ORESTES: Scalability and Low Latency for Polyglot Database Services

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About me

- Since 2 years: PhD student (advisor: Norbert Ritter)
- Since 1 year: CEO of Baqend

Research Project for PhD

Orestes

Baqend

Build faster Apps faster.

Cloud Database Startup

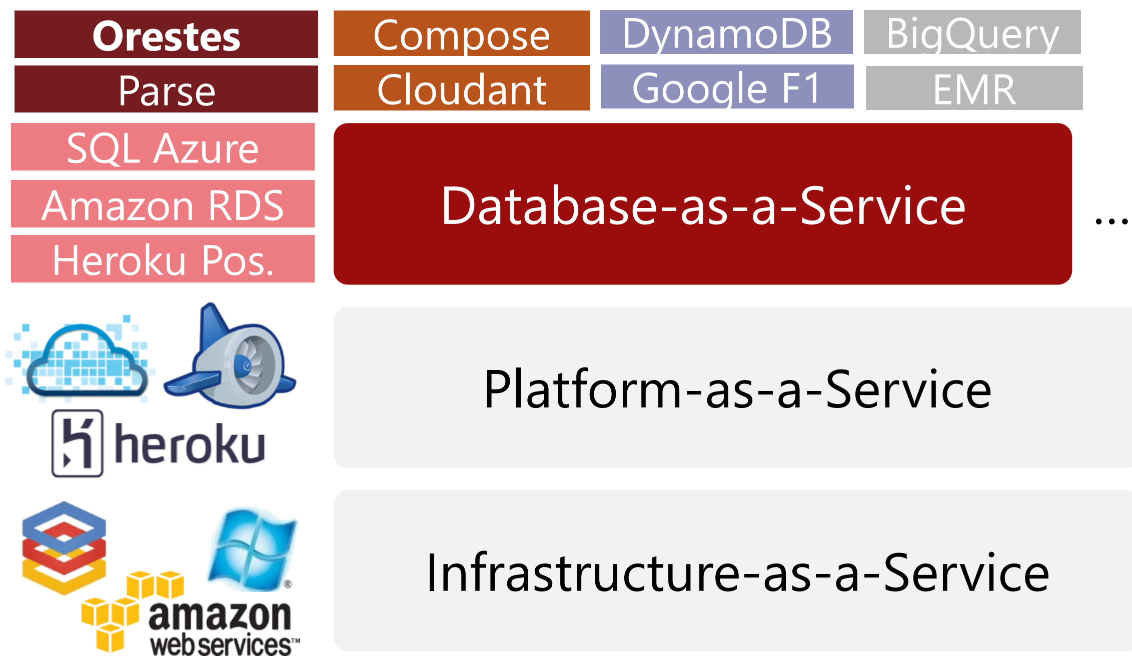
Outline

- **Motivation**
- Cache Sketch Approach
- Polyglot Persistence Mediator
- Wrap-up and future work

- Cloud Databases
- The Latency Problem of the web

Introduction: Which classes of cloud databases are there?

Cloud Databases



Cloud Databases

Orestes | Compose | DynamoDB | BigQuery

Parse | Cloudant | Google F1 | EMR

SQL Azure

Amazon RDS

Heroku Pos.

Database-as-a-Service …

Managed RDBMS

heroku

Platform-as-a-Service

amazon webservices™

Infrastructure-as-a-Service

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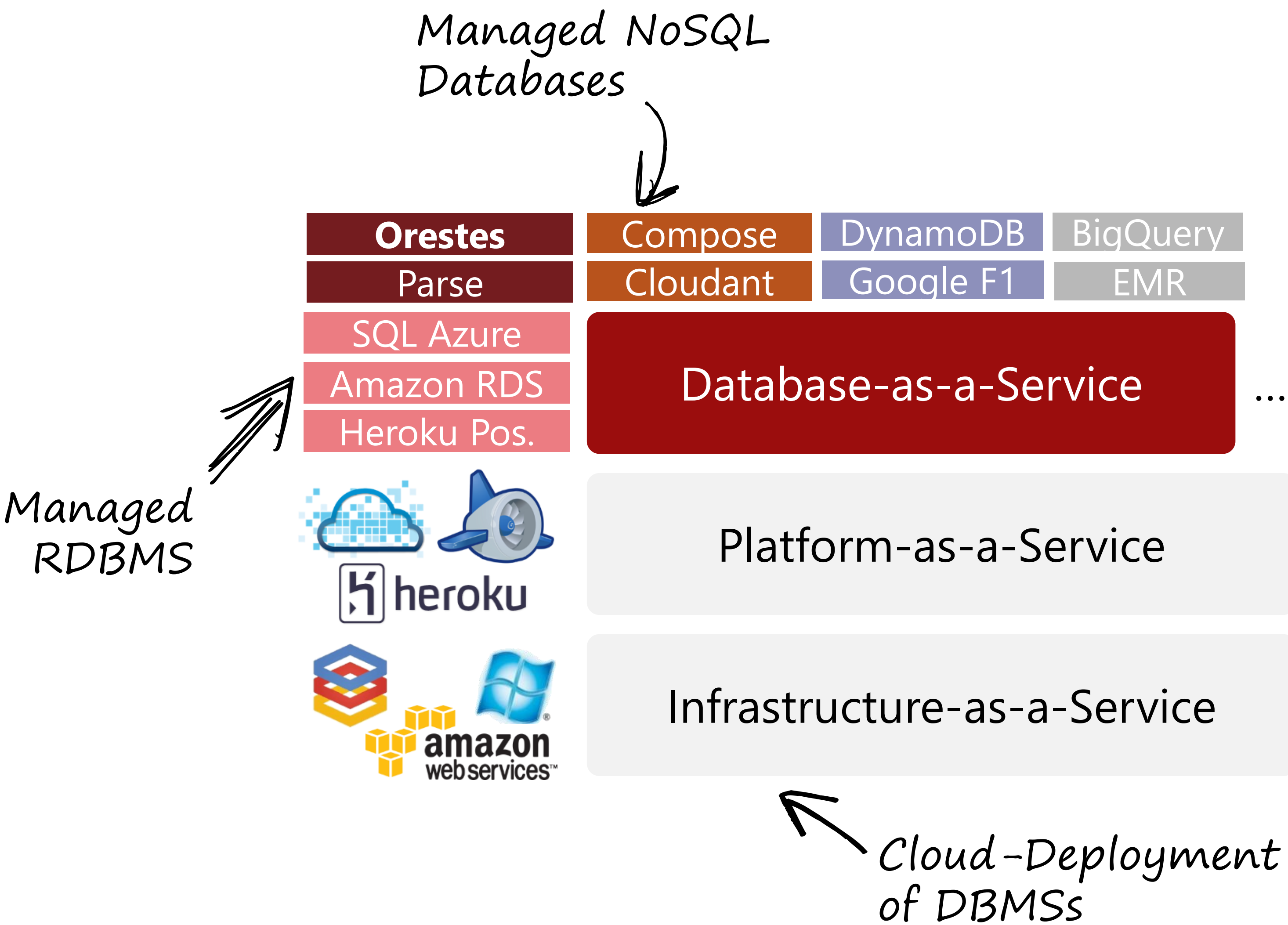
Cloud-Deployment of DBMSs

Cloud Databases



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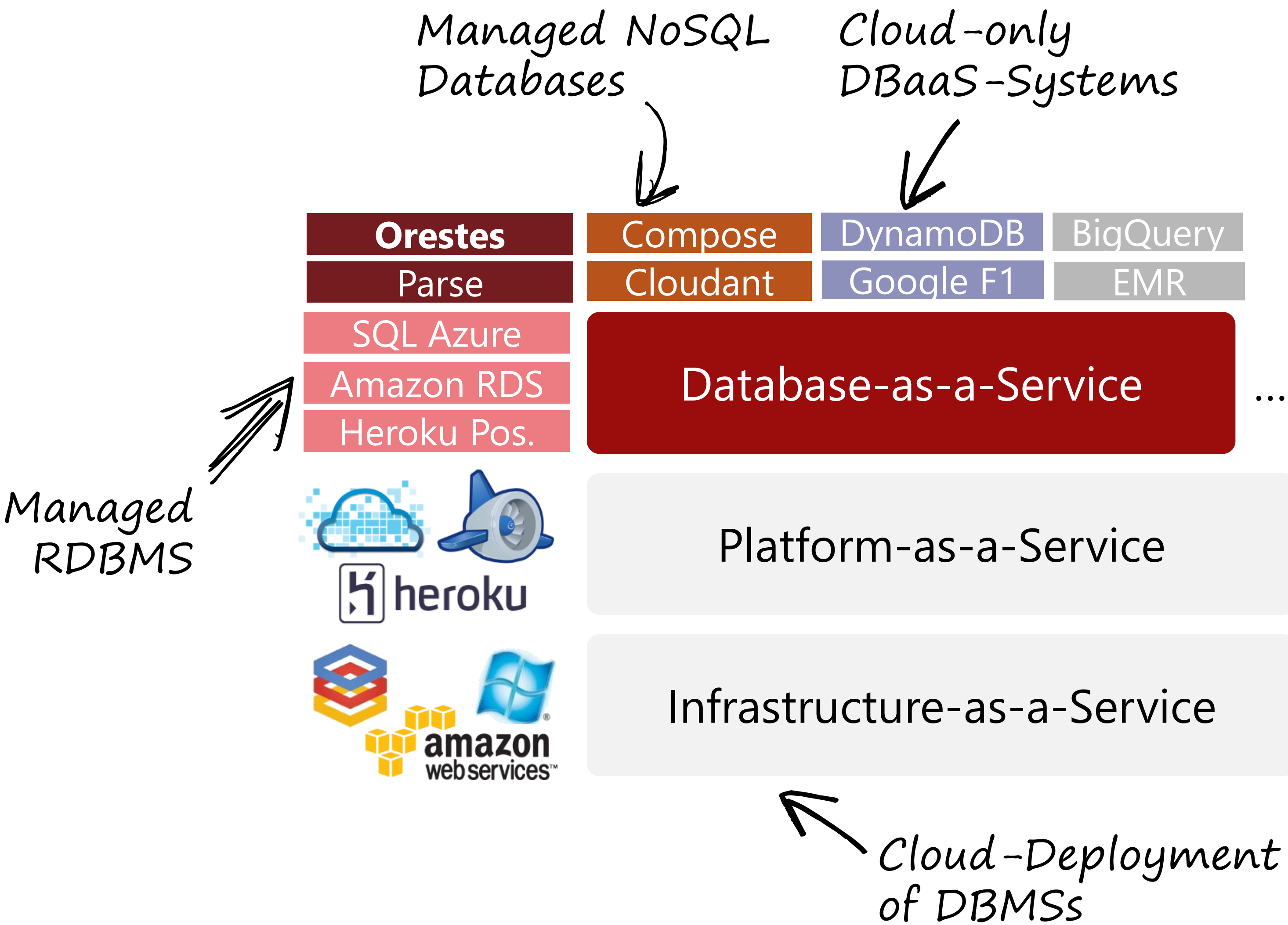

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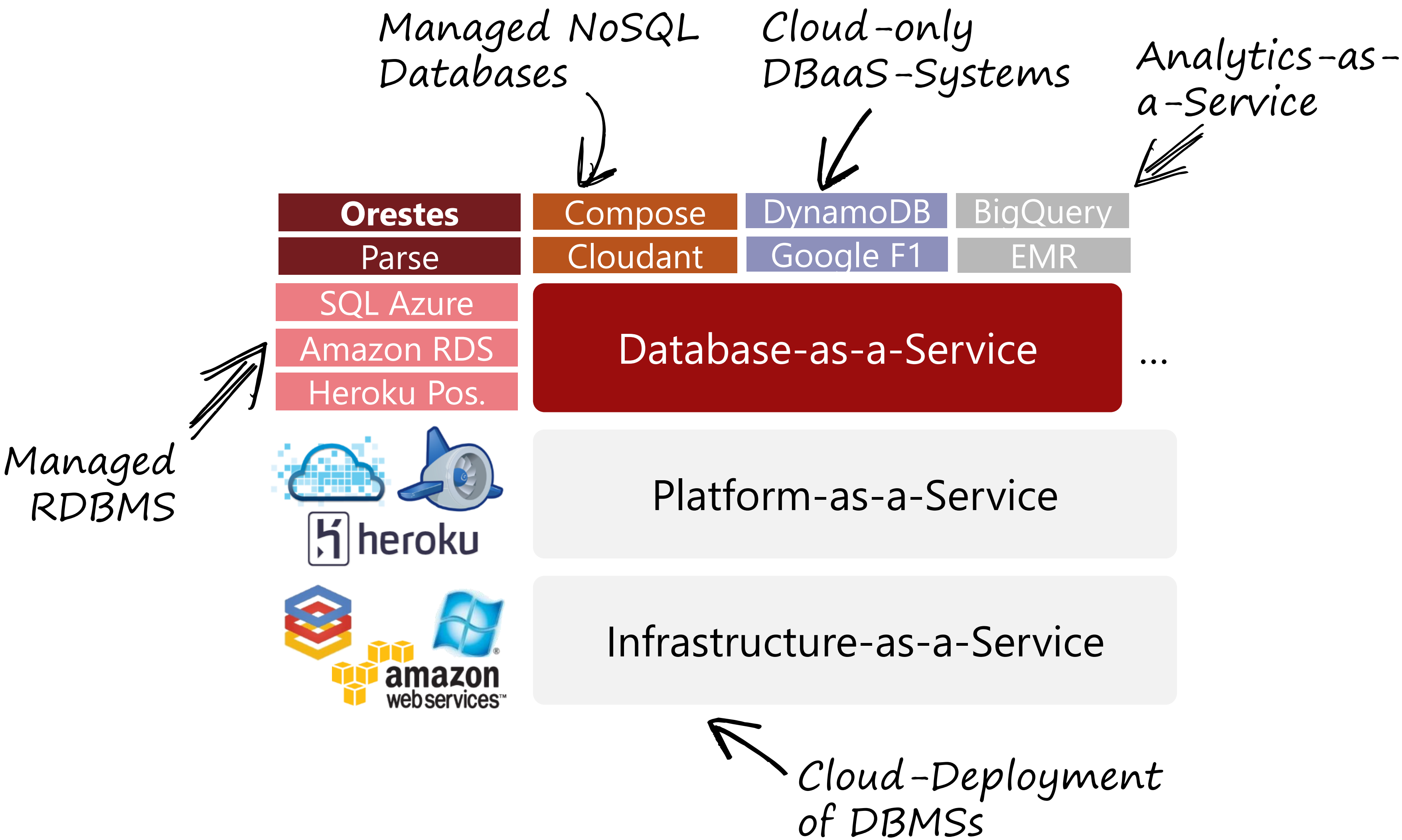

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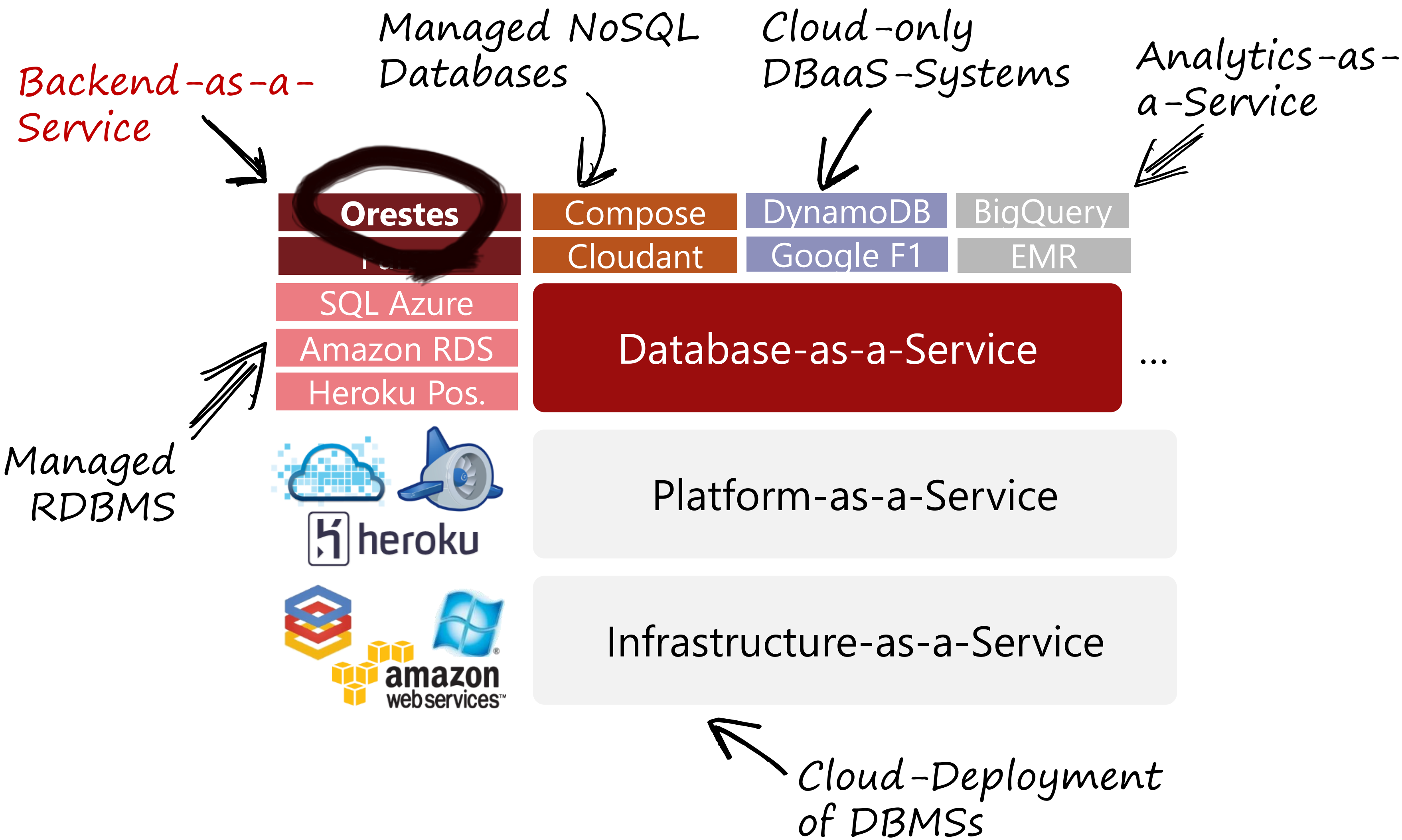

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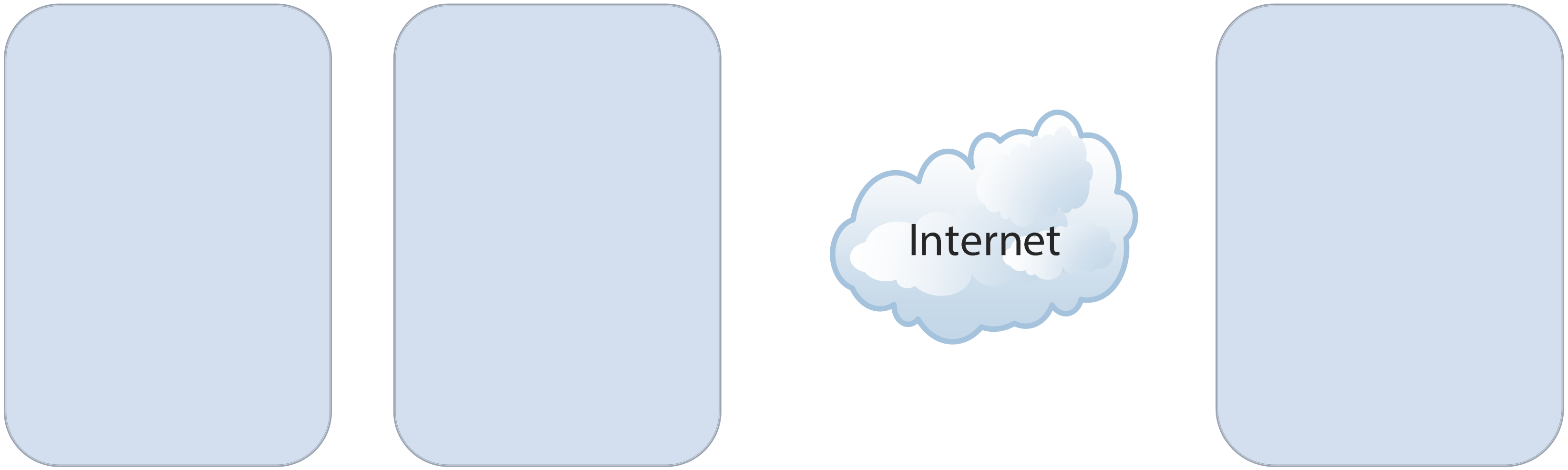

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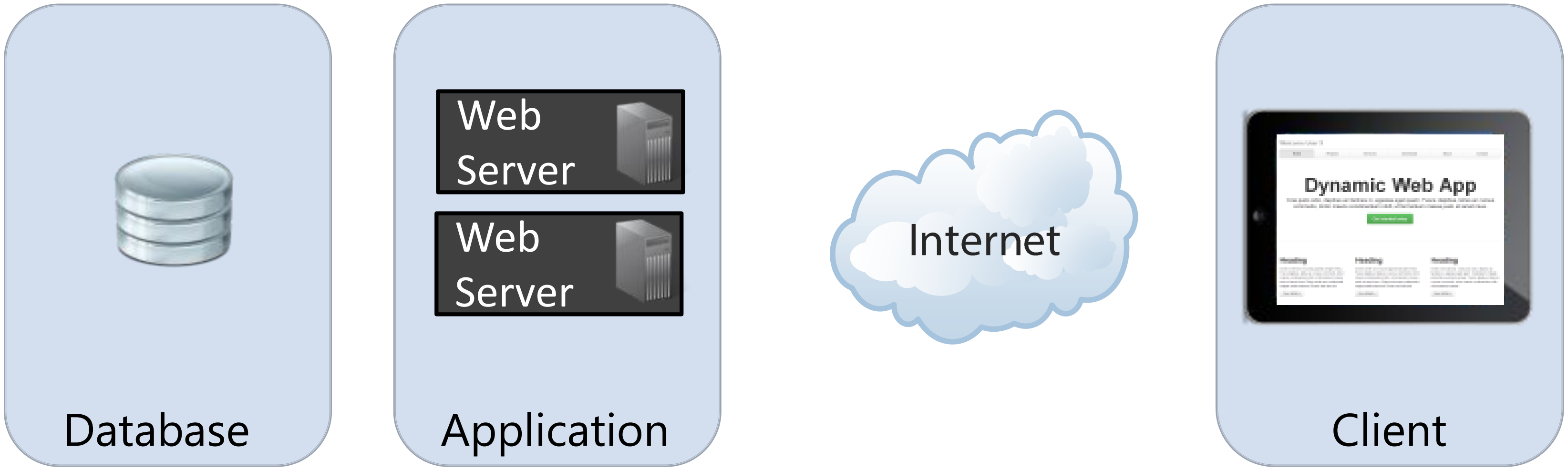
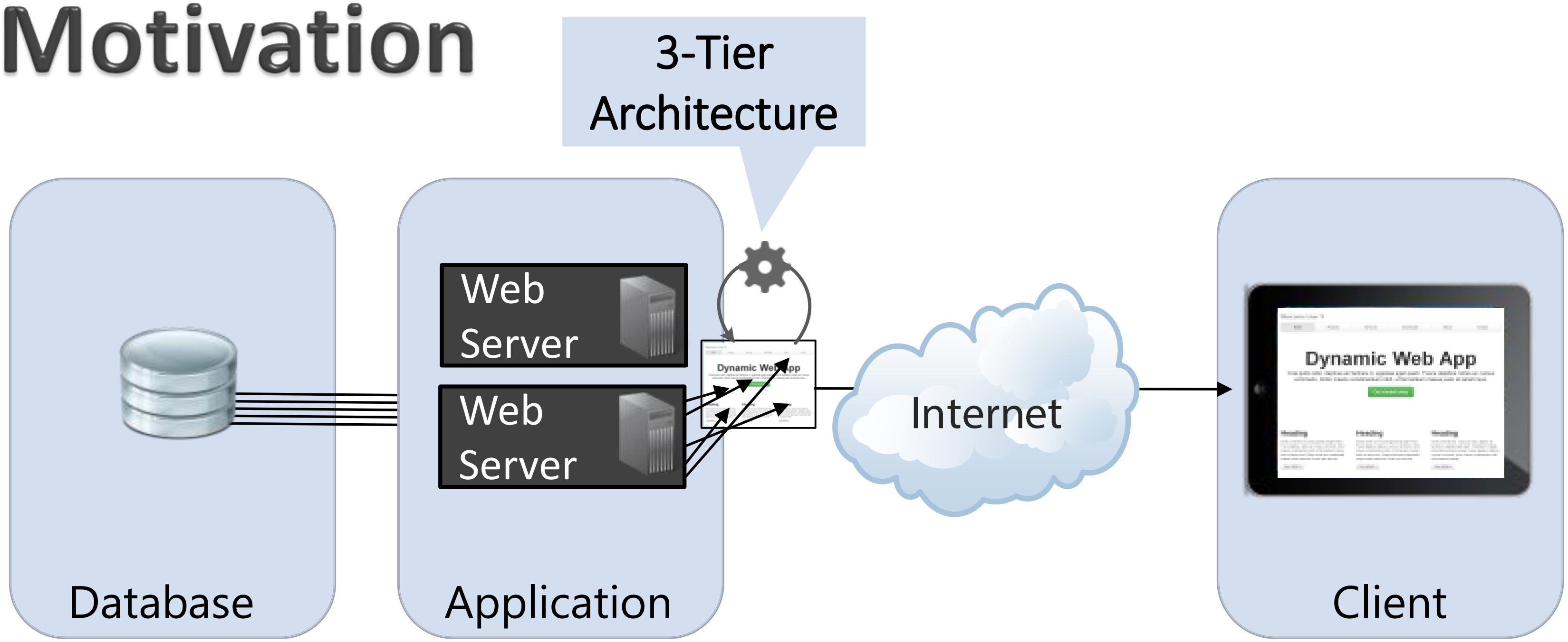

