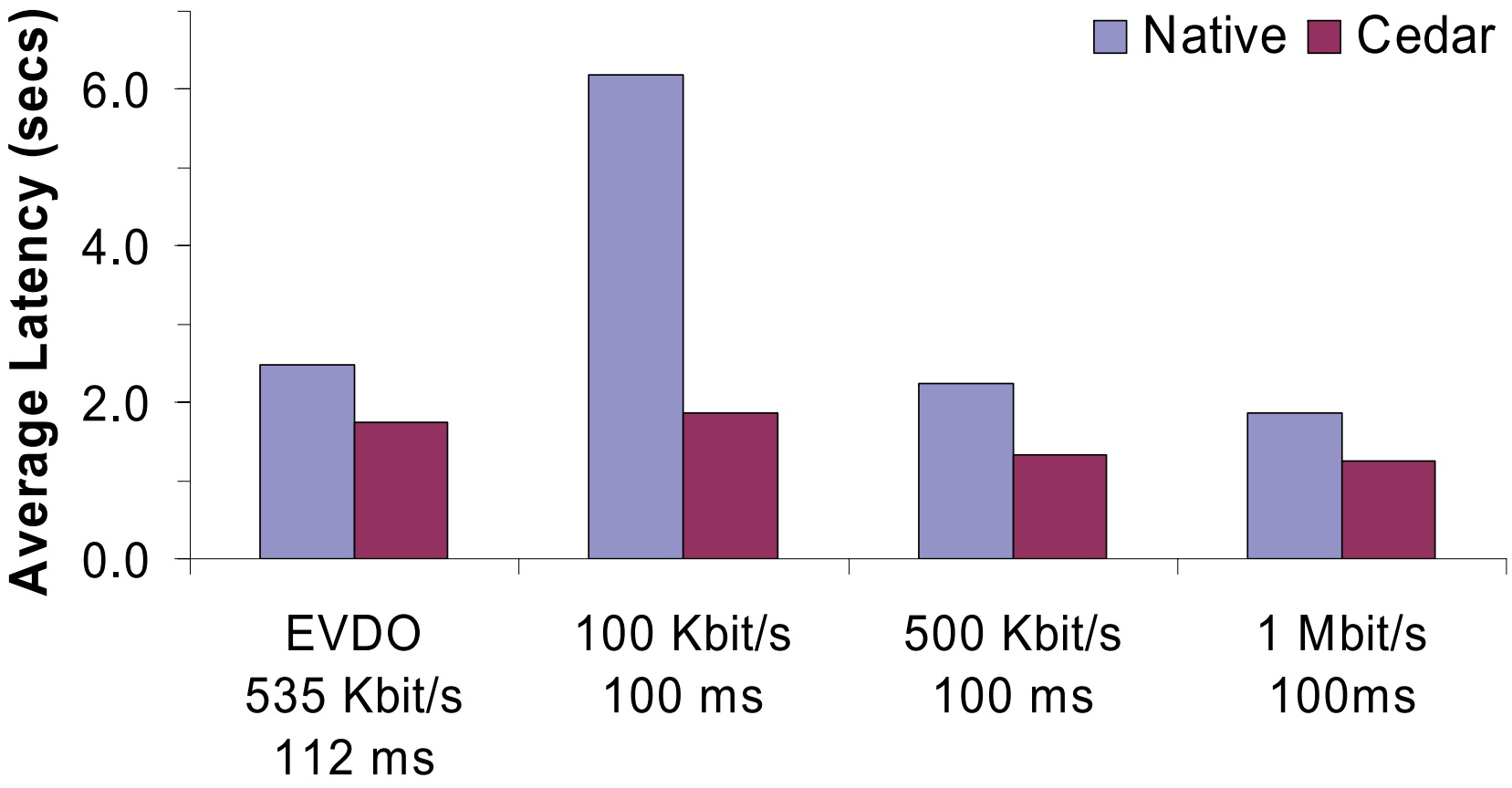
- Online distributor system (based on TPC-App)
  - Clients perform ***Interactions***: add orders, add customers, view orders, list catalog, modify catalog...
- Performance metrics
  - Throughput (Total No. of Interactions)
  - Latency (Average Interaction completion time)
- Experimental configuration
  - 40:60 Read:Write Interaction ratio
  - Benchmark Length: 5 minutes

MobileSales – Throughput



Full Hoard Profile, 50 Background Clients

MobileSales – Latency



Full Hoard Profile, 50 Background Clients

Cedar Summary

- Cedar enables efficient mobile database access
  - In low bandwidth conditions
  - While preserving consistency
- Uses Content Addressability + Client Resources