Web Server
Web Server
Internet
Dynamic Web App
Database
Application
Client

Motivation


3-Tier
Architecture
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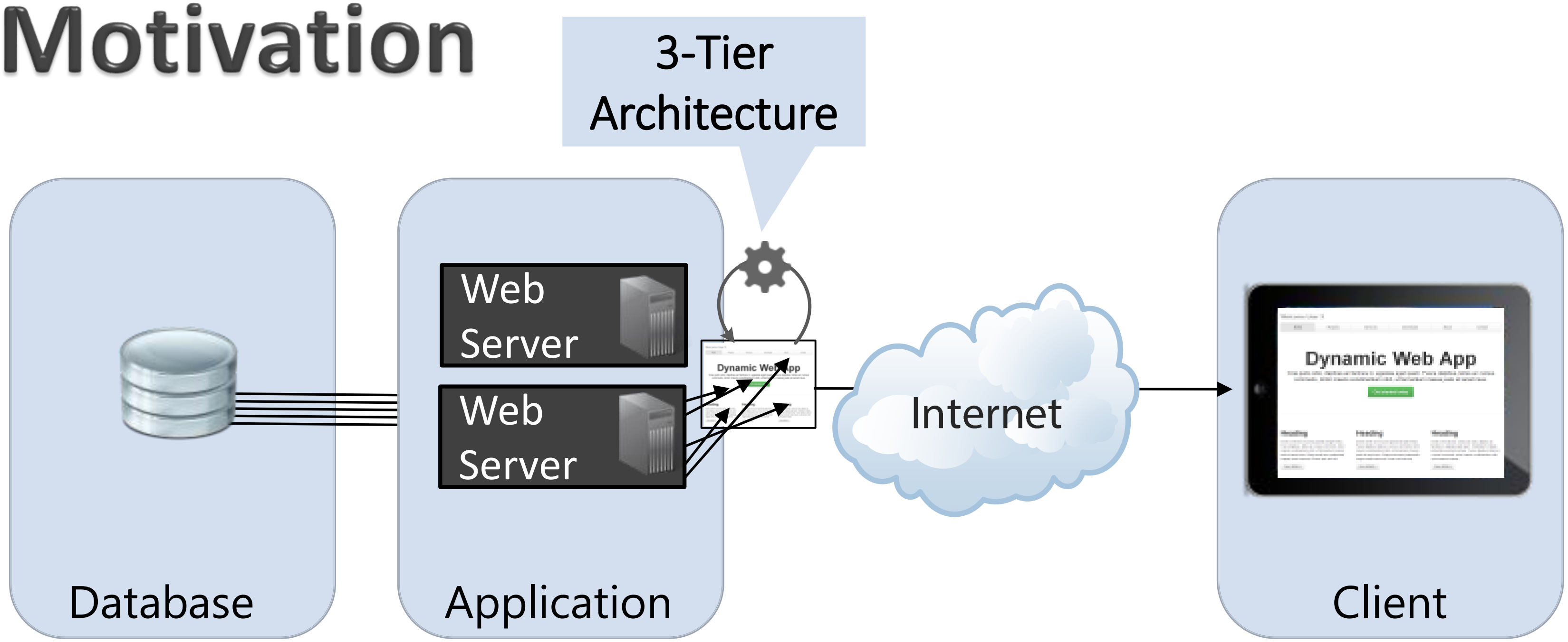
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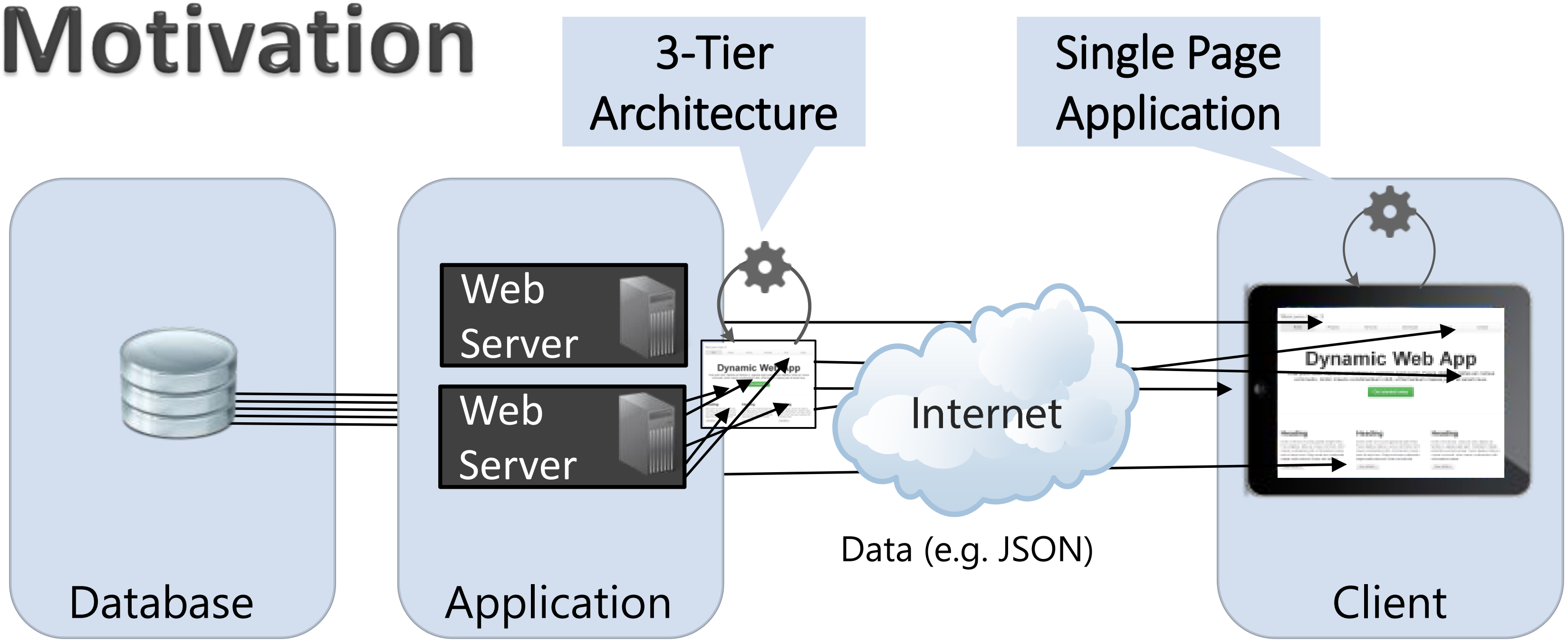
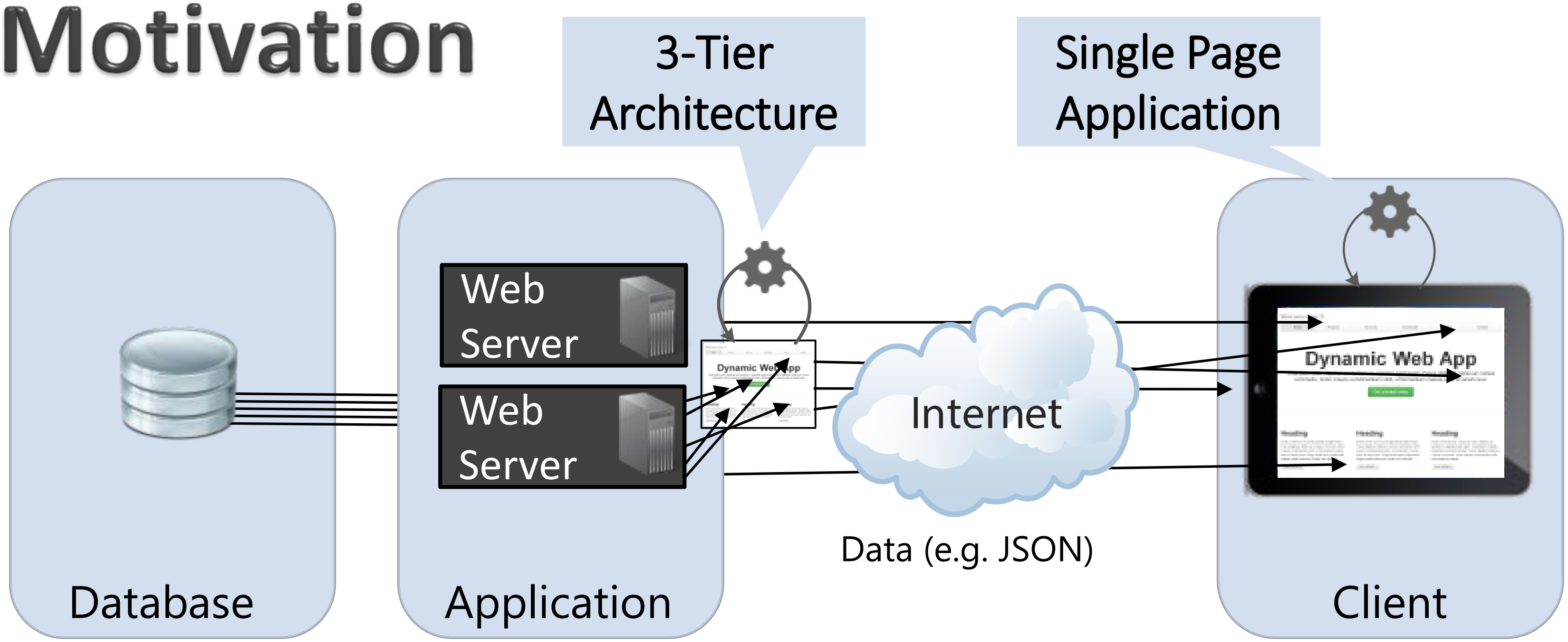
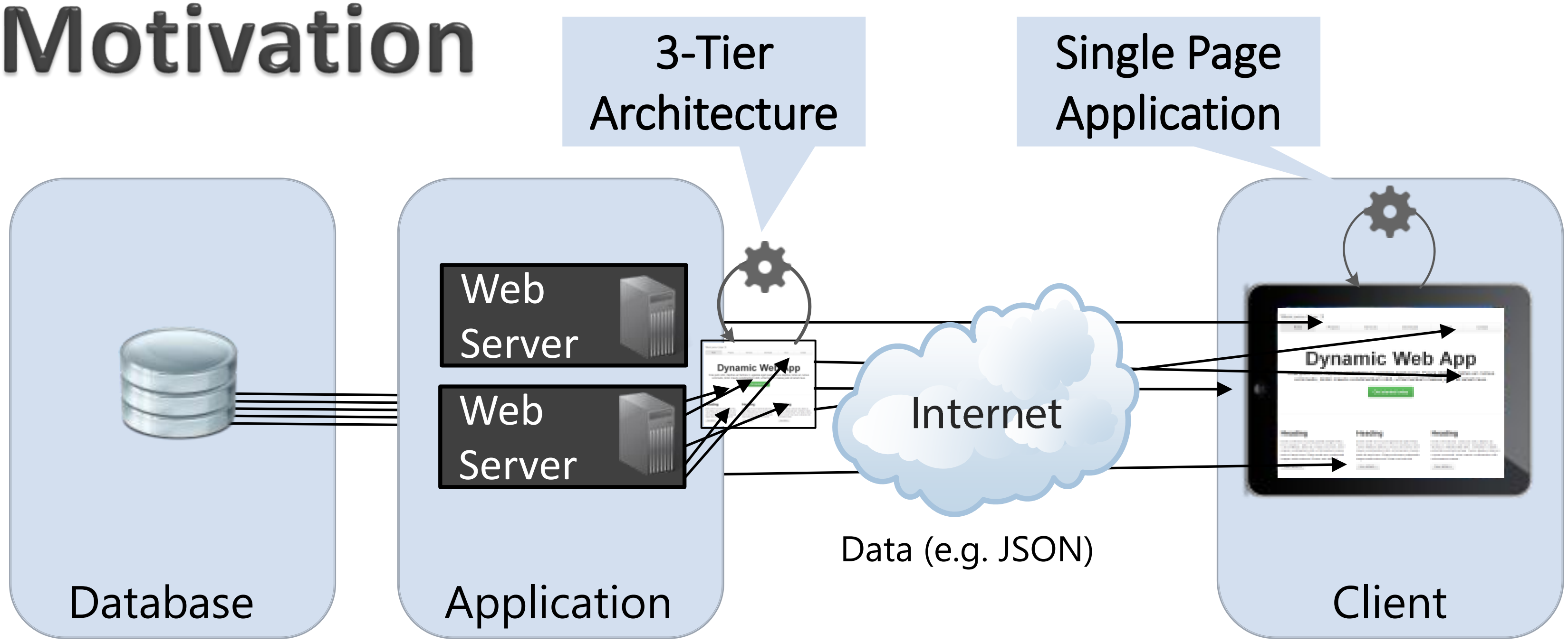

3-Tier Architecture
Single Page Application
Web Server
Web Server
Dynamic Web App
Internet
Dynamic Web App
Data (e.g. JSON)
Database
Application
Client

Motivation



Redundance
Applications reimplement
backend functionality

Motivation



Redundance
Applications reimplement backend functionality

Database Dependence
Strong coupling between application and database system

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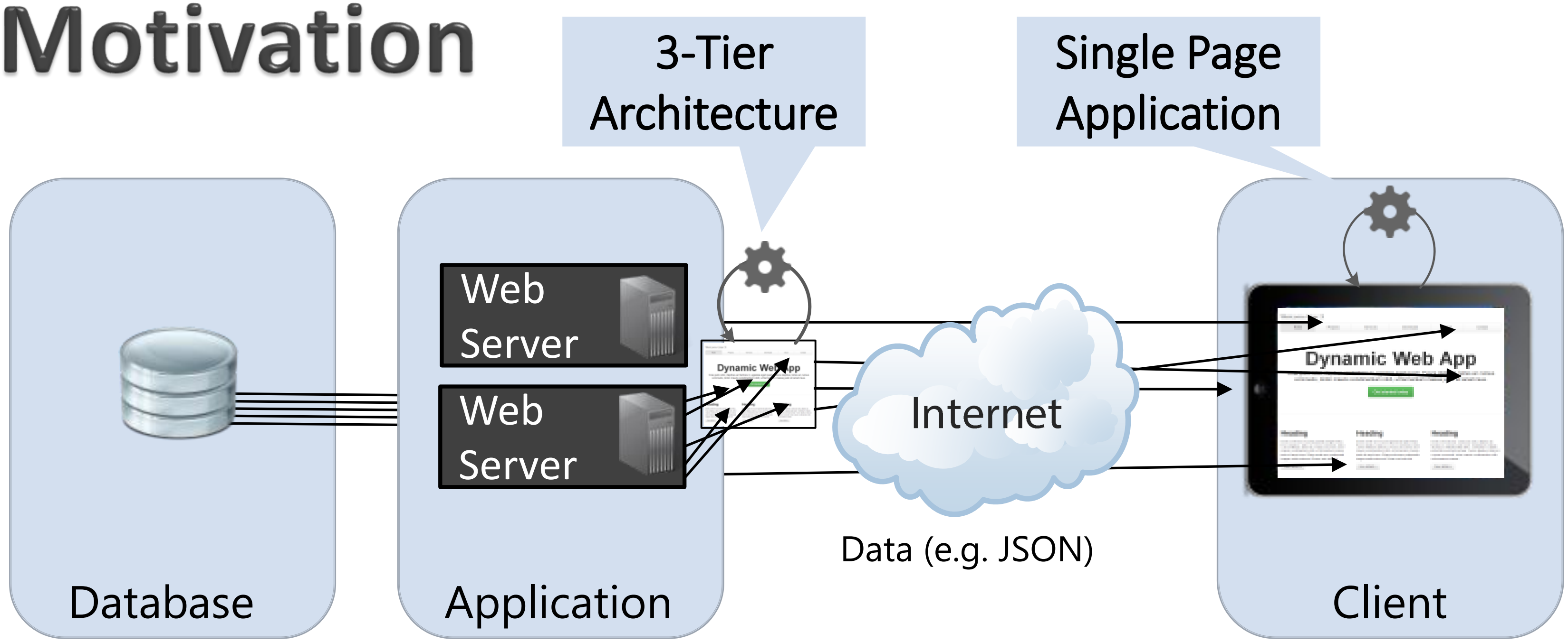

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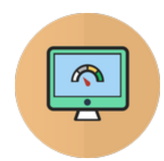

Performance & Scalability
Error-prone application-specific scaling policies

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Strong coupling between application and database system

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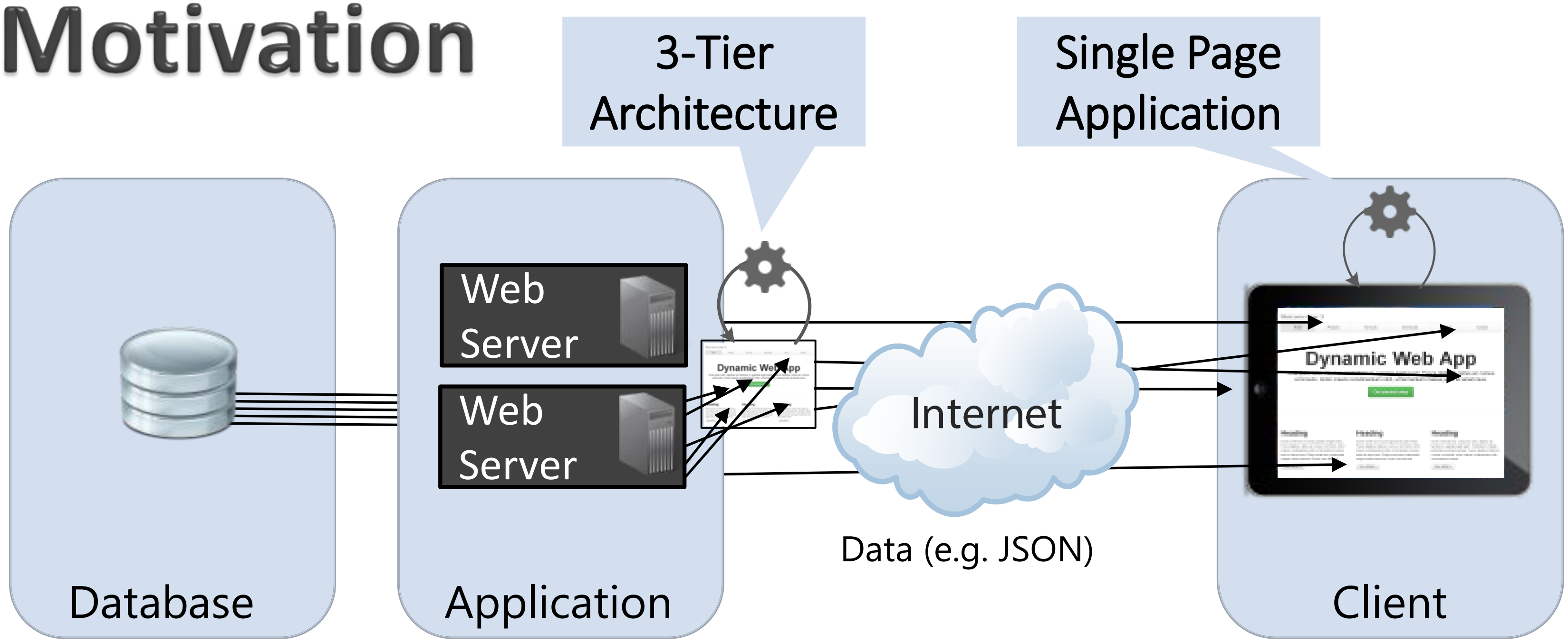

Redundance
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Performance & Scalability
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Database Dependence
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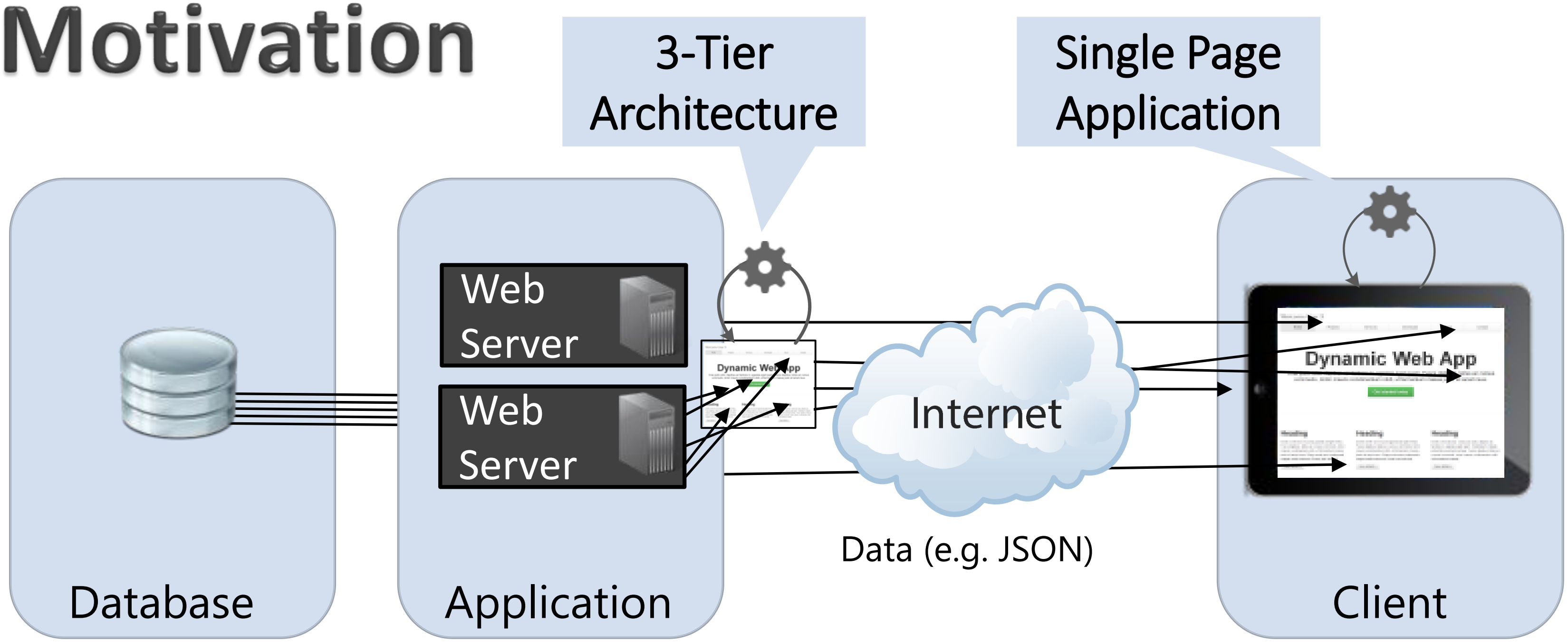
Difficult Development
Both client and server have to be implemented

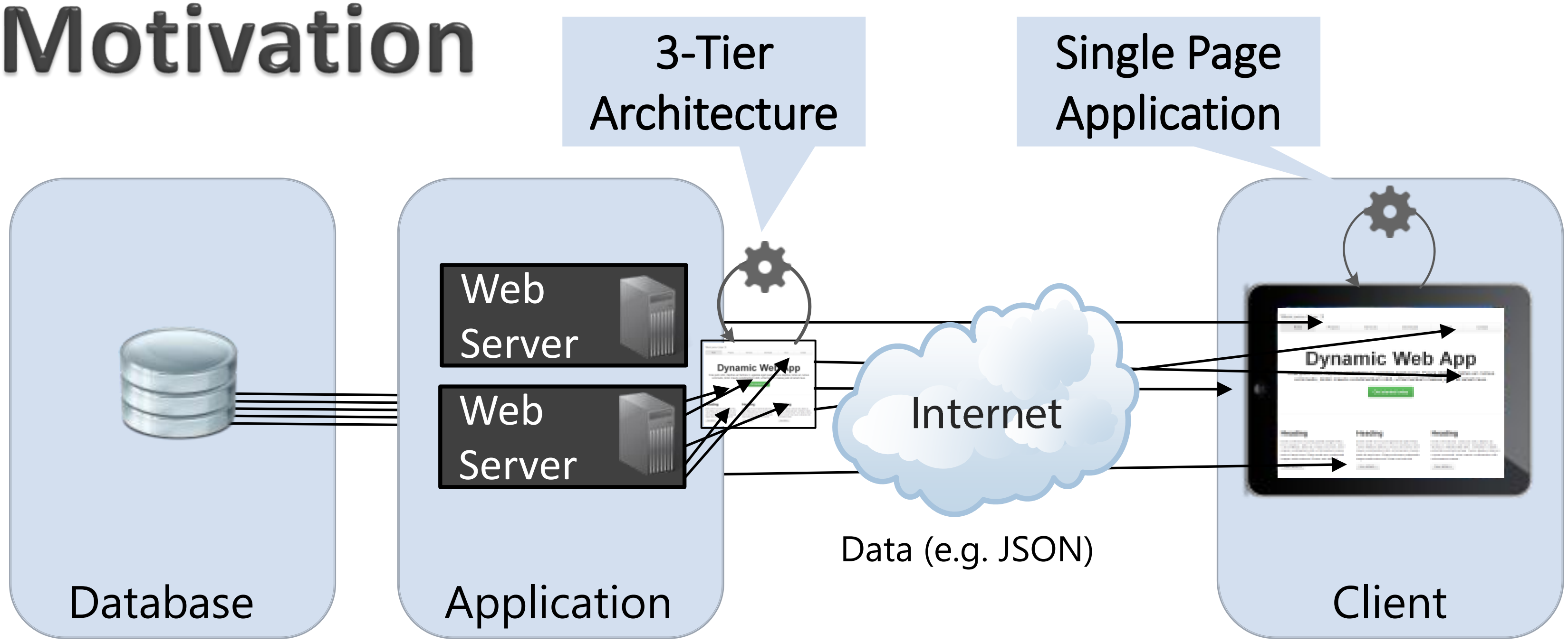
Motivation



With every **100ms** of additional page load time, revenue decreases by 1%.

Study by **Amazon**

Motivation



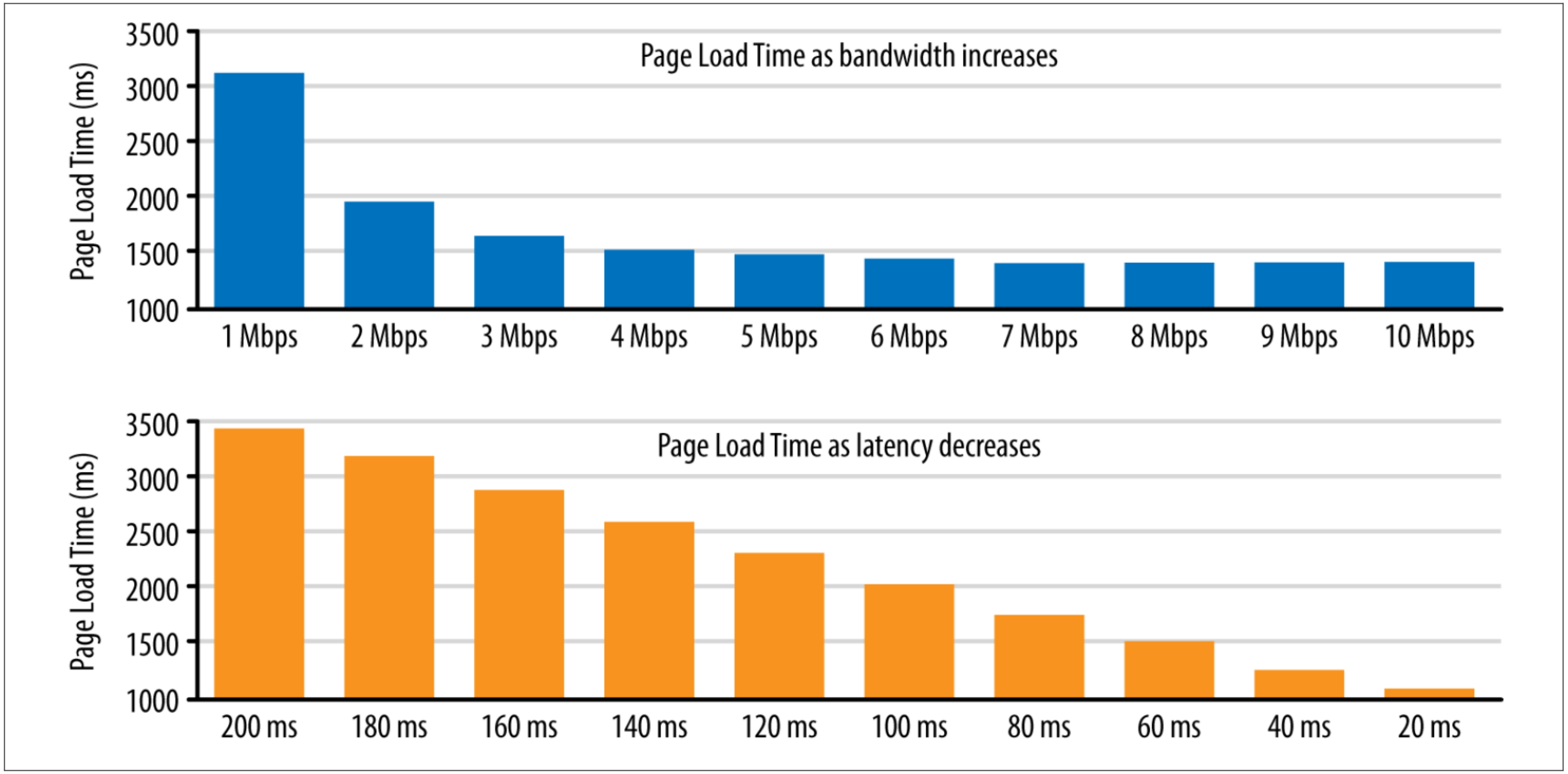
When increasing load time of search results by **500ms**, traffic decreases by 20%.

Study by **Google**

Motivation

3-Tier Architecture

Single Page Application



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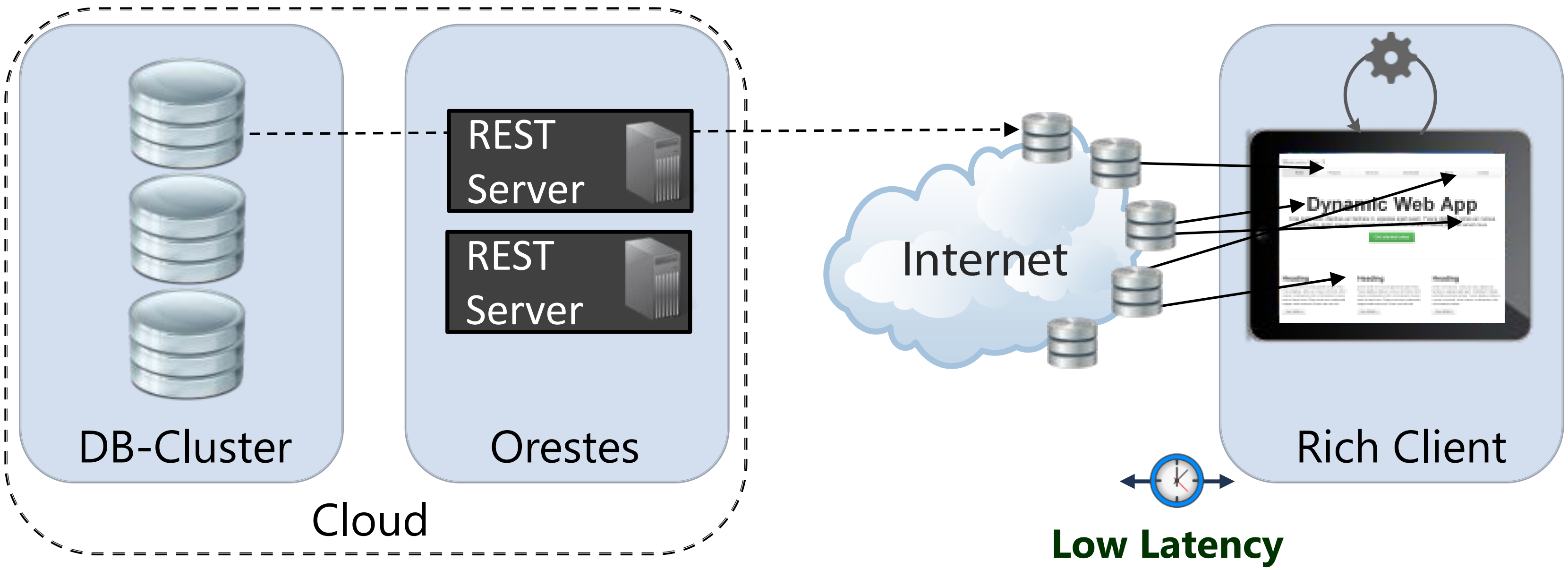
Study by **Google**

Vision: Orestes



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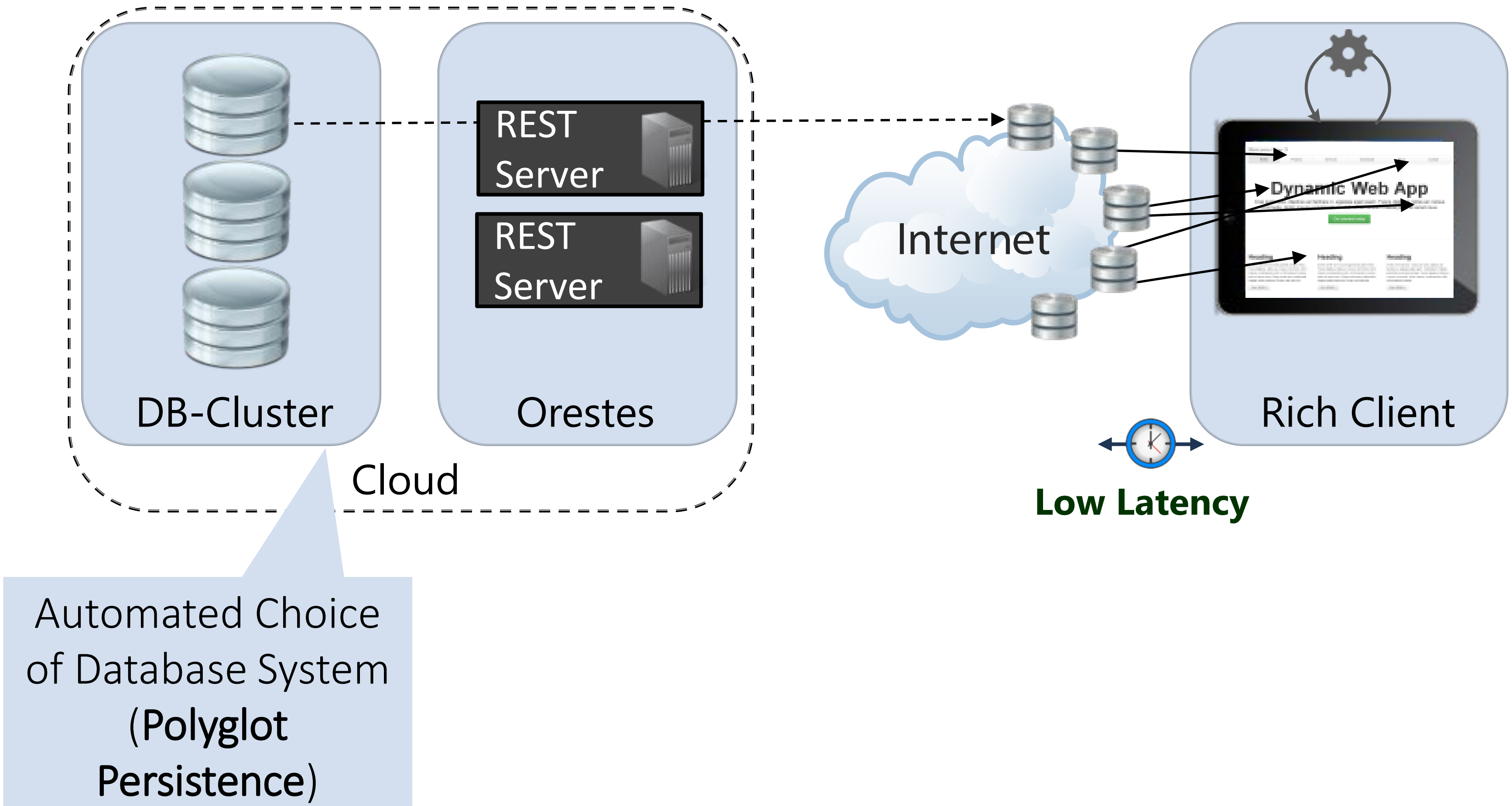

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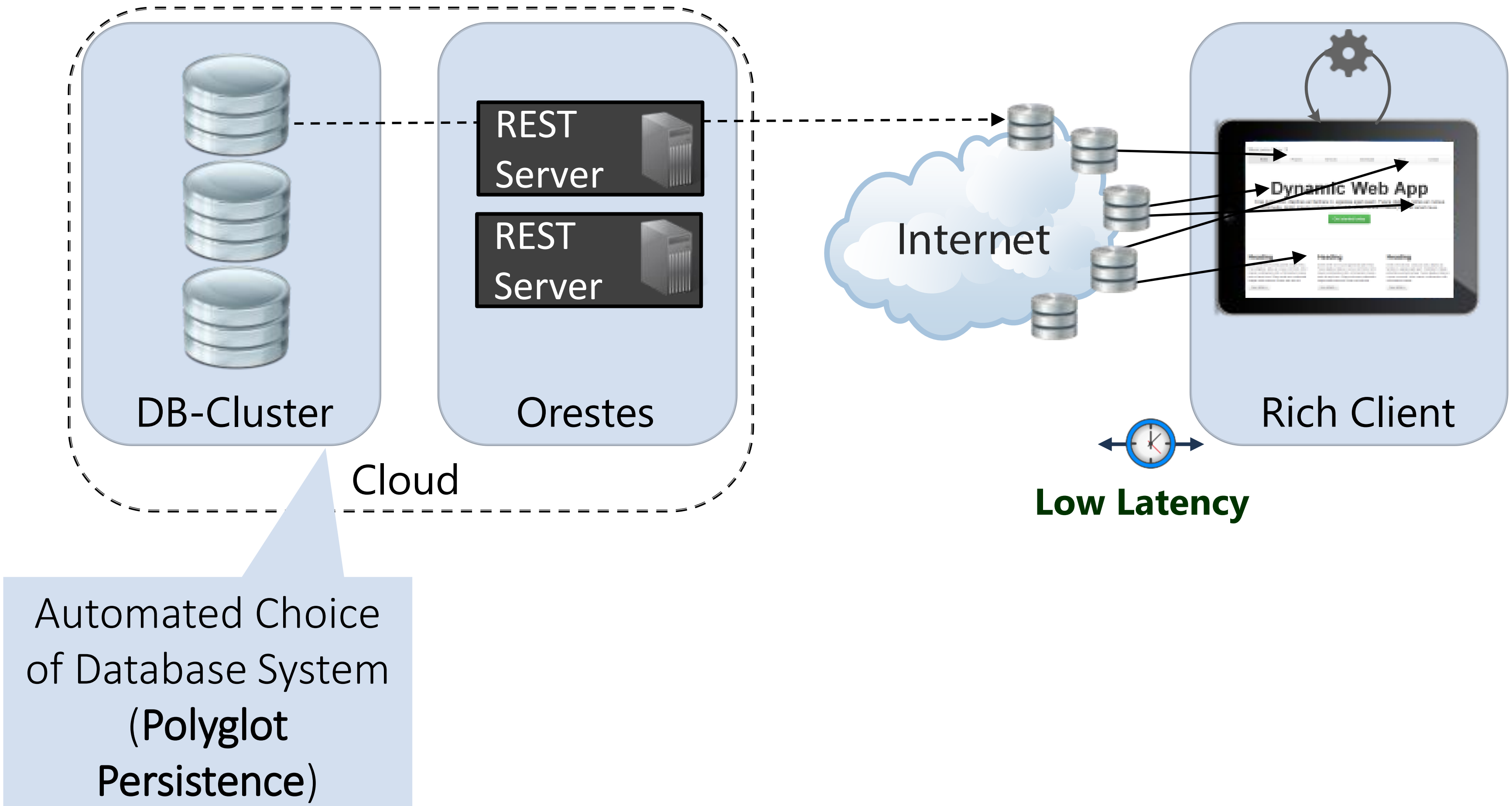

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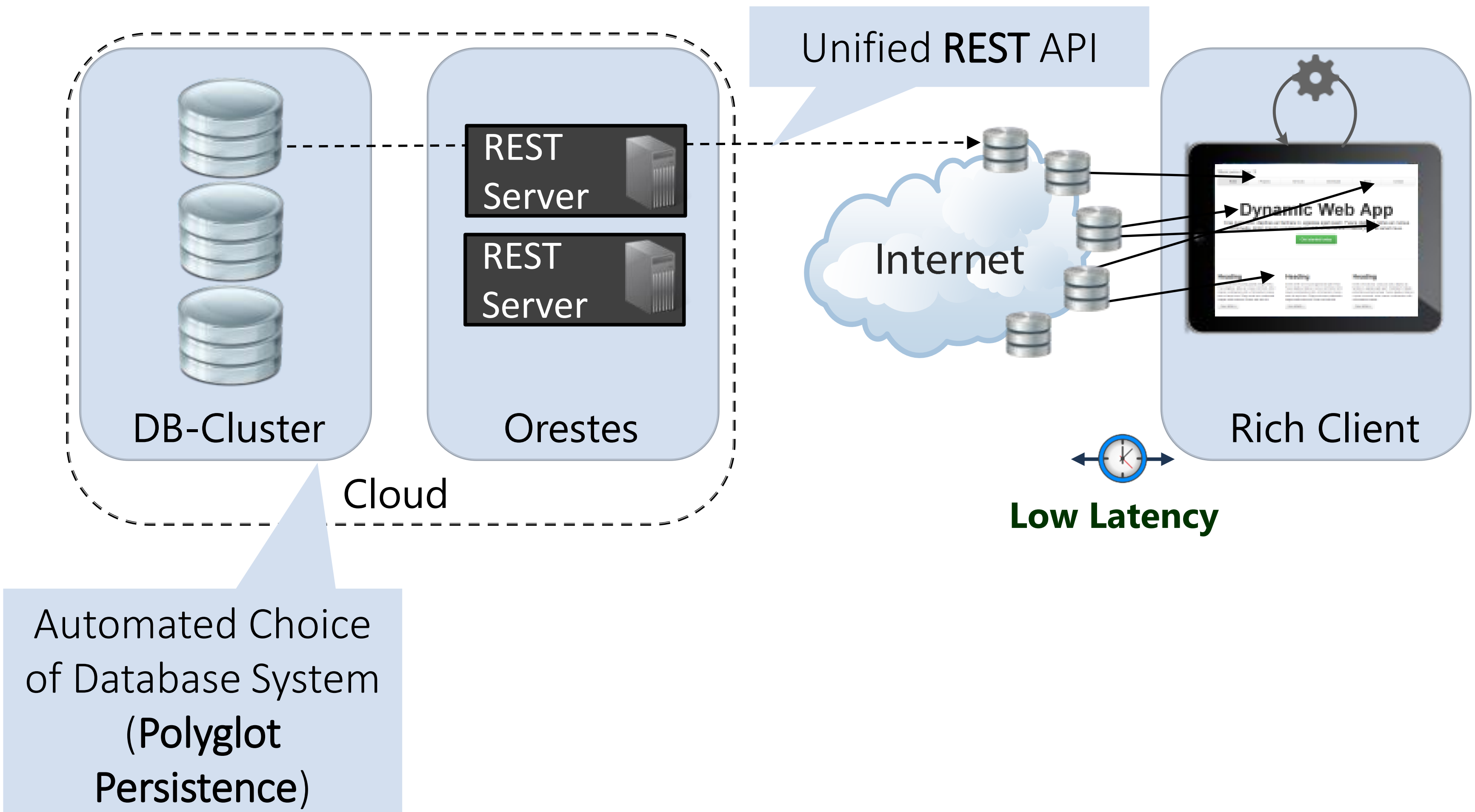

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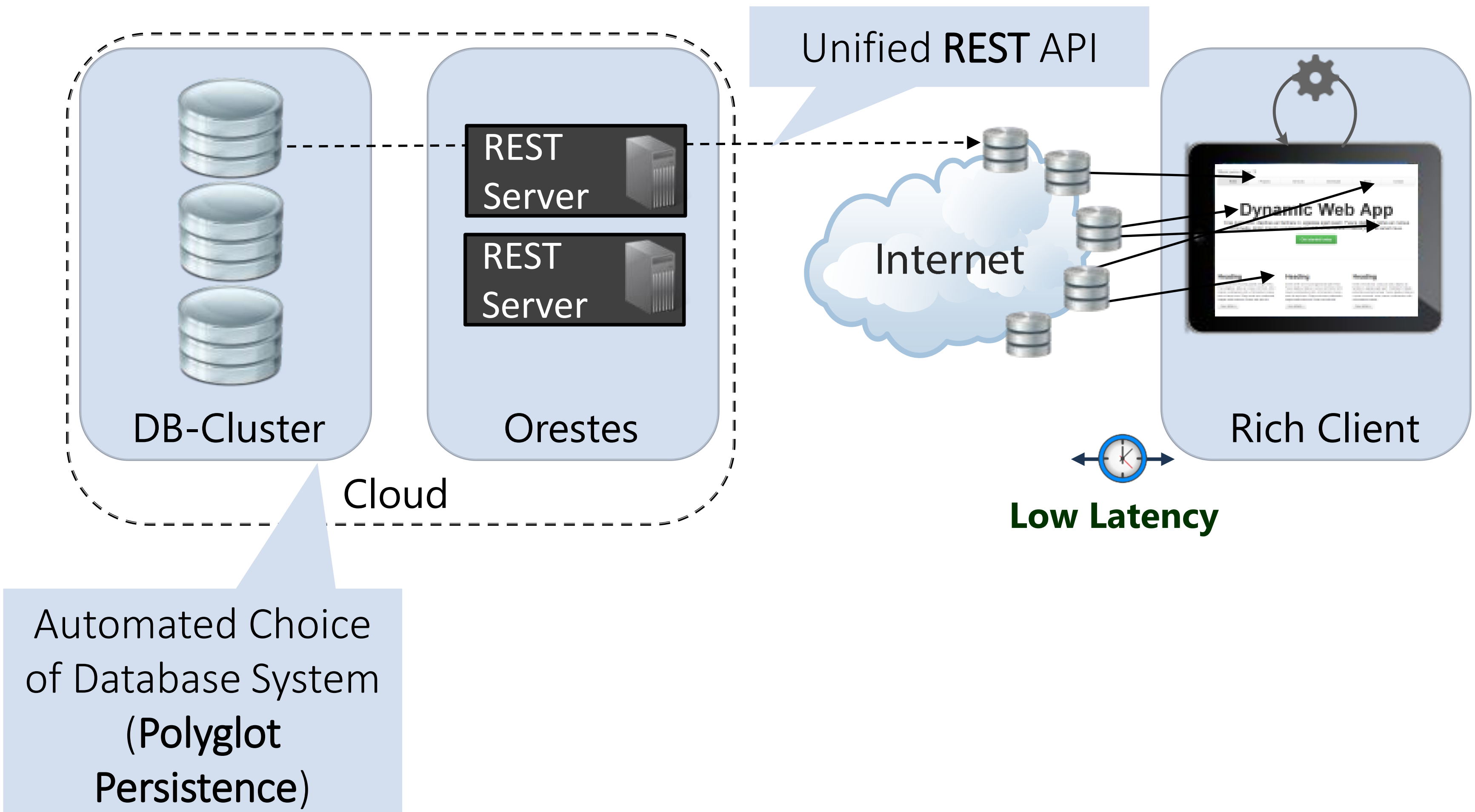

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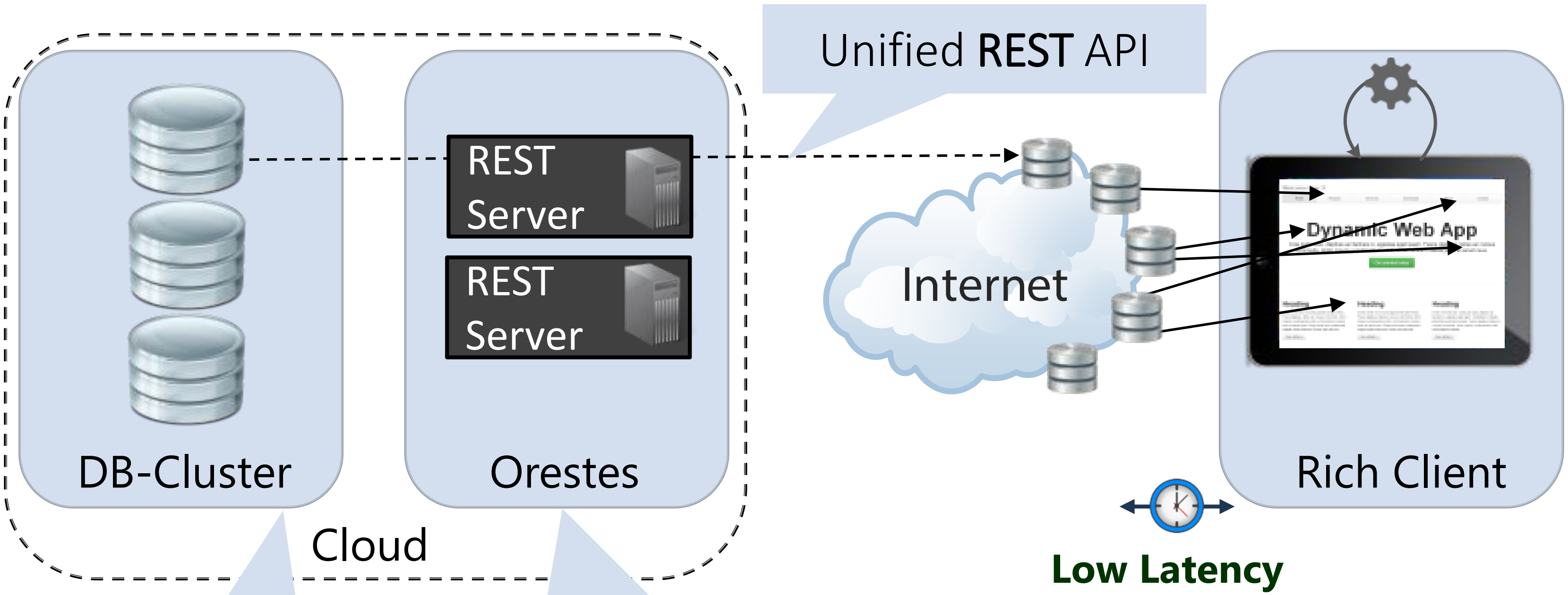
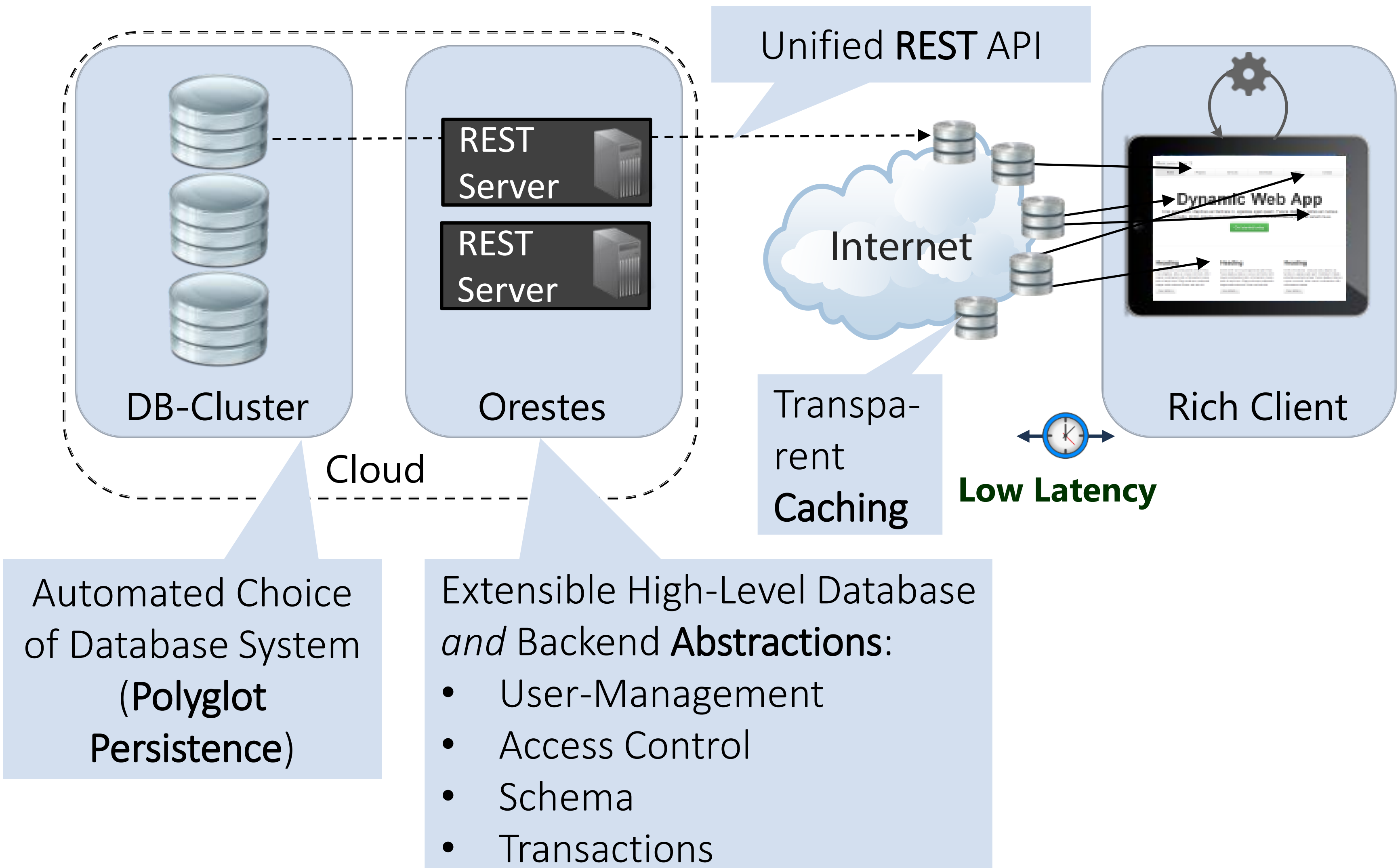


Automated Choice of Database System (**Polyglot Persistence**)

Extensible High-Level Database *and* Backend **Abstractions**:

- User-Management
- Access Control
- Schema
- Transactions

Vision: ORESTES



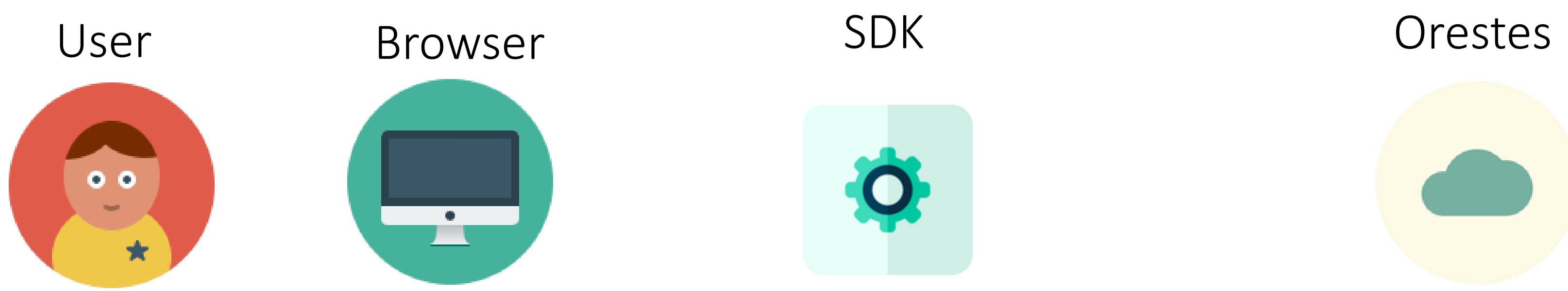
Outline

- Motivation
- **Cache Sketch Approach**
- Polyglot Persistence Mediator
- Wrap-up and future work

- REST/HTTP API
- HTTP Caching
- The Cache Sketch
  - Principle
  - Construction
  - Use

Unified REST API

- Platform-specific interfaces map to unified REST API



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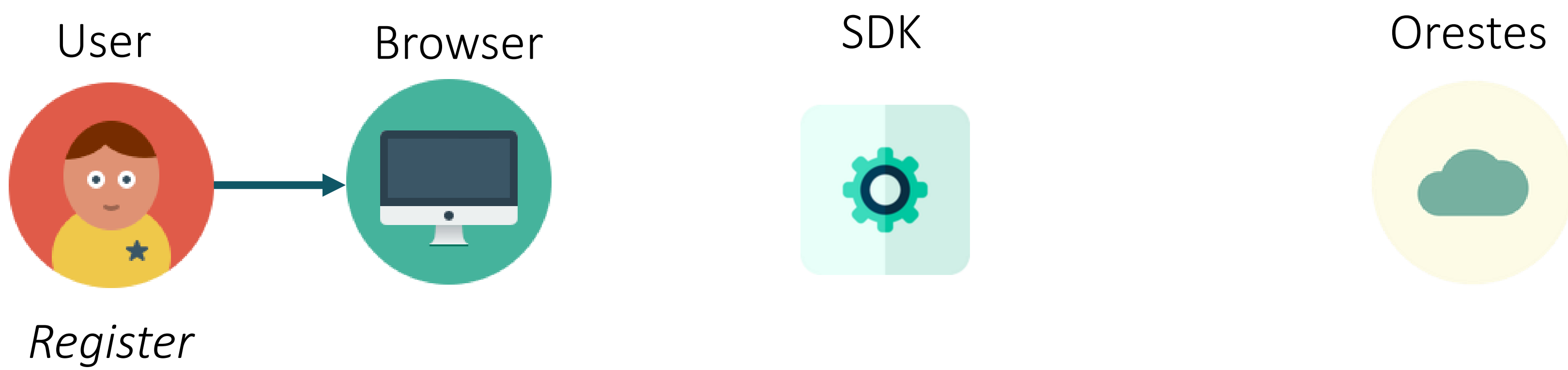

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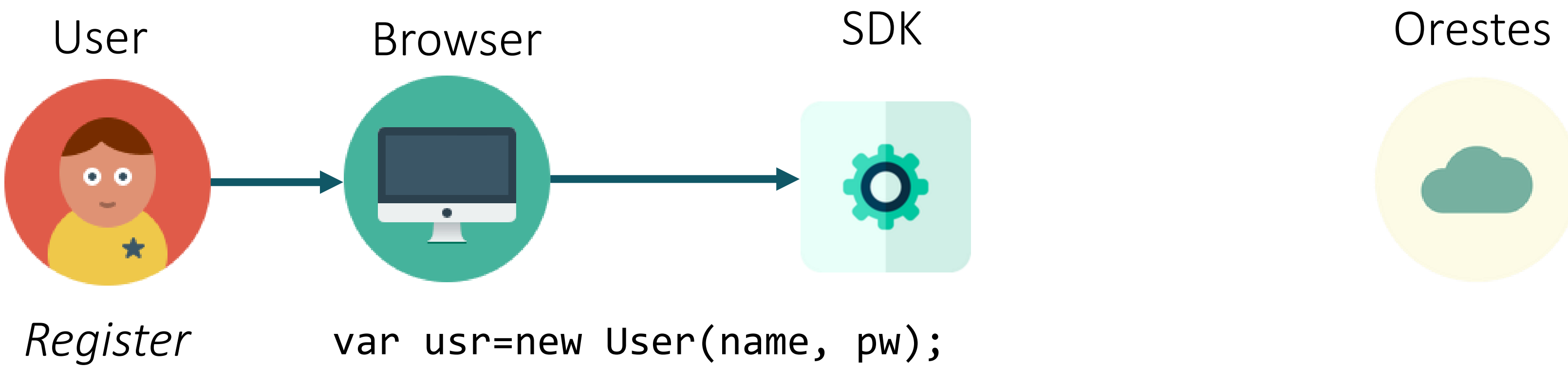


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var usr=new User(name, pw);
usr.register();
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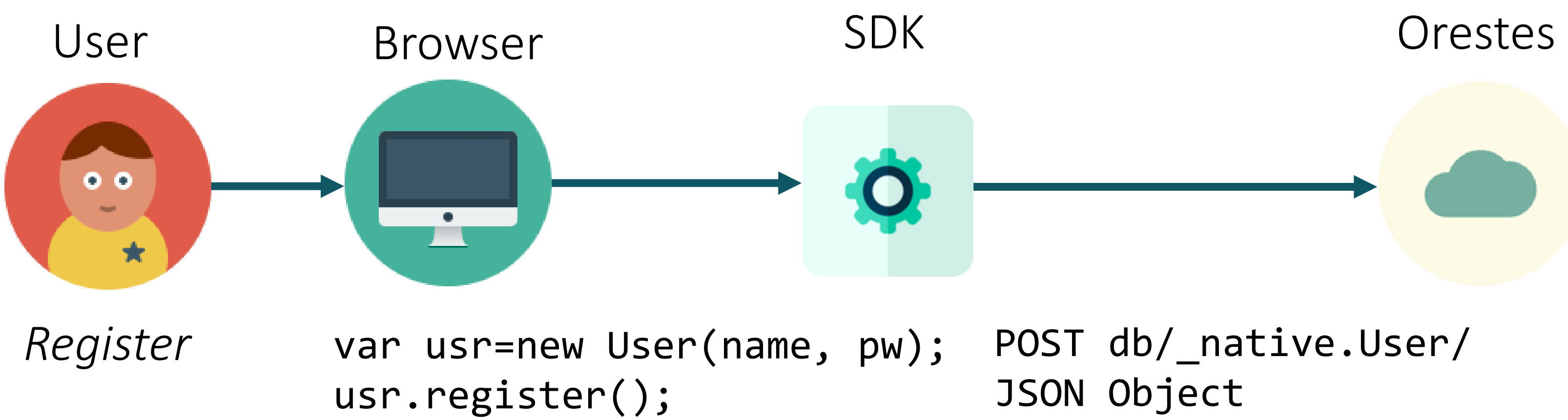

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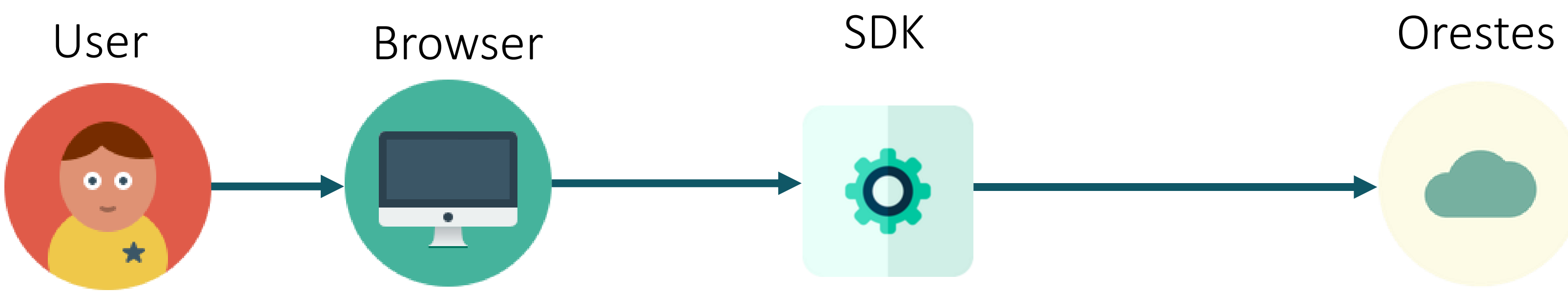

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JSON Object
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Unified REST API

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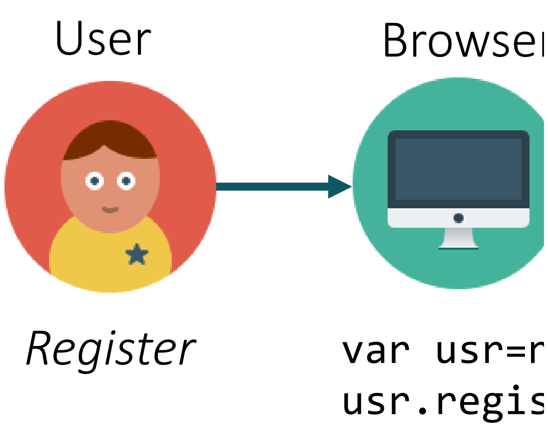

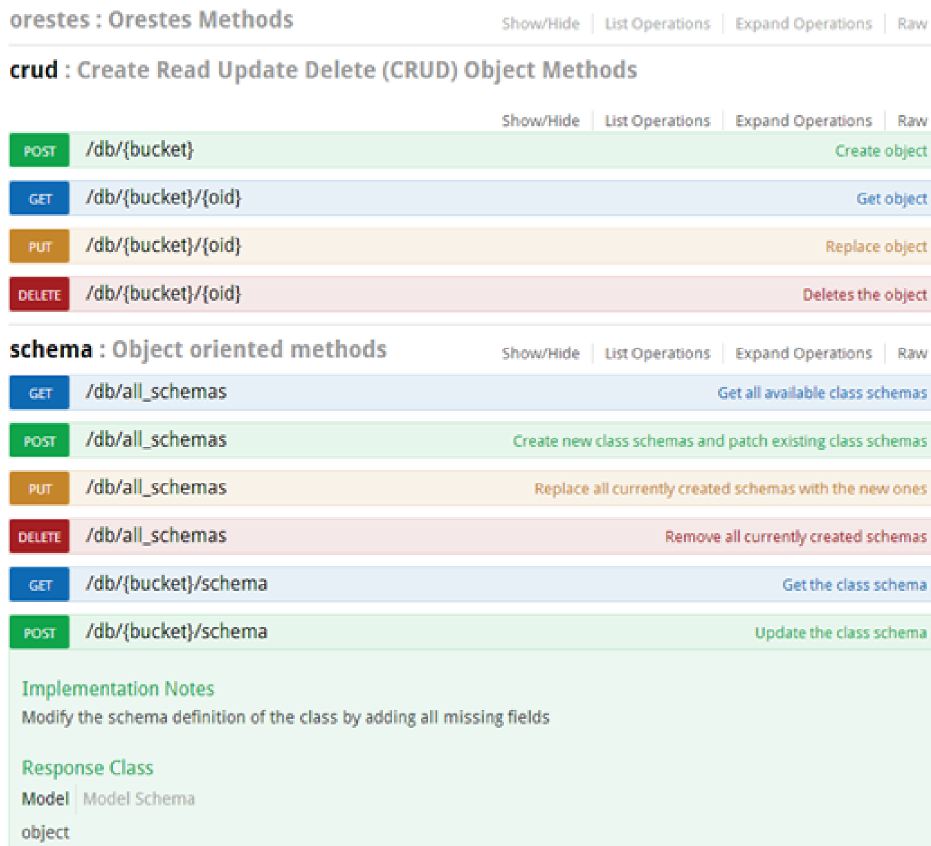

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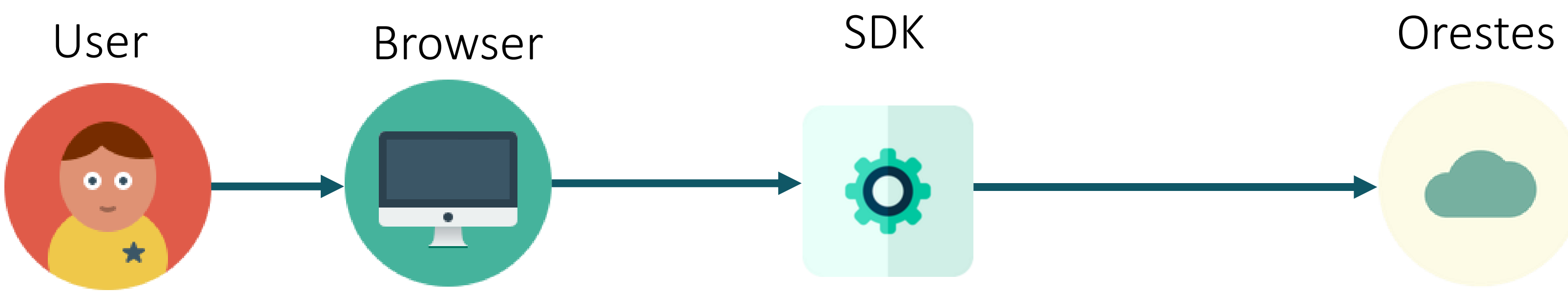

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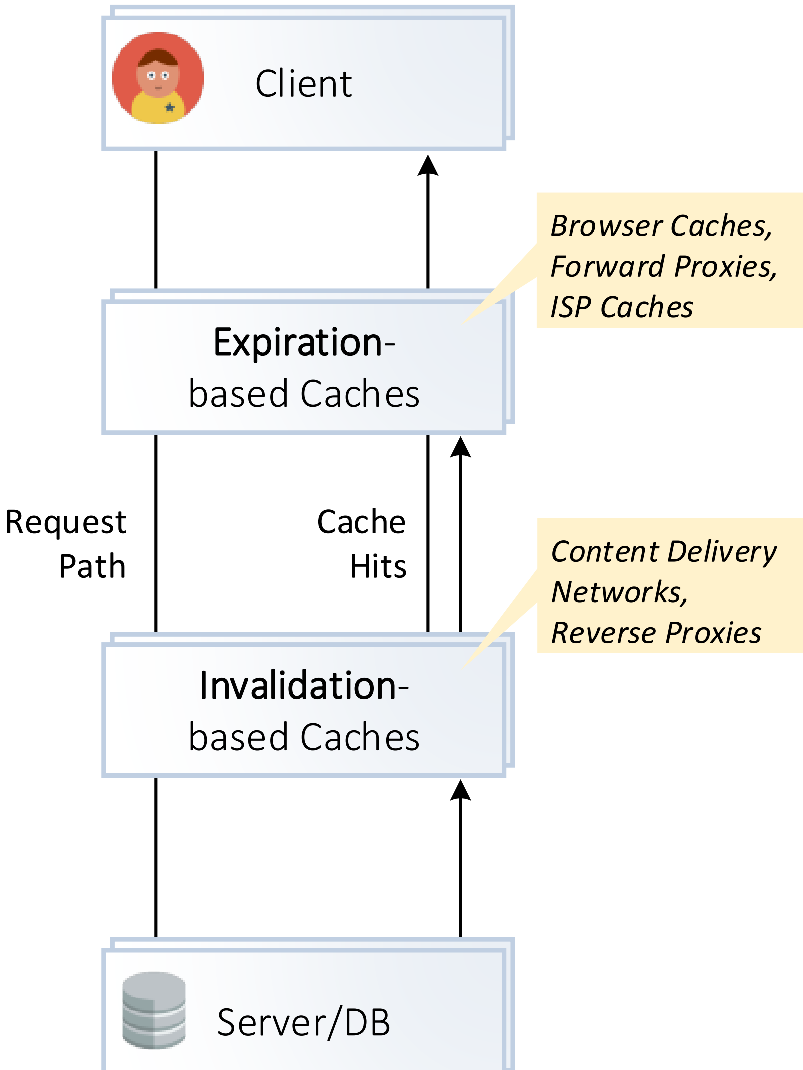
- REST API leverages existing HTTP infrastructure
  - Load-Balancer (*stateless communication REST constraint*)
  - Web-Caches (*caching REST constraint*)

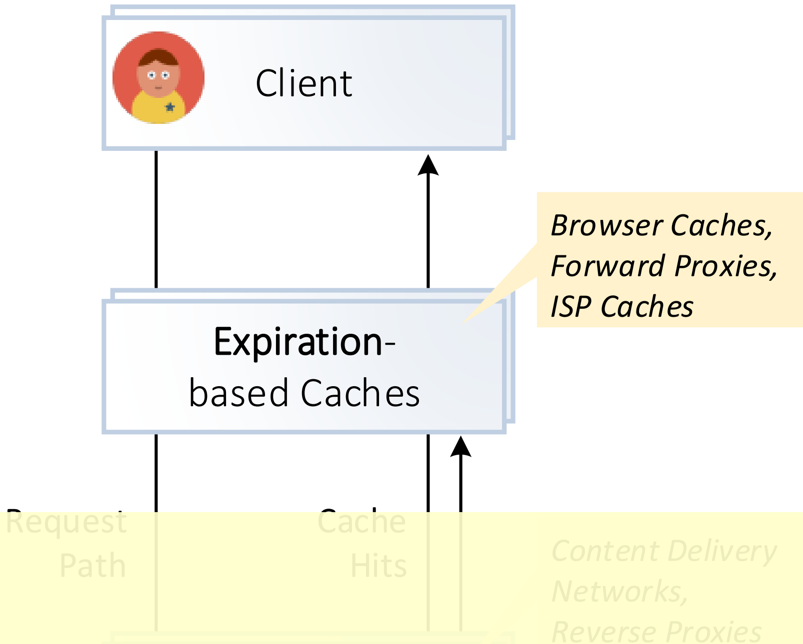
Expiration-based Caching



HTTP Caching Model:

- **Expiration-based** with defined *TTL*
- **Revalidations** check freshness at the server

Expiration-based Caching



HTTP Caching Model:

- **Expiration-based** with defined *TTL*
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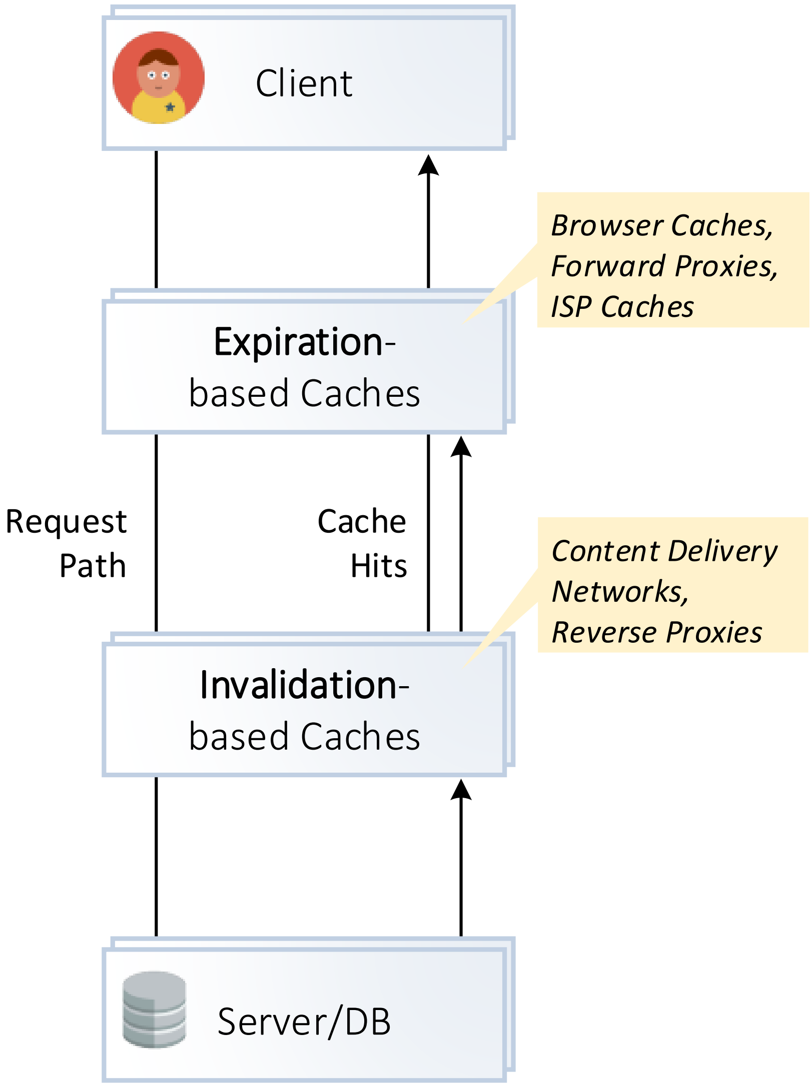
Research Question:
Can database services leverage the web caching infrastructure for low latency with rich consistency guarantees?

The Cache Sketch approach



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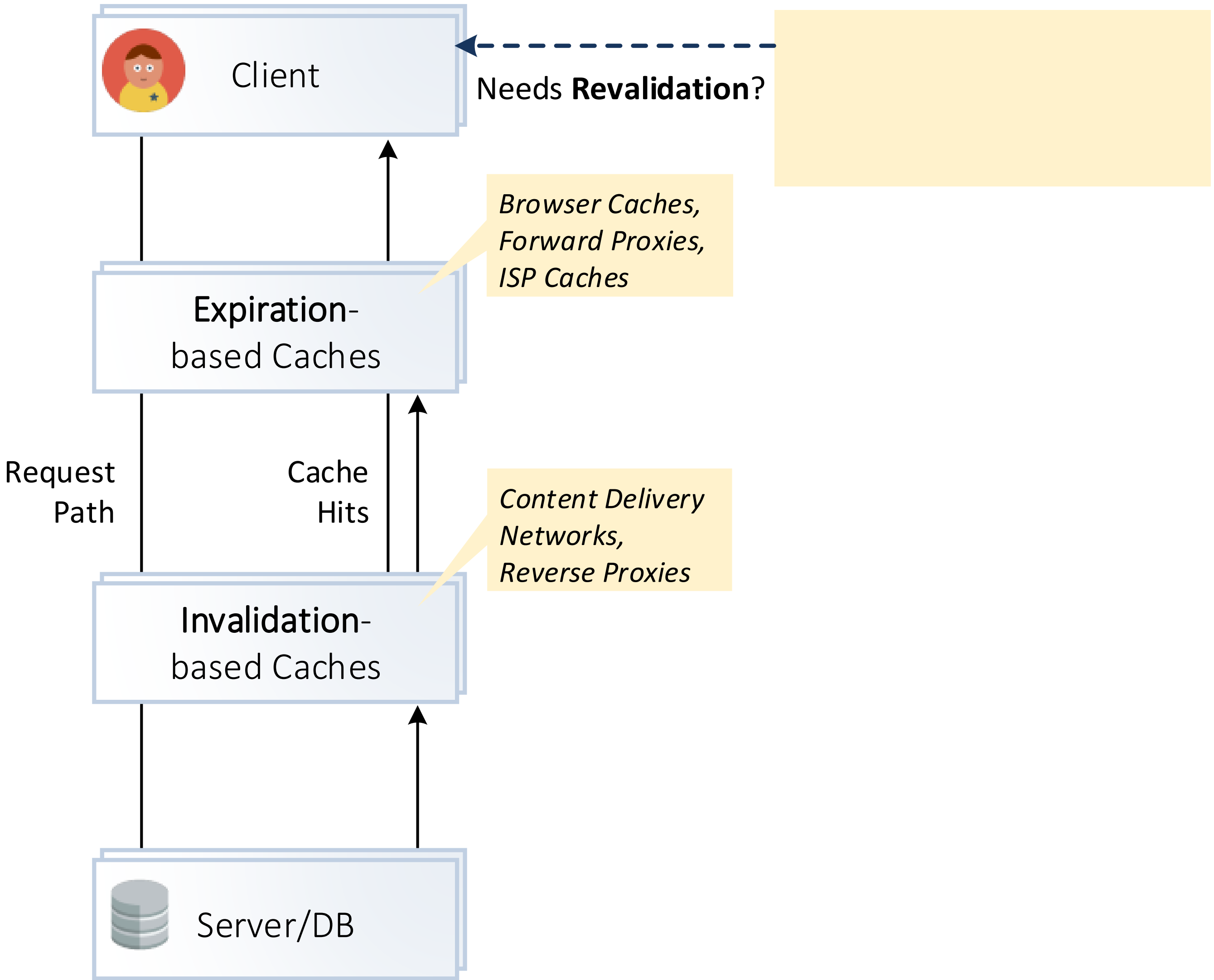

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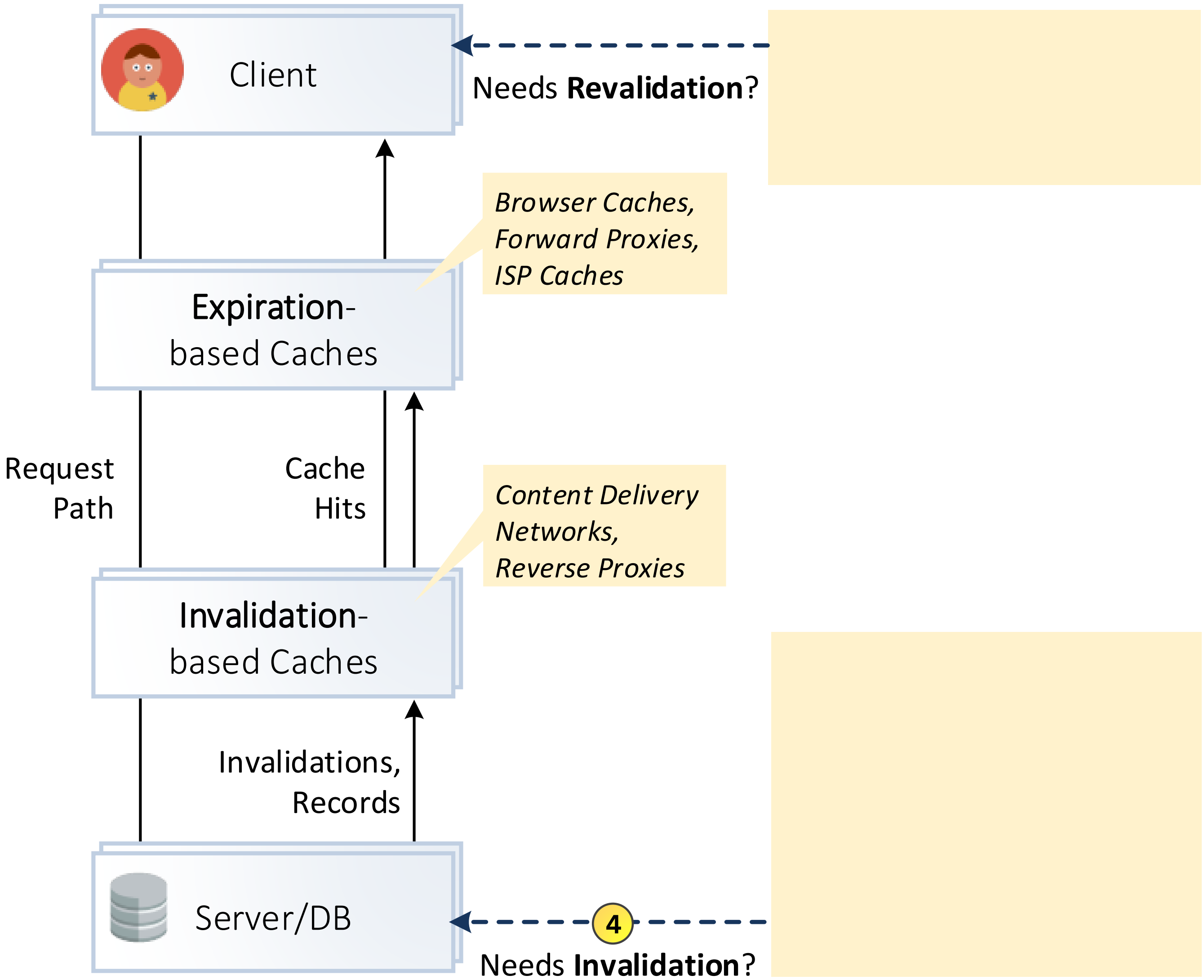

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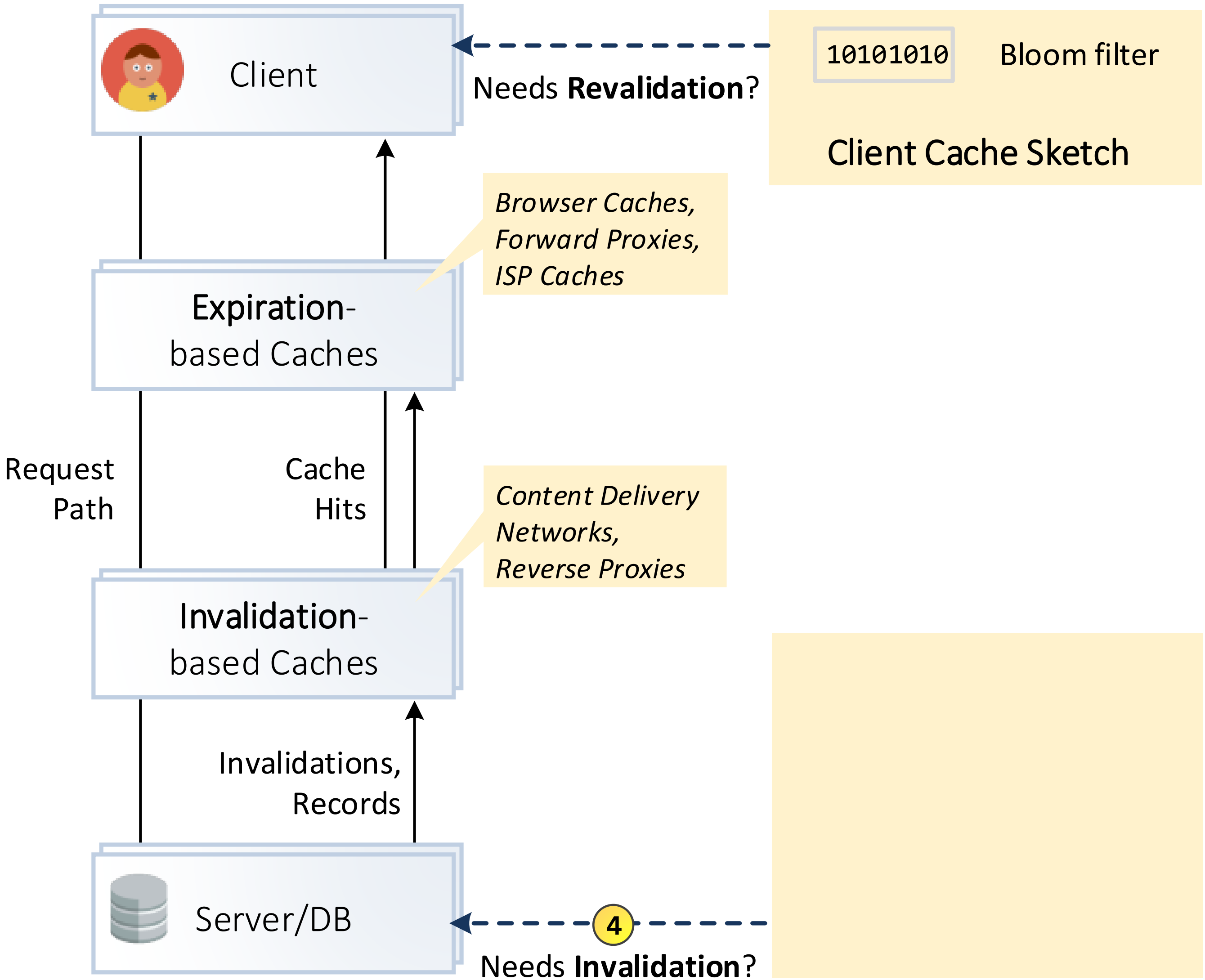

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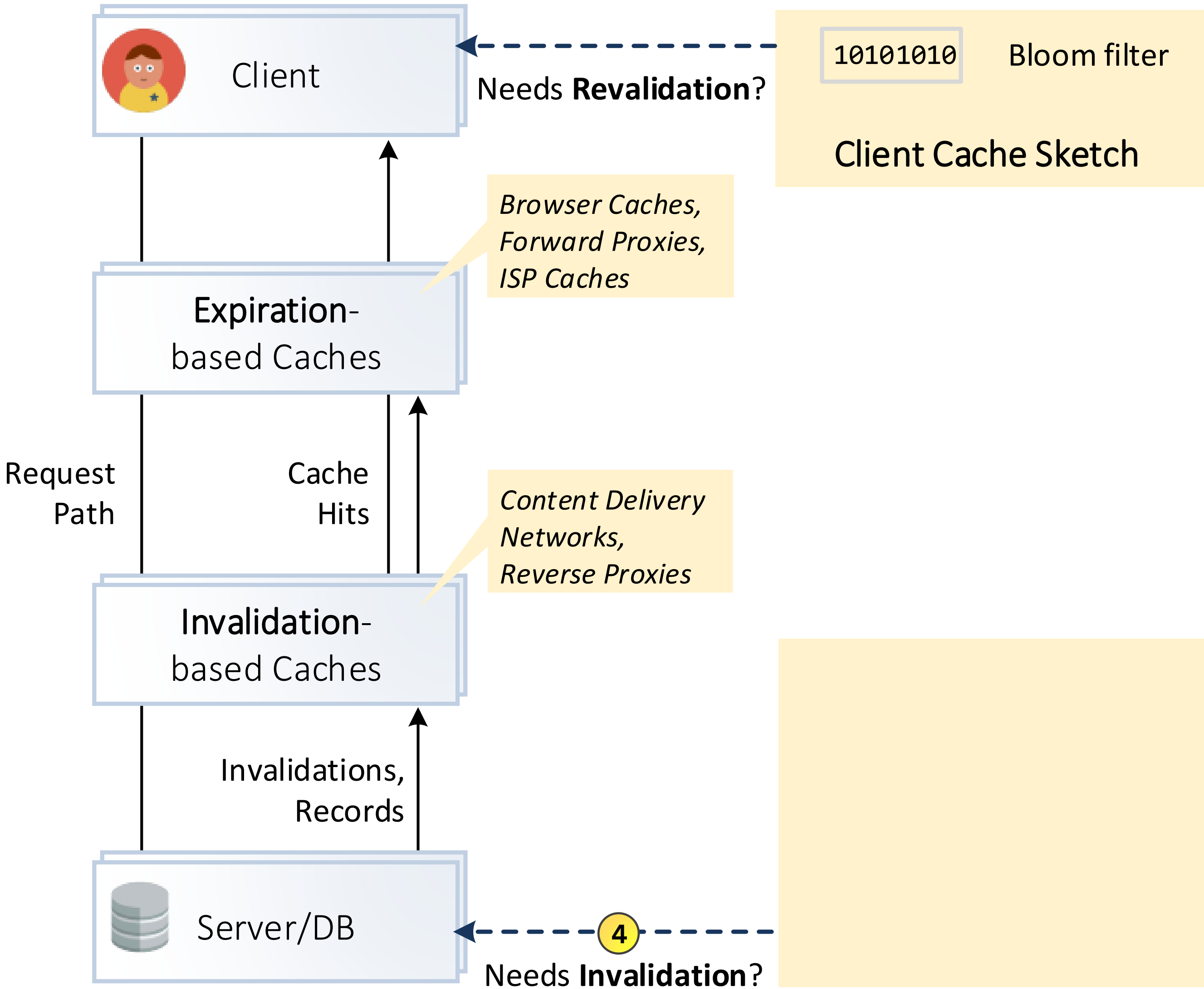

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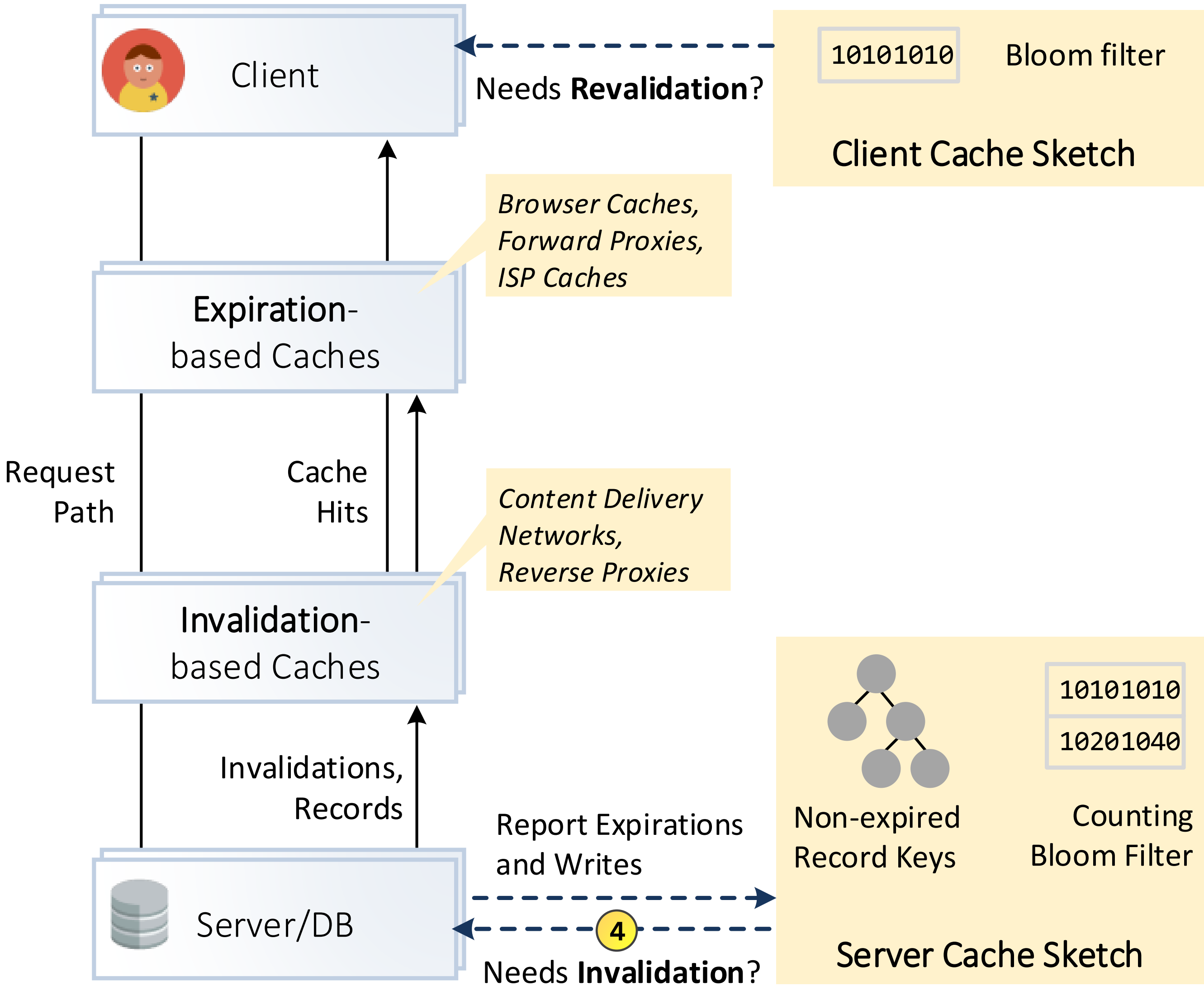

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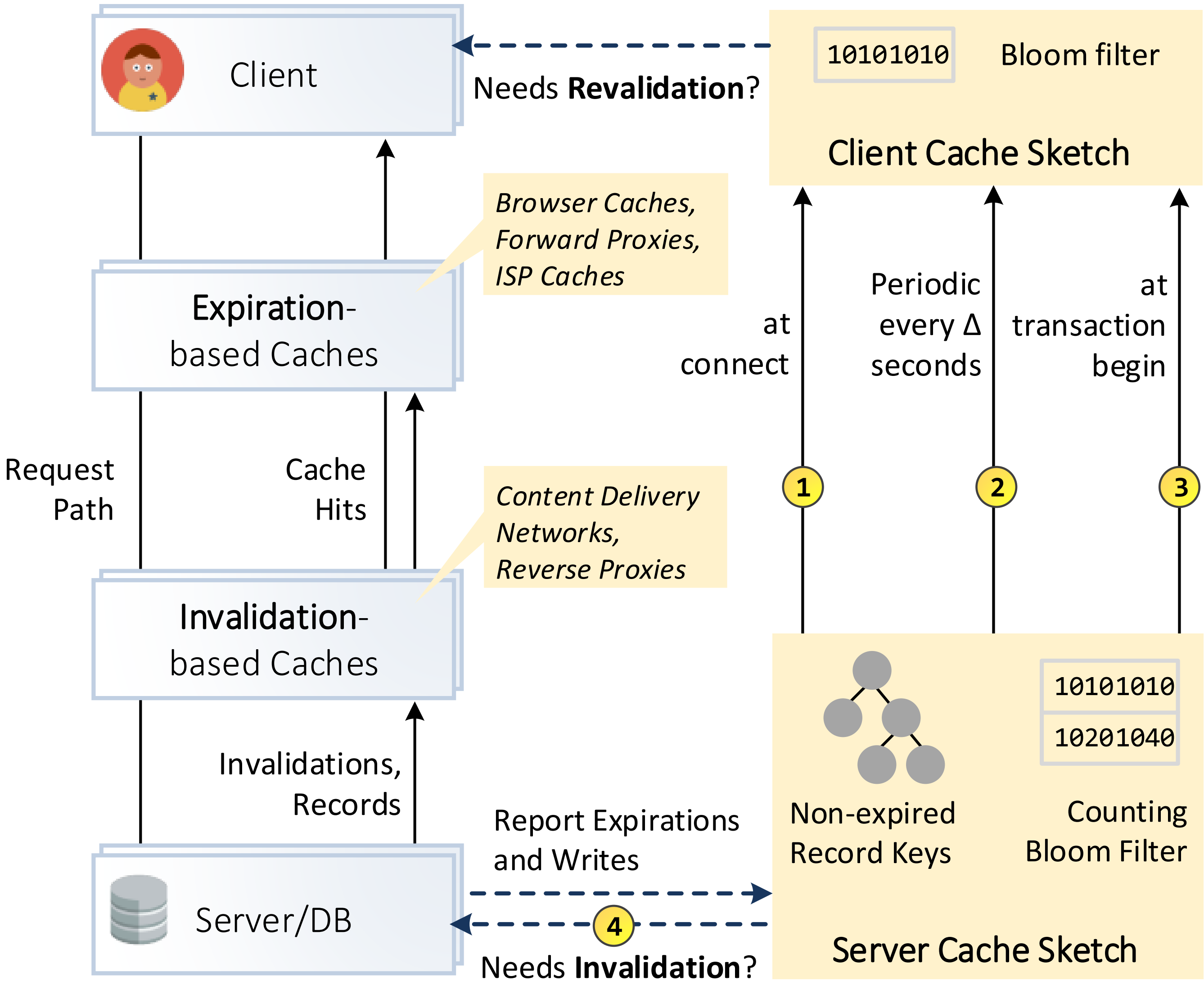

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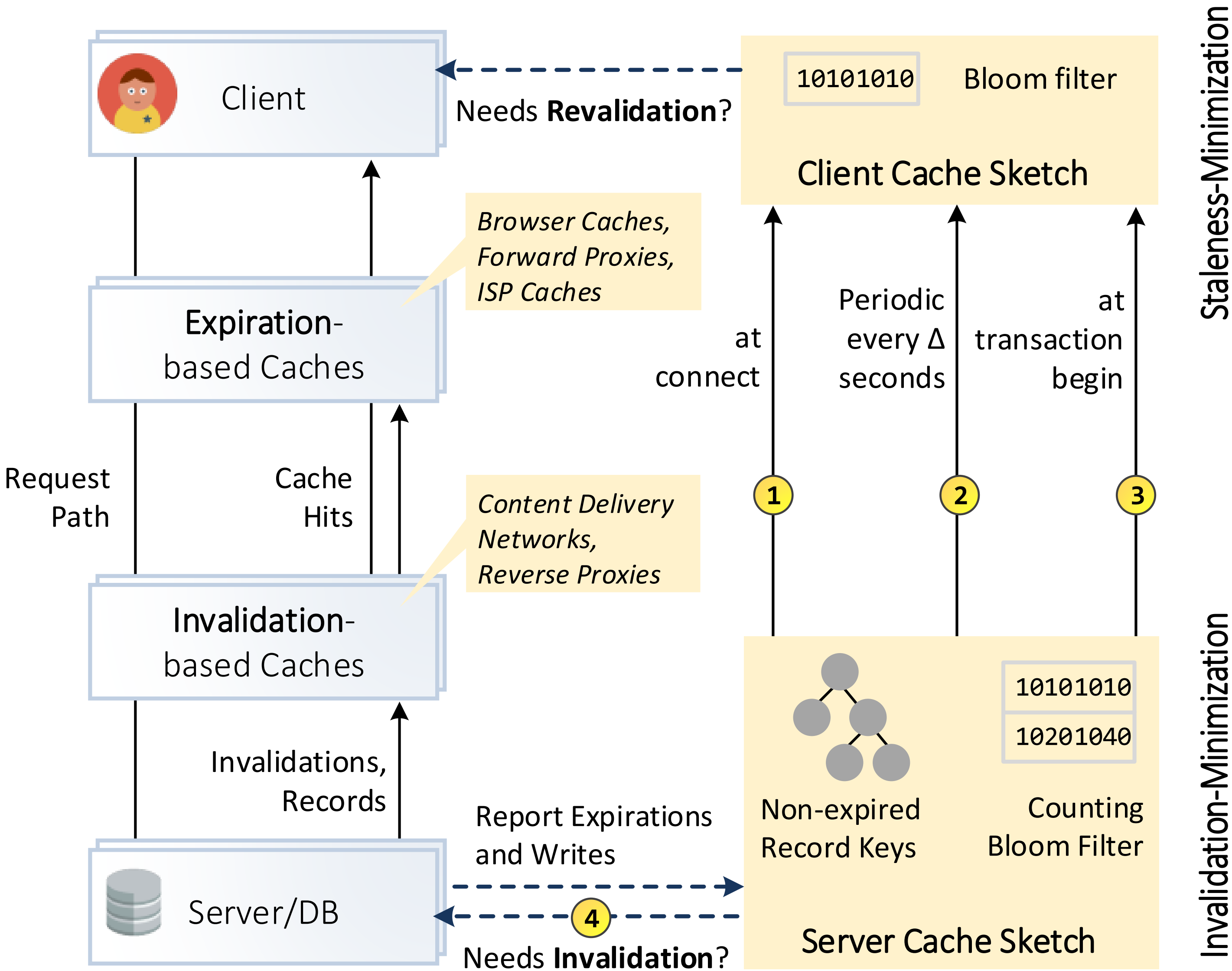

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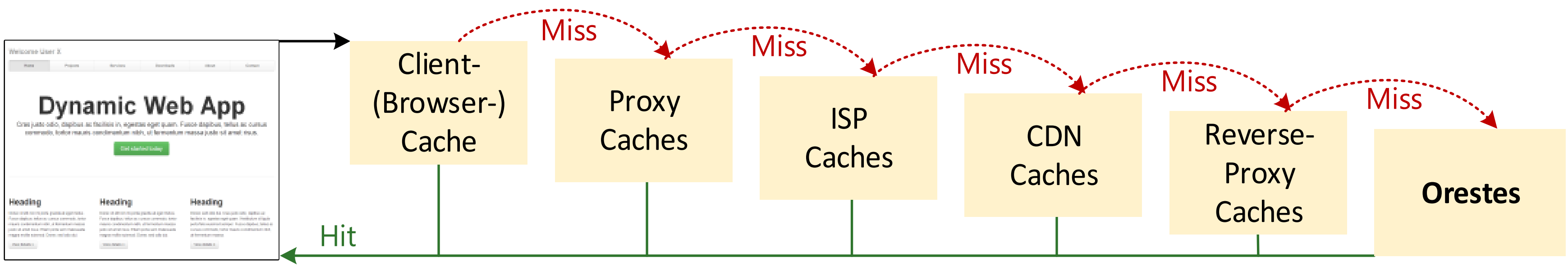

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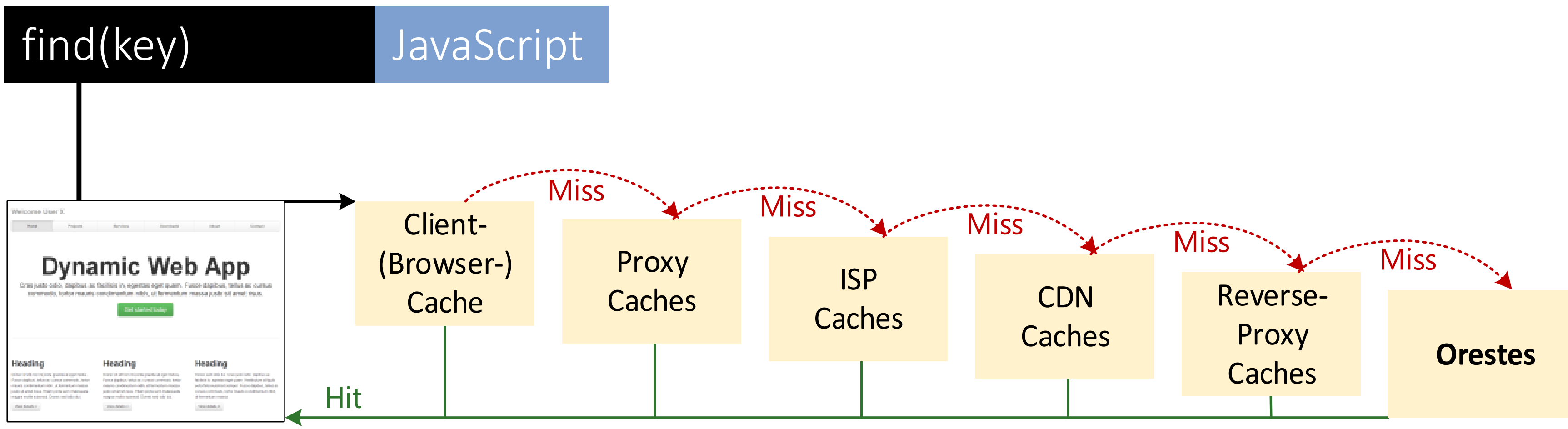

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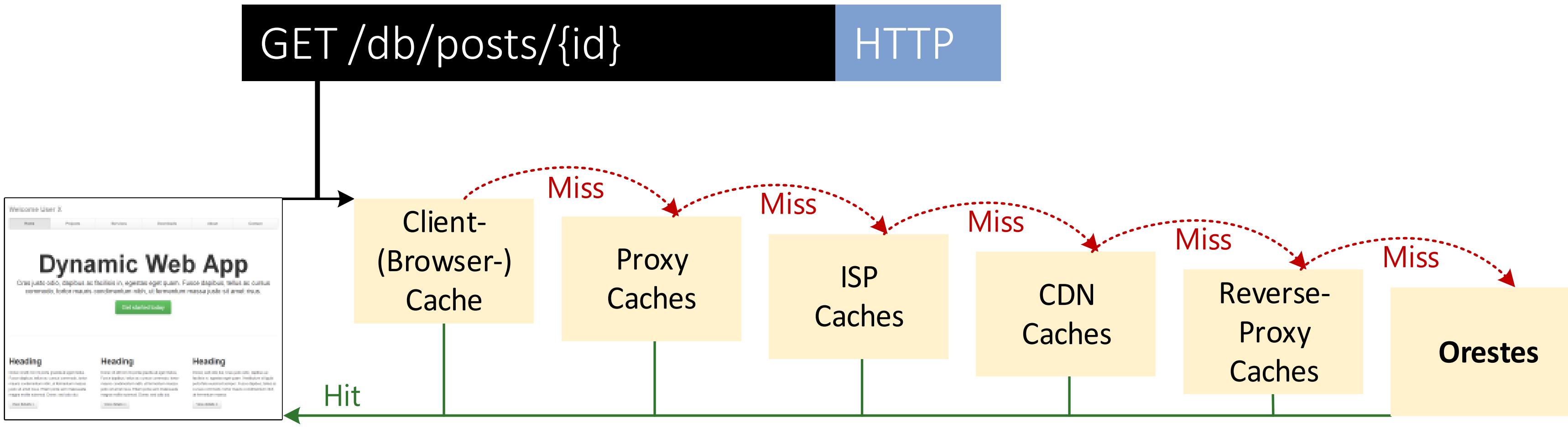

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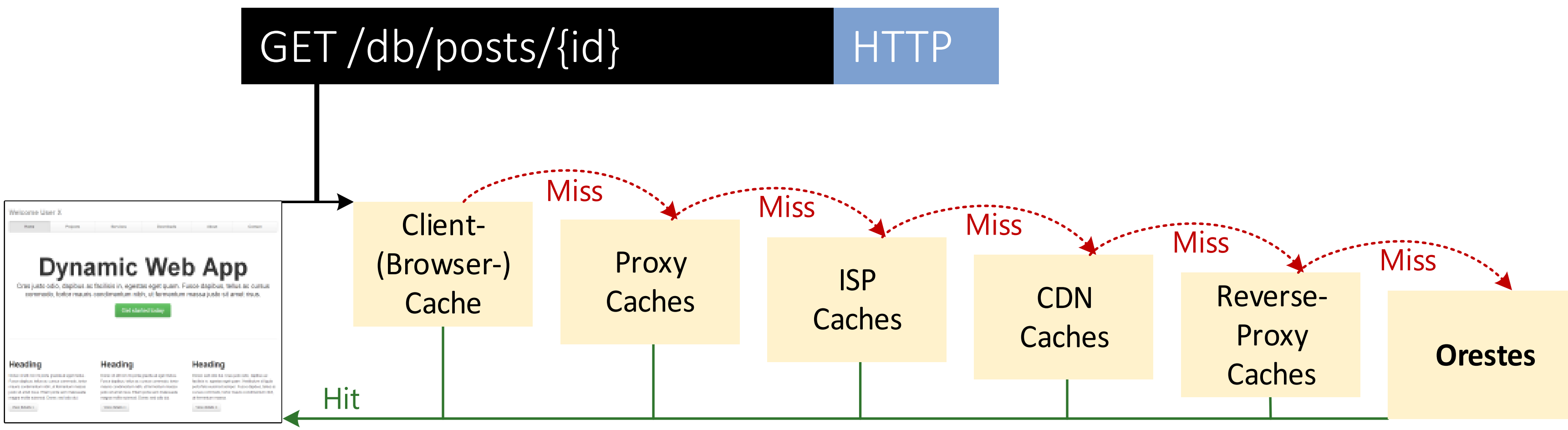
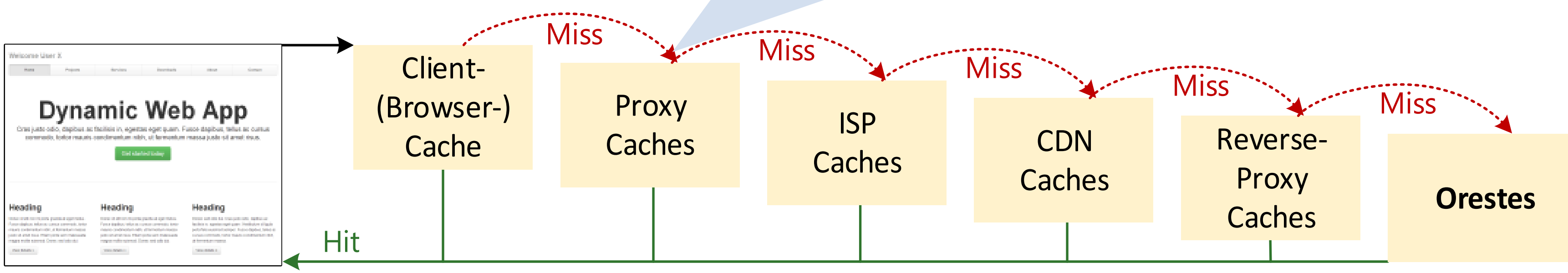


The Caching Hierarchy

Cache-Hit: Return Object
Cache-Miss or Revalidation:
Forward Request



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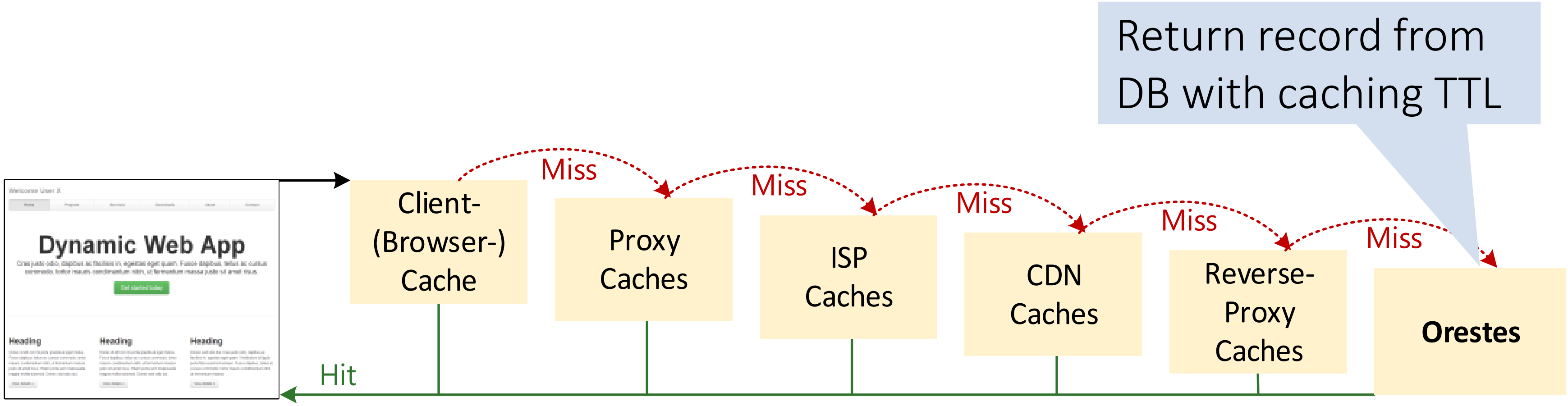

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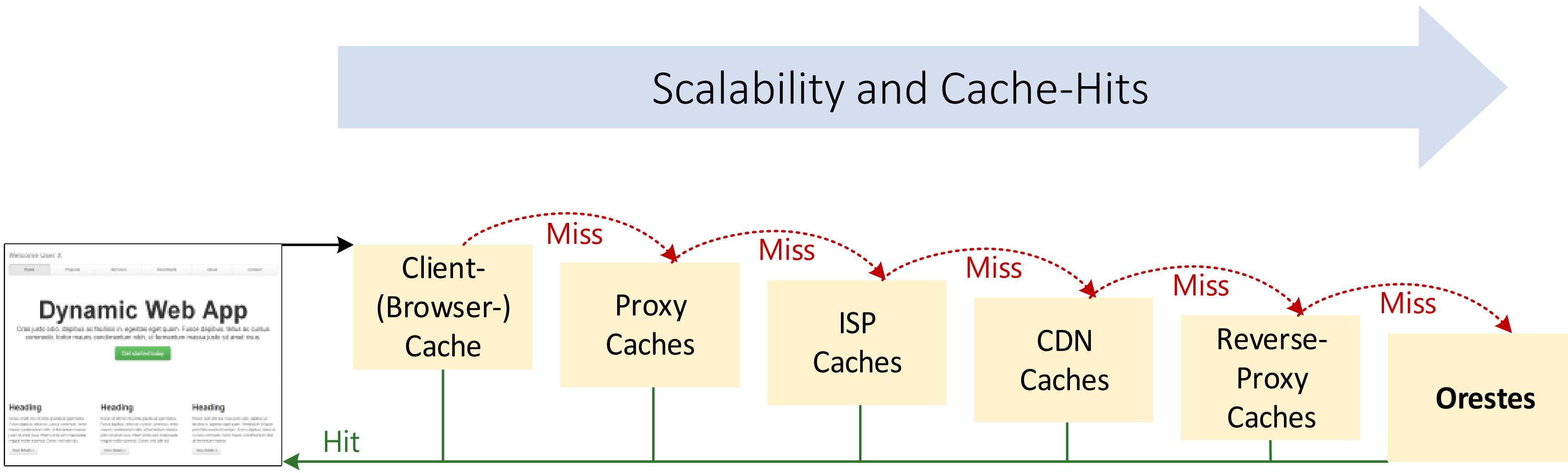

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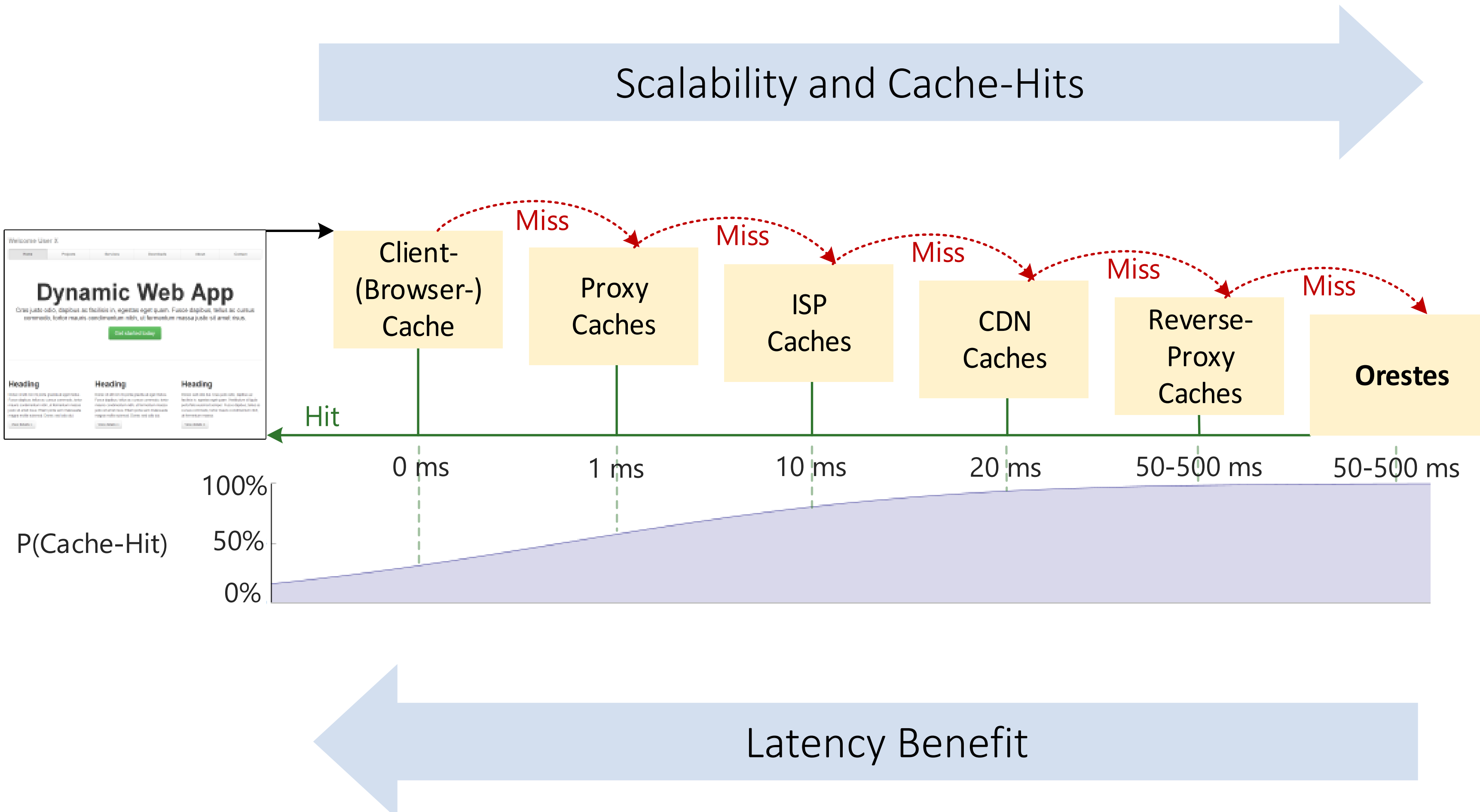

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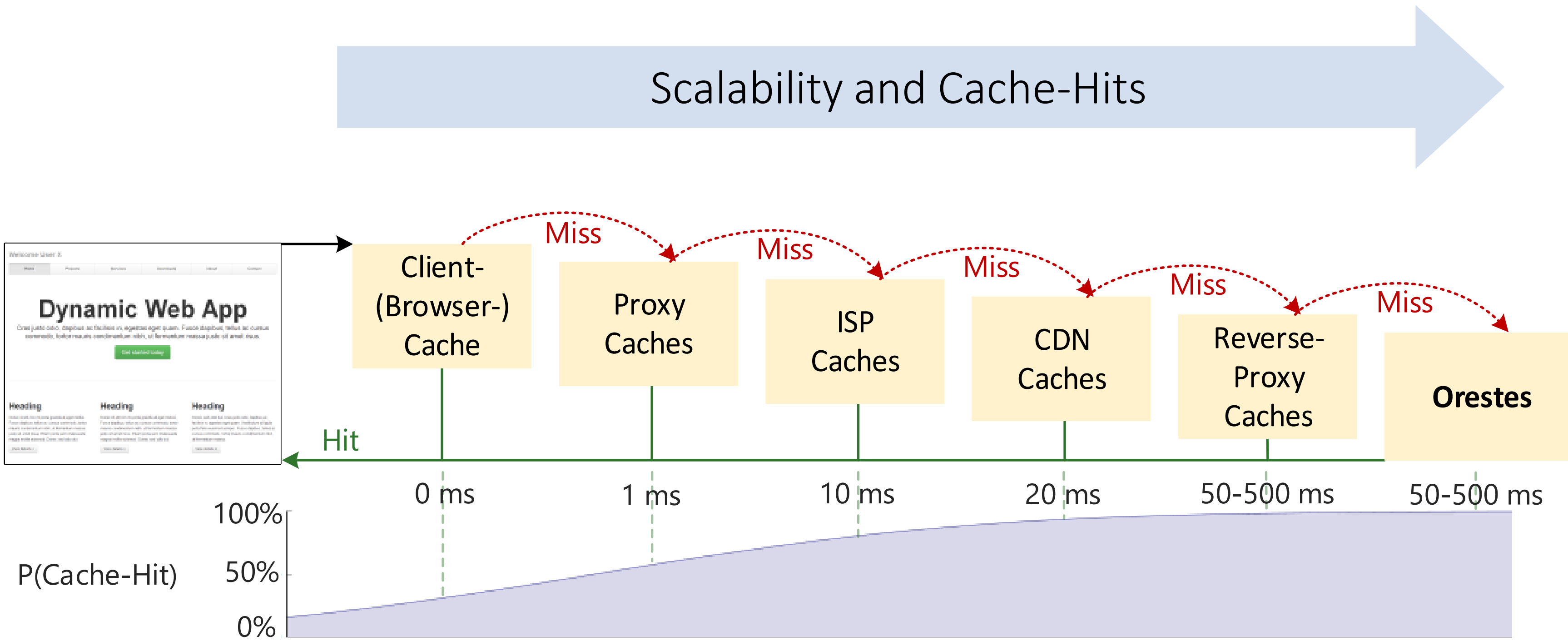


Low Latency

Less Load on Database Service

Protection Against Flash Crowds

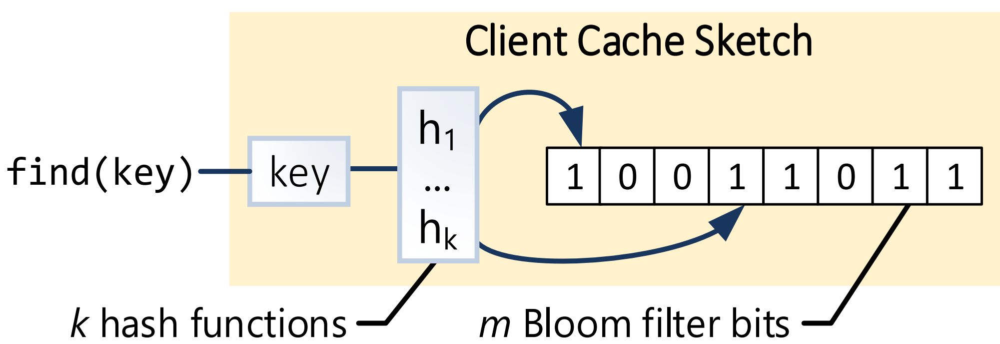
Better Availability

Clients Profit from Each Other

The Client Cache Sketch

- *Let* $\boldsymbol{c_t}$ *be the client Cache Sketch generated at time* $\boldsymbol{t}$*, containing the key* $\boldsymbol{key_x}$ *of every record* $\boldsymbol{x}$ *that was <u>written before it expired</u> in all caches, i.e. every* $\boldsymbol{x}$ *for which holds:*

$$\exists\, r(x, t_r, TTL), w(x, t_w) : \; t_r + TTL > t > t_w > t_r$$



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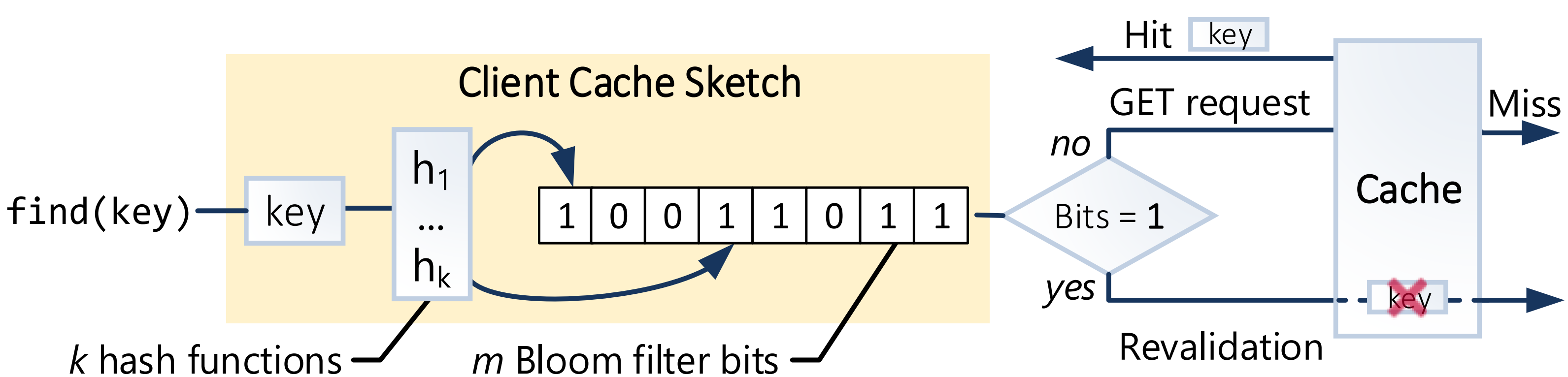

Problem I: Slow initial page loads

- Solution: **Cached Initialization**
  - Clients load the Cache Sketch at connection
  - Every non-stale cached record can be reused without degraded consistency

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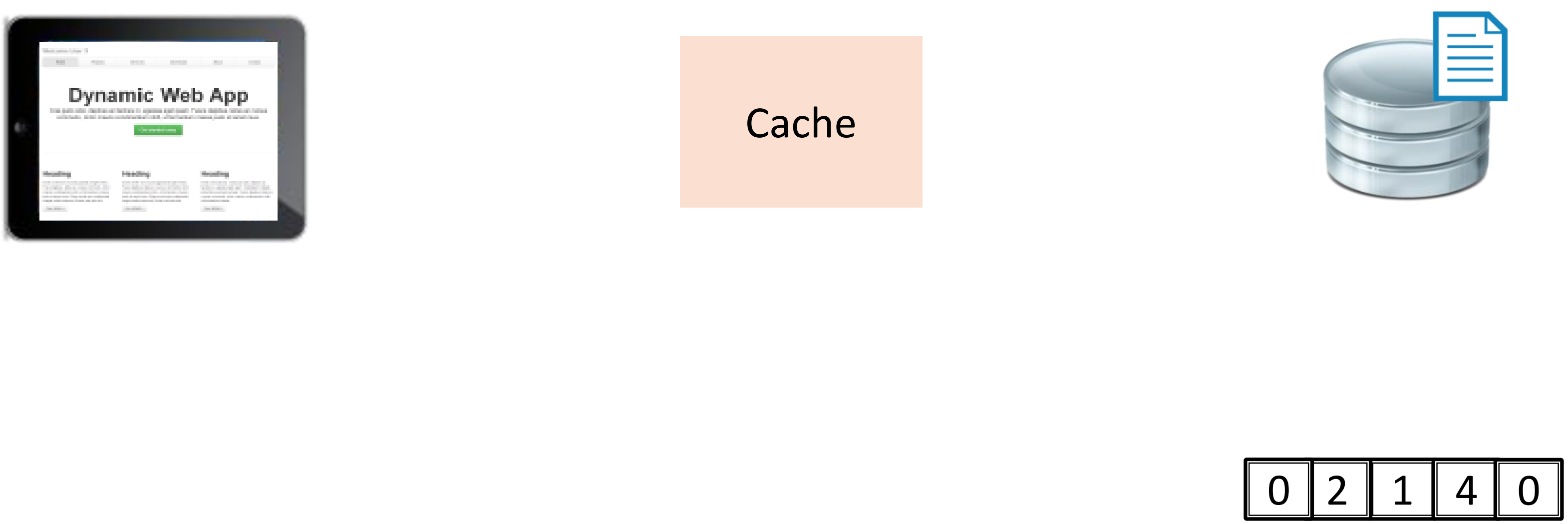

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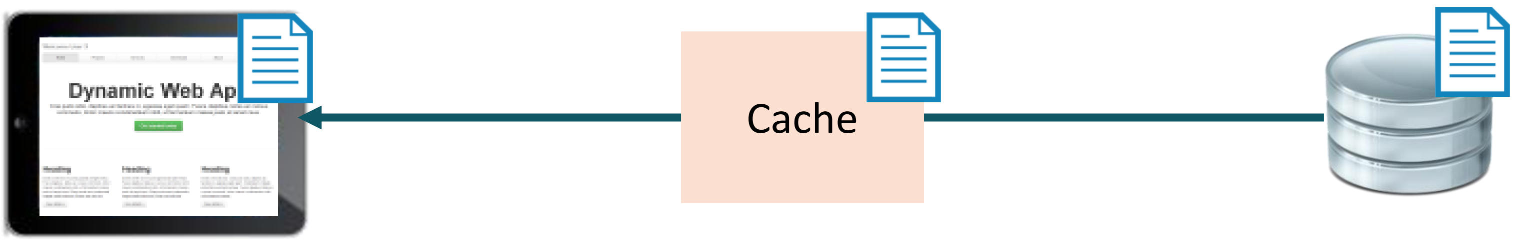

0	2	1	4	0

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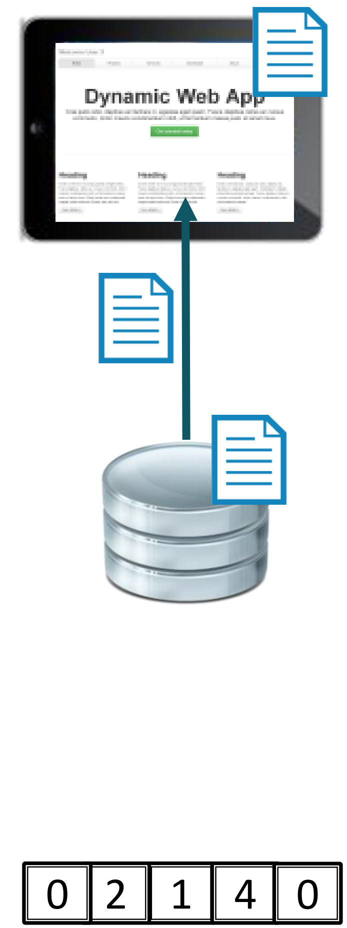

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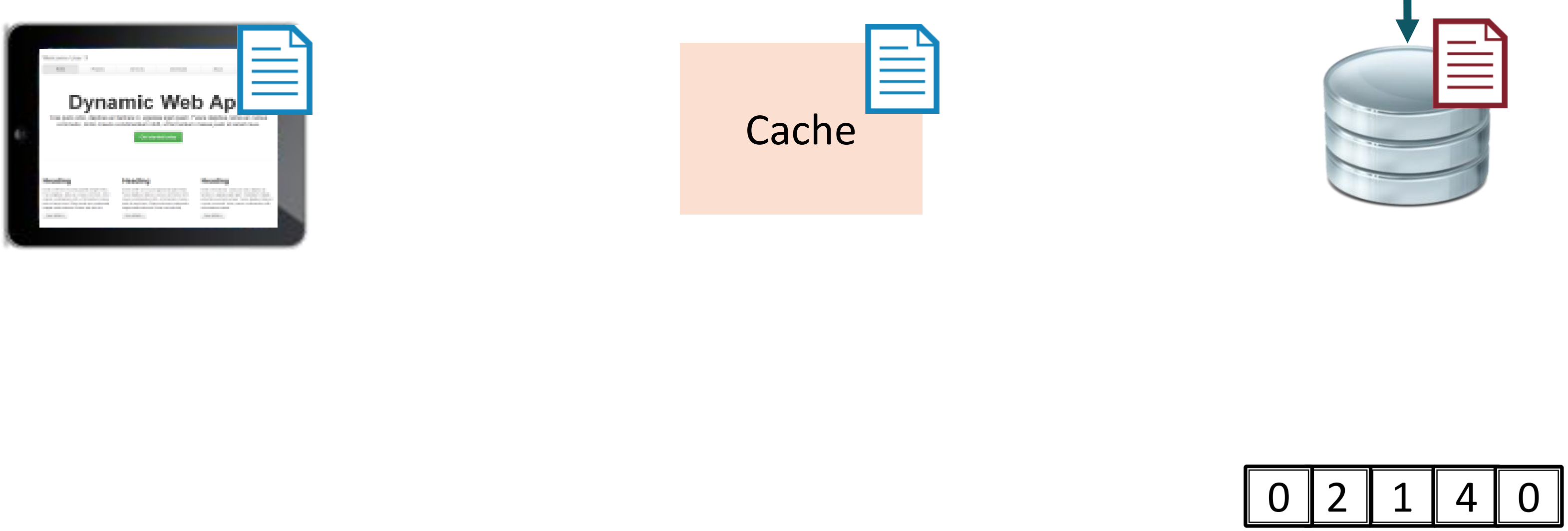

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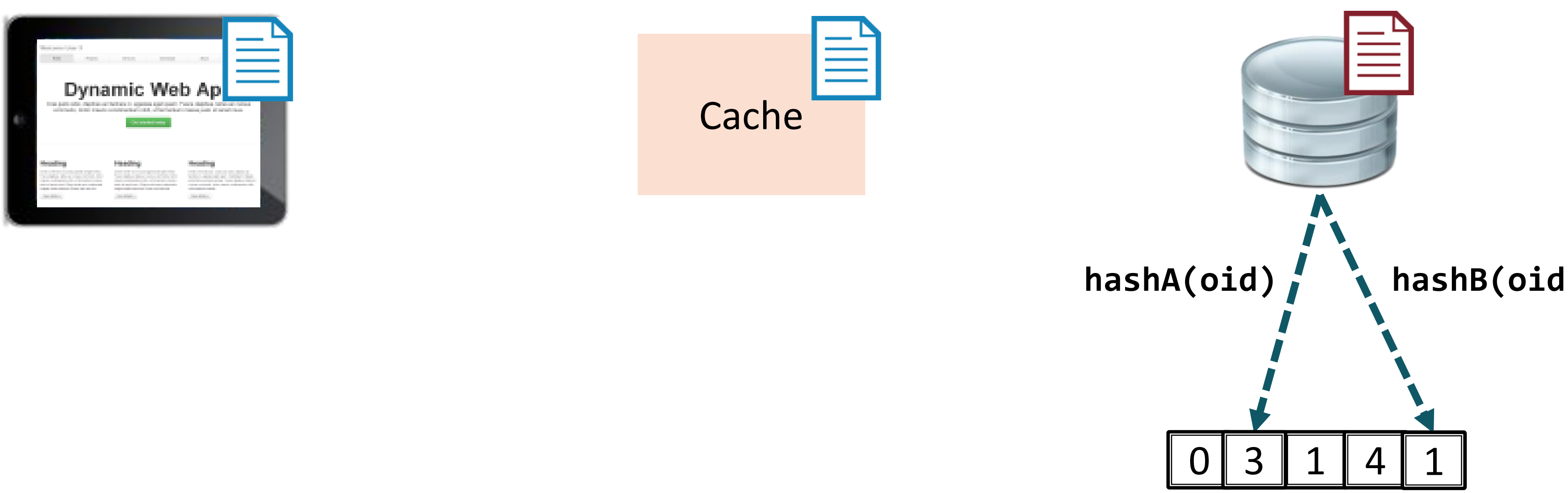

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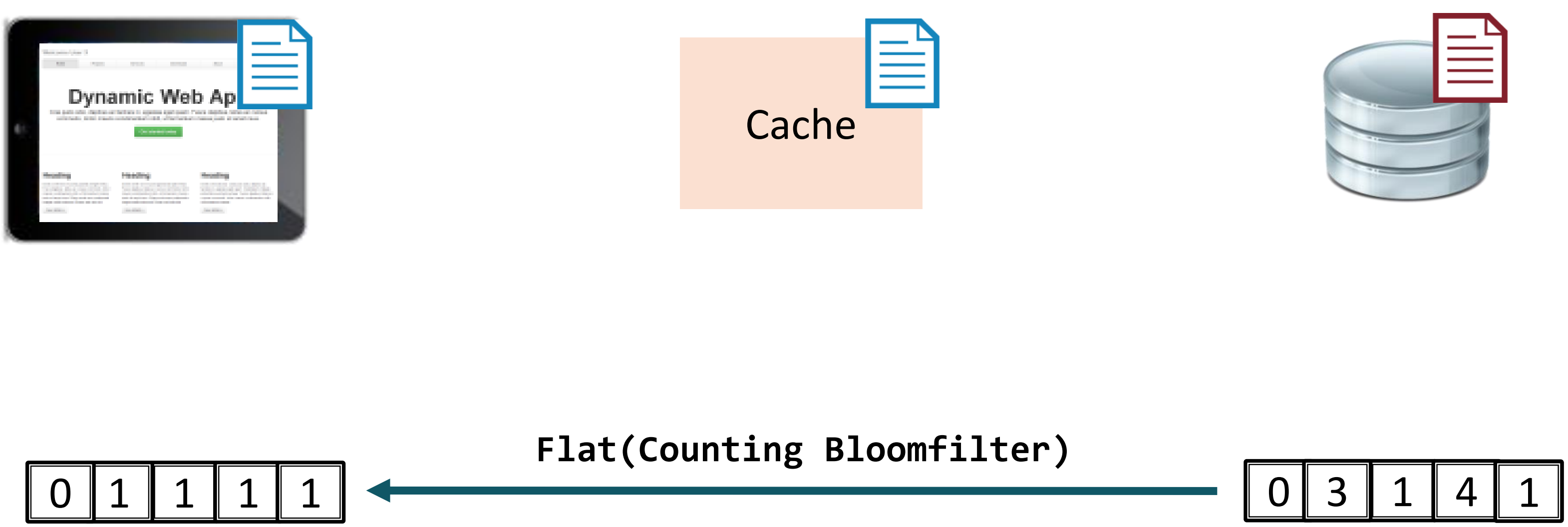

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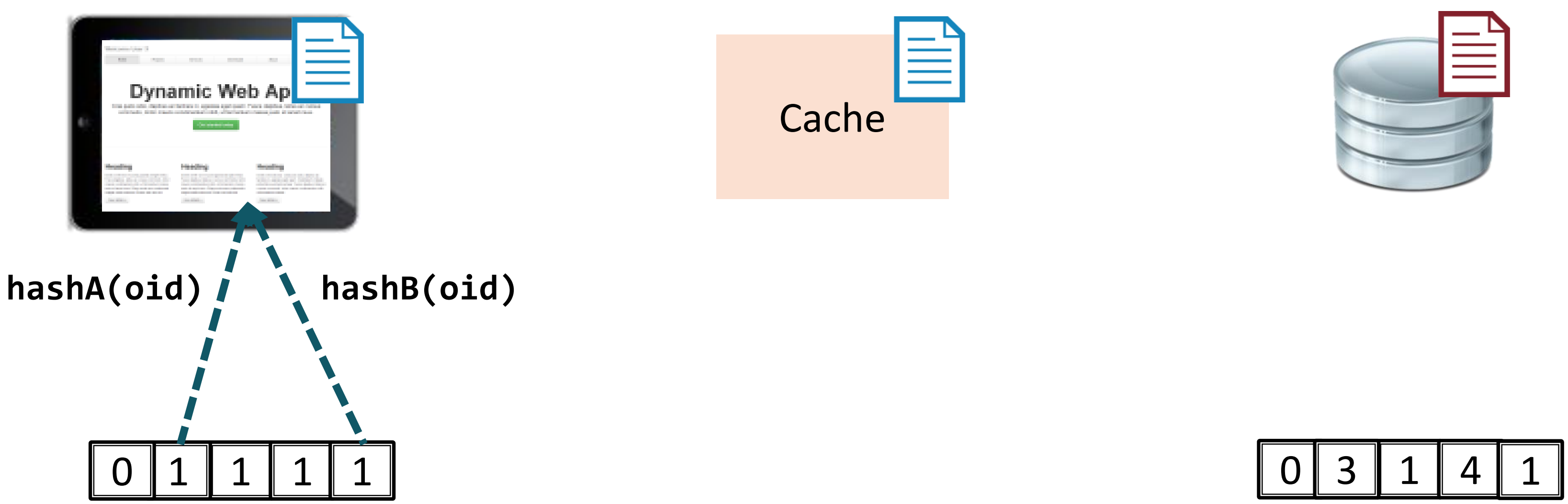

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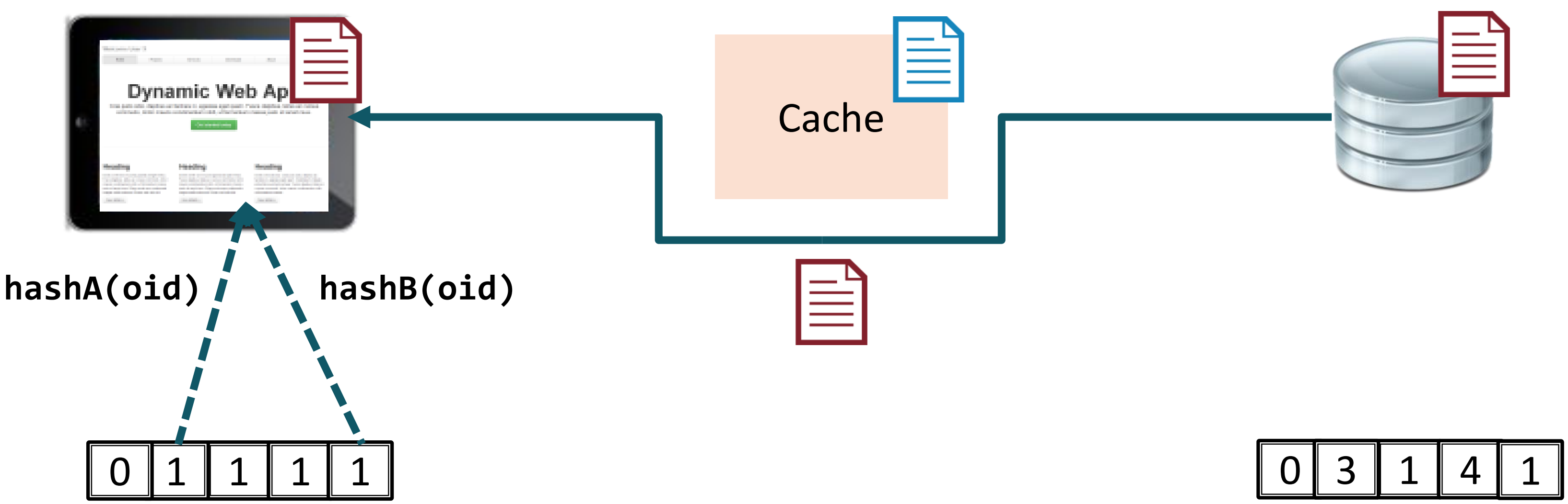

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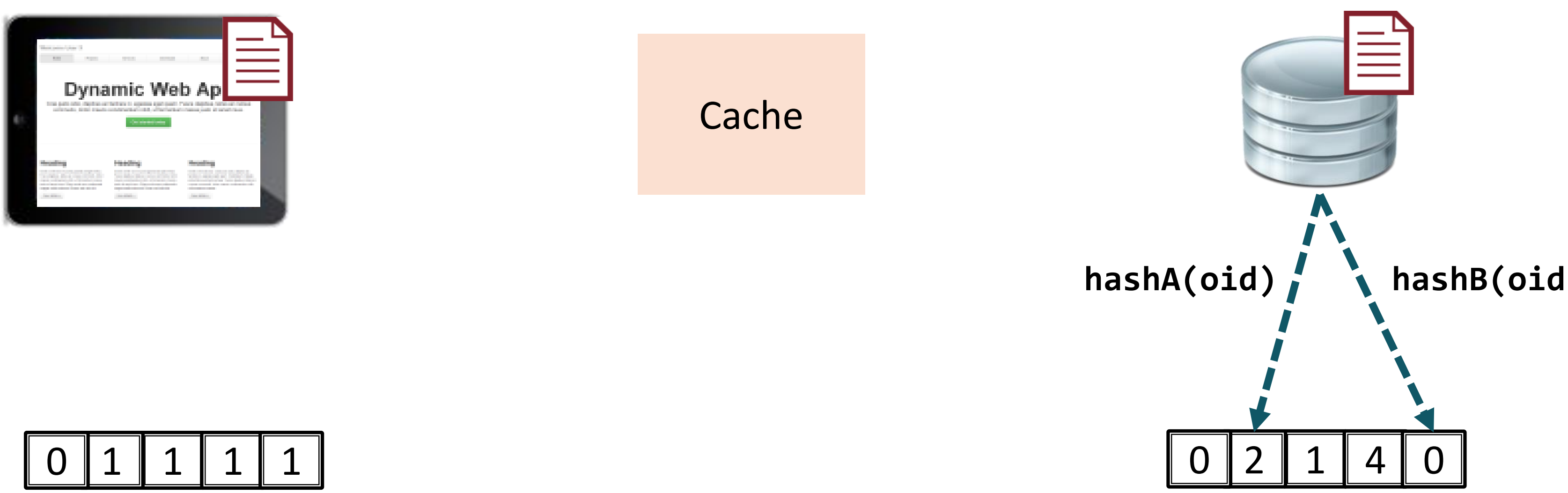

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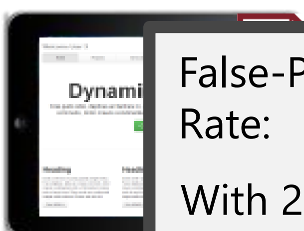
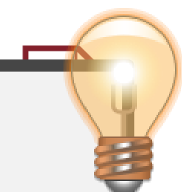
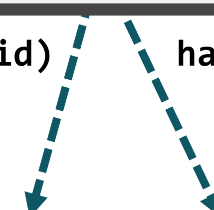




False-Positive Rate: $f \approx \left(1 - e^{-\frac{kn}{m}}\right)^k$

Hash-Functions: $k = \left\lceil \ln(2) \cdot \left(\frac{n}{m}\right) \right\rceil$

With 20.000 distinct updates and 5% error rate: **14 KByte**



0	1	1	1	1

0	2	1	4	0

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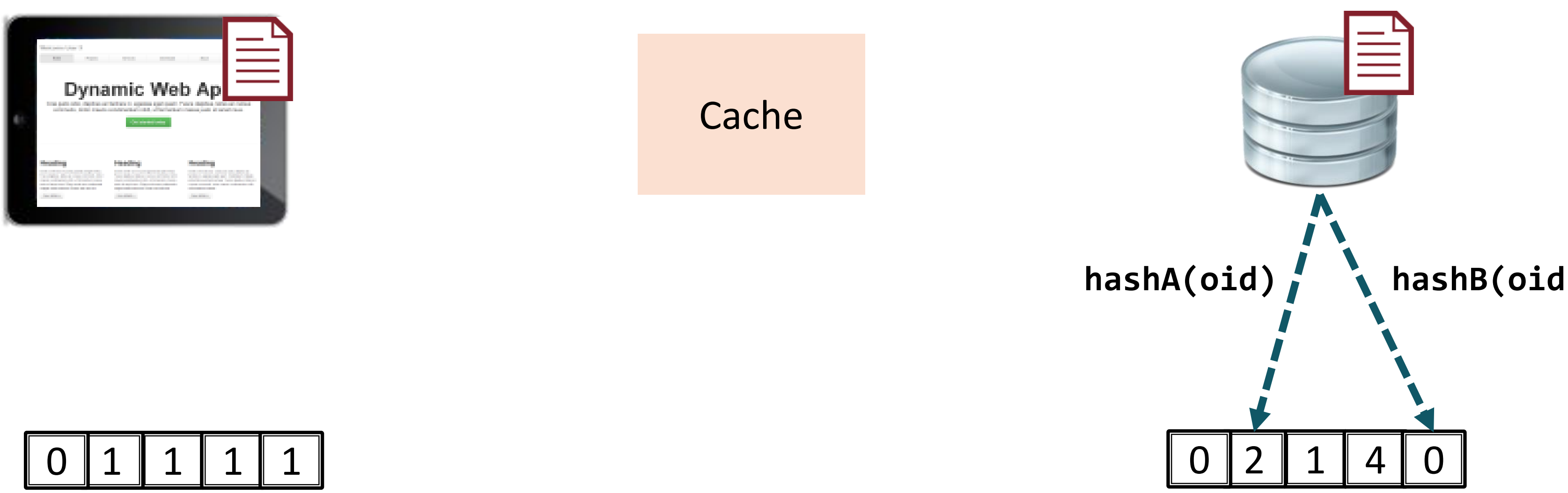

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- Solution: **Δ-Bounded Staleness**
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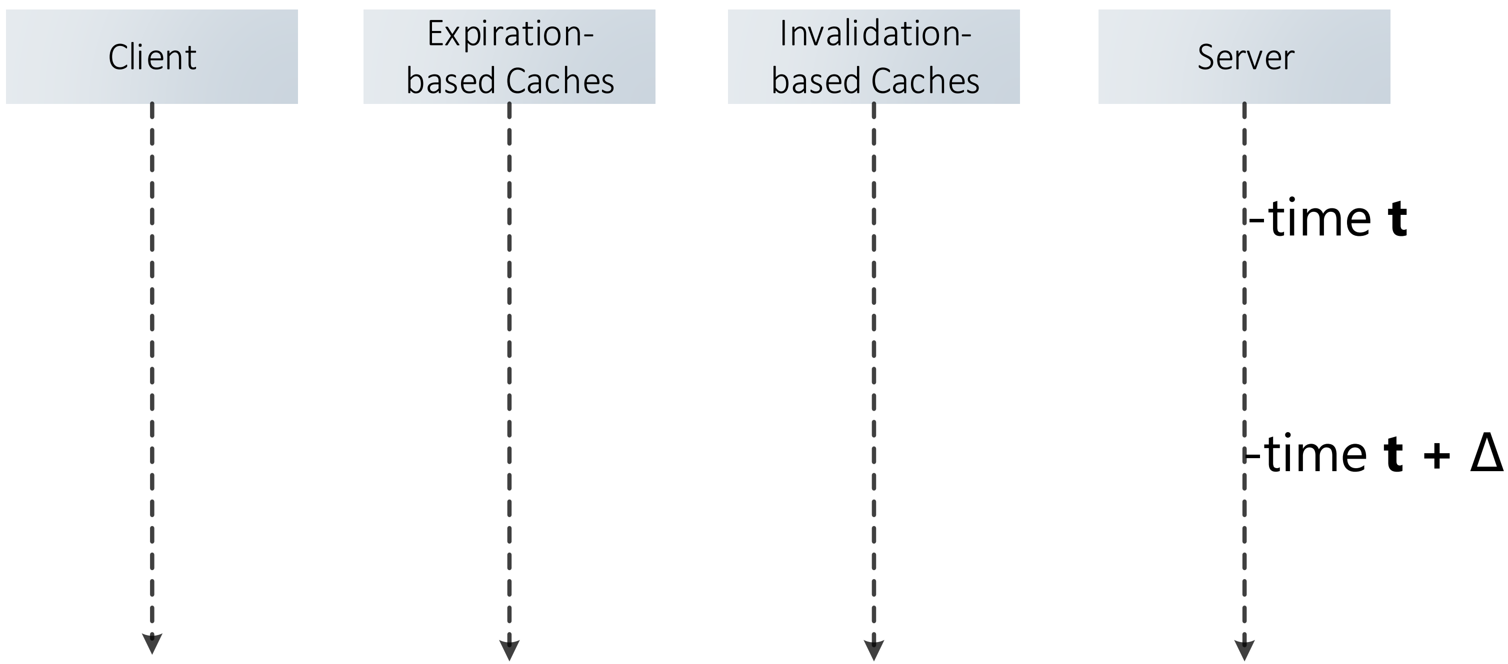
  → *Consistency guarantee*: Δ-atomicity



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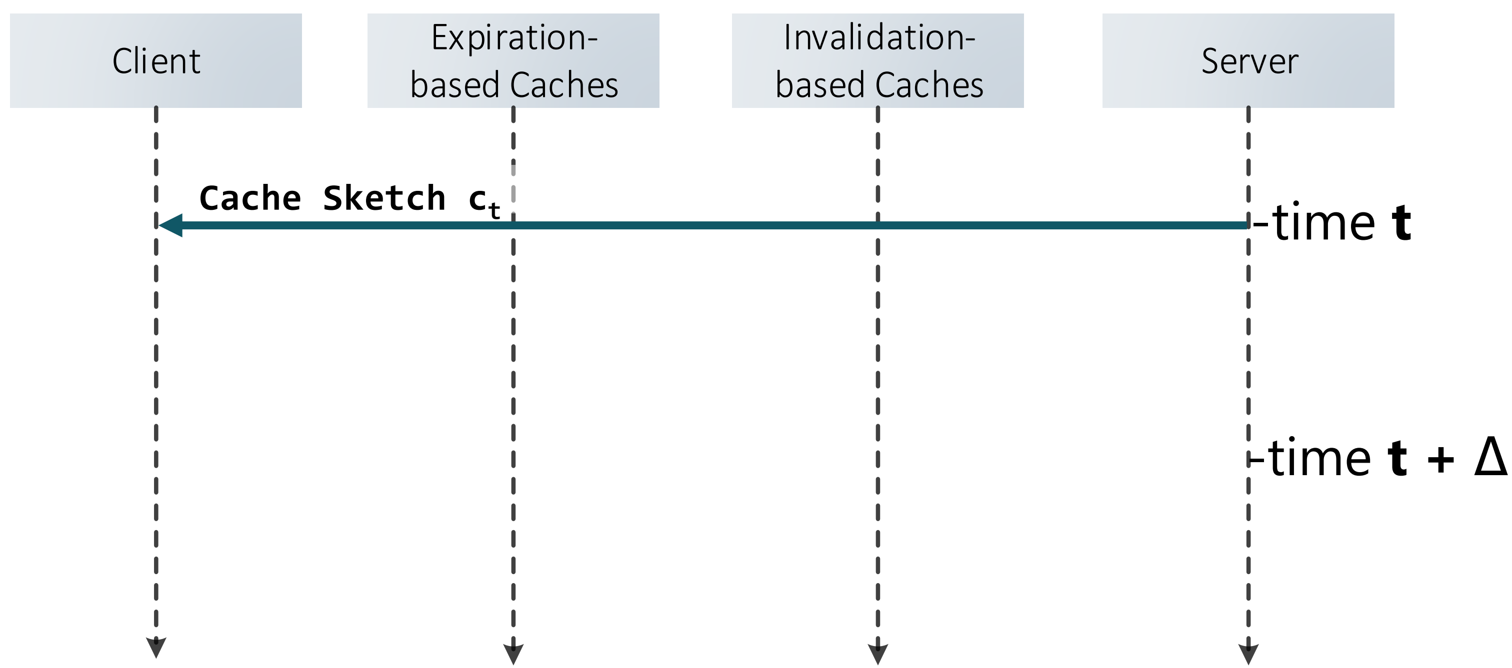

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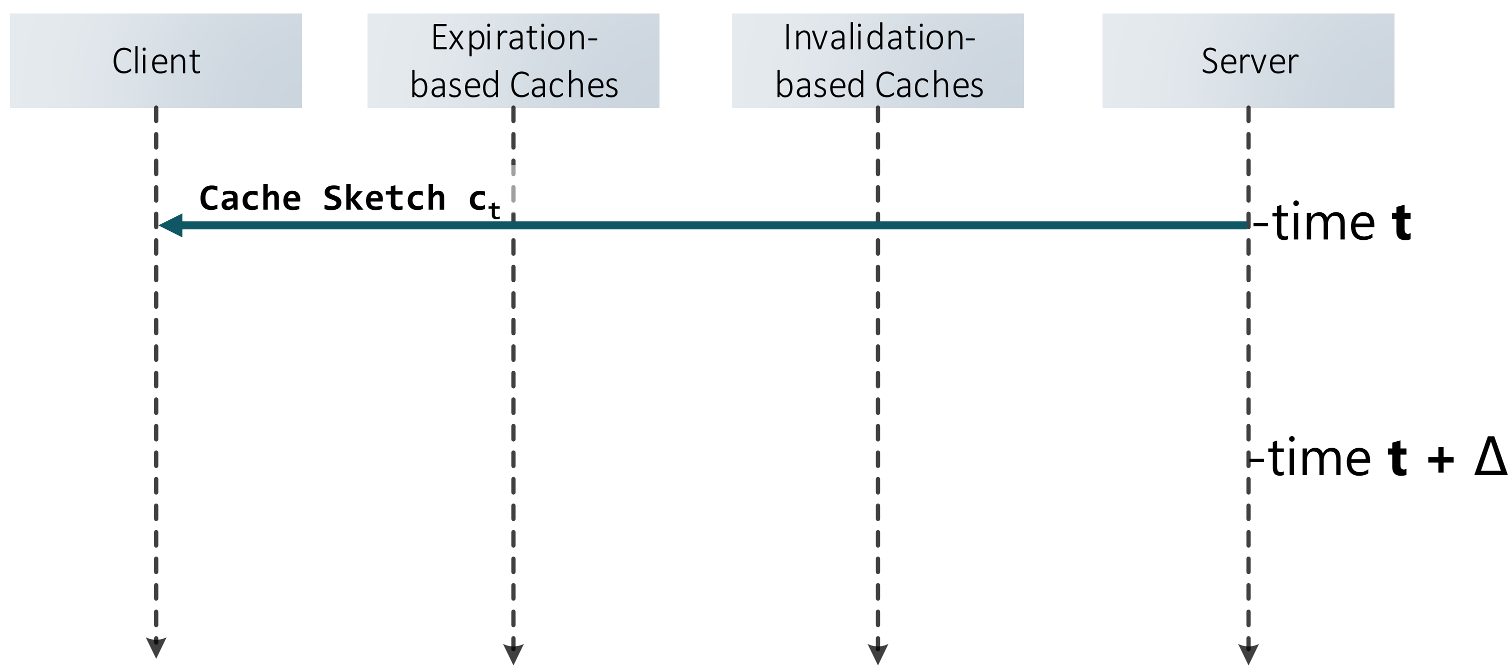

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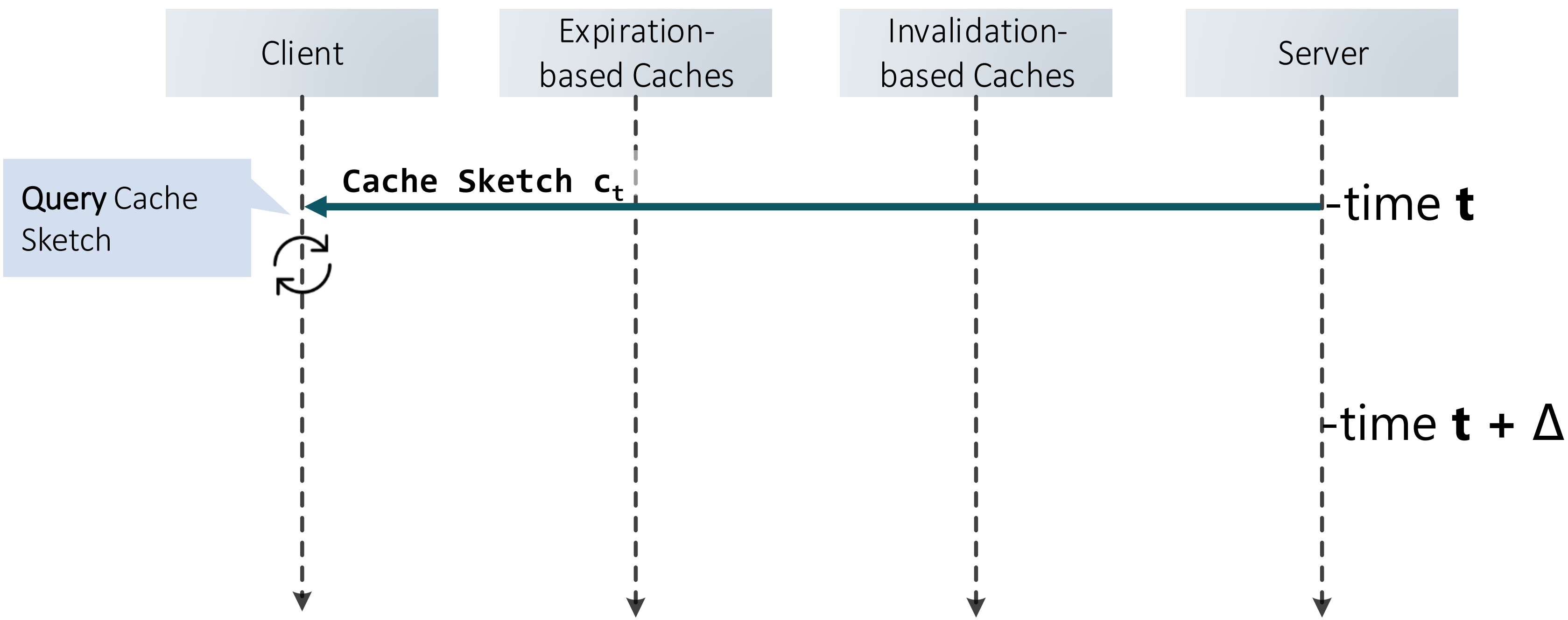

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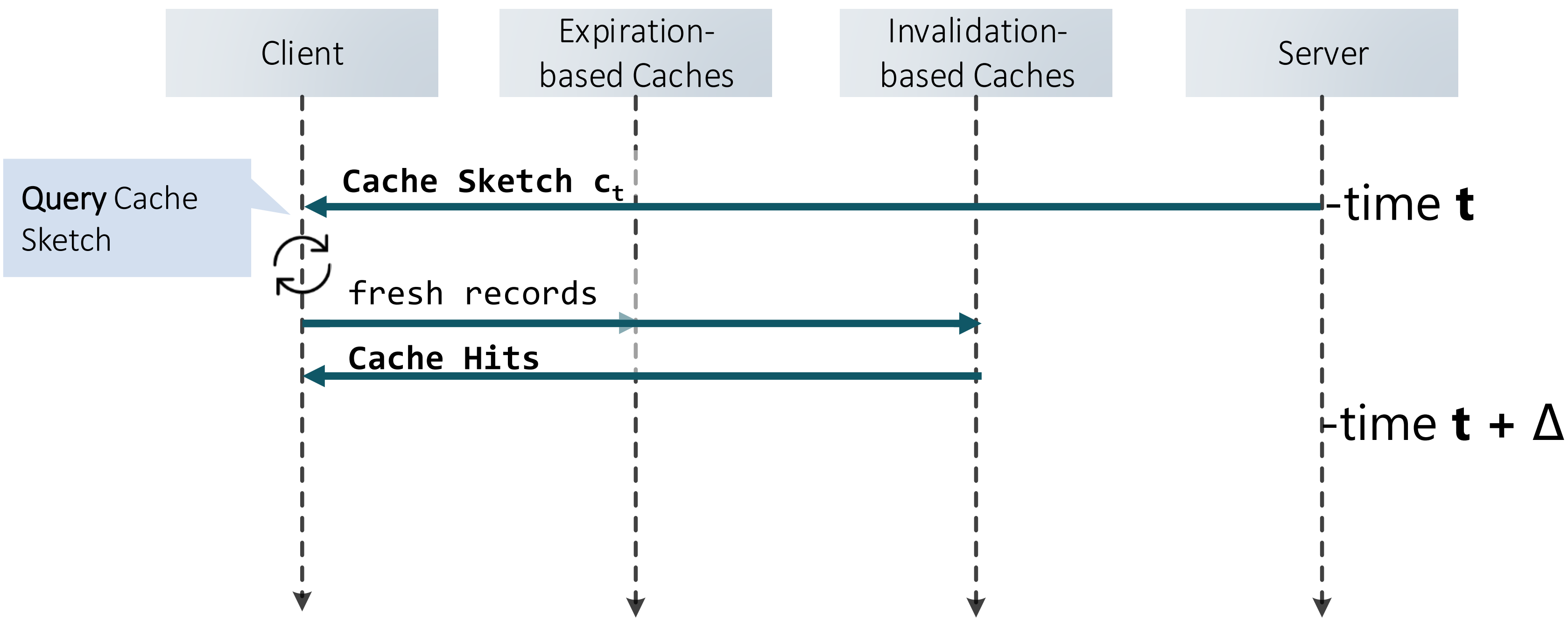

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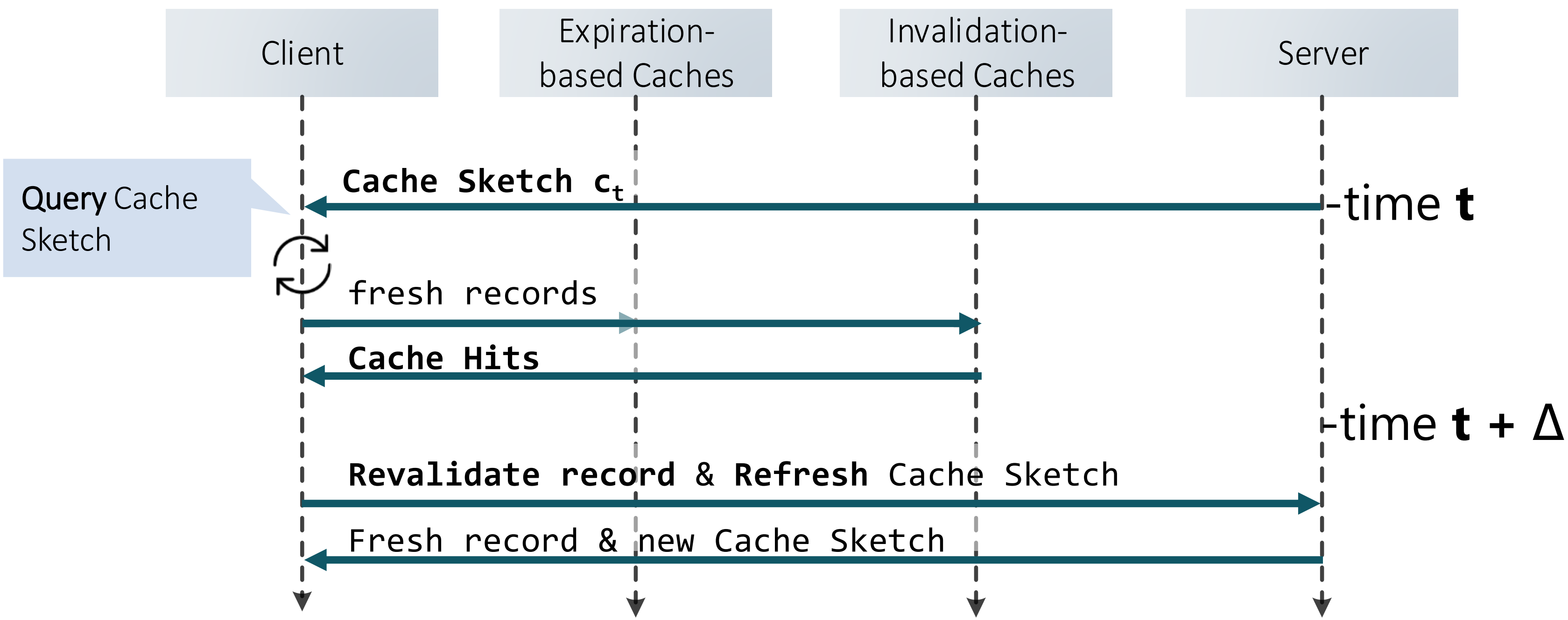

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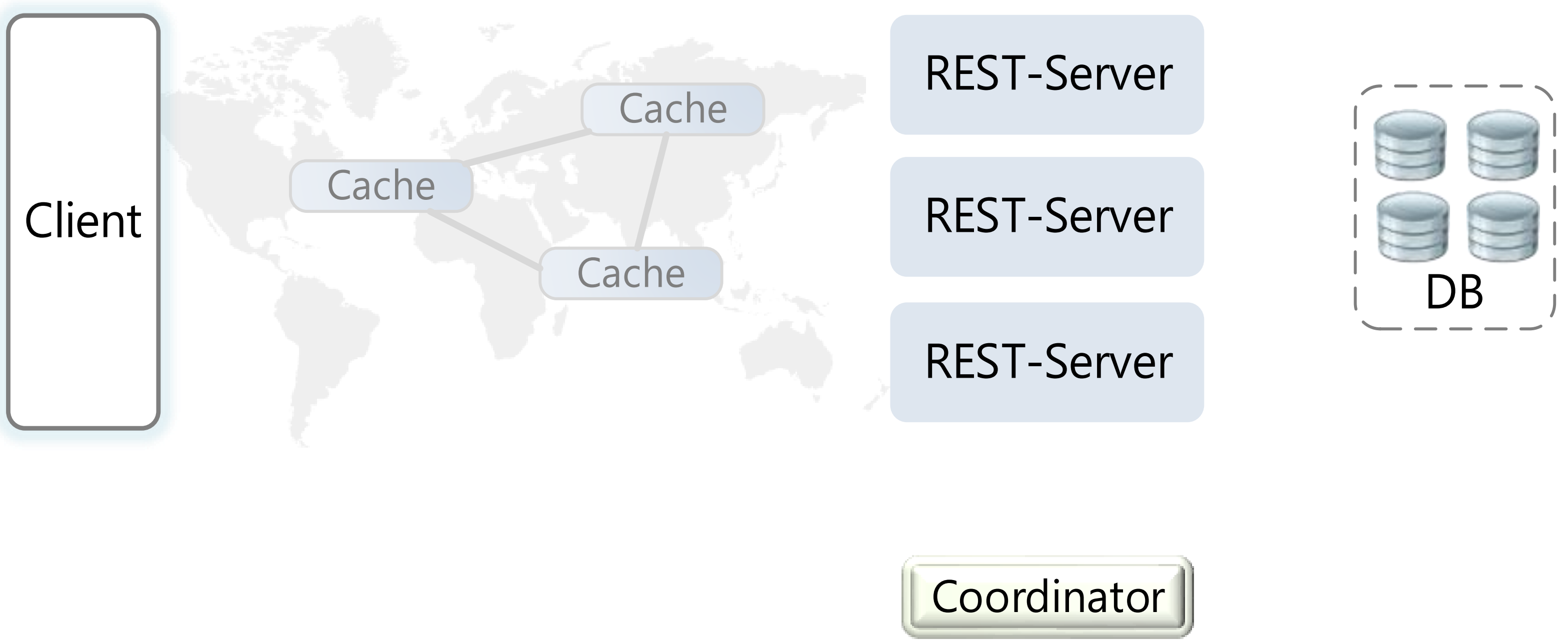

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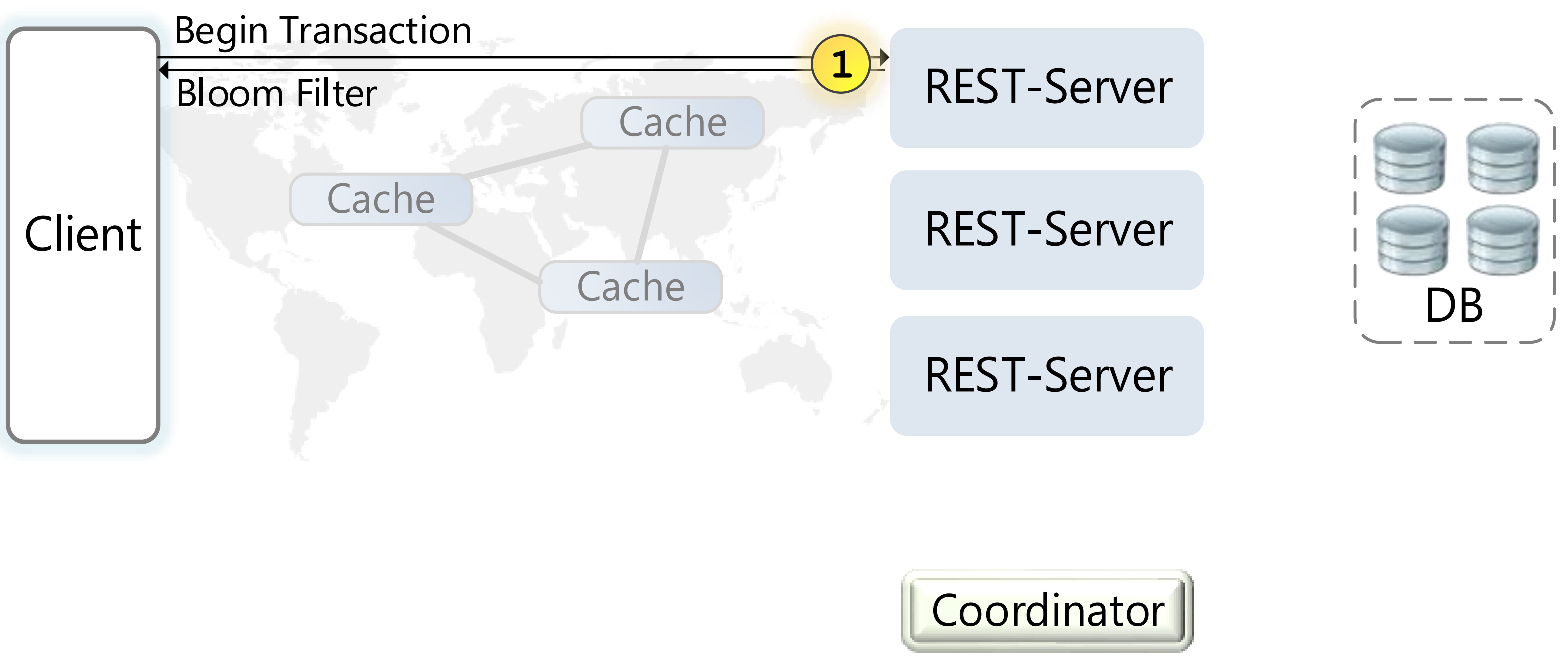

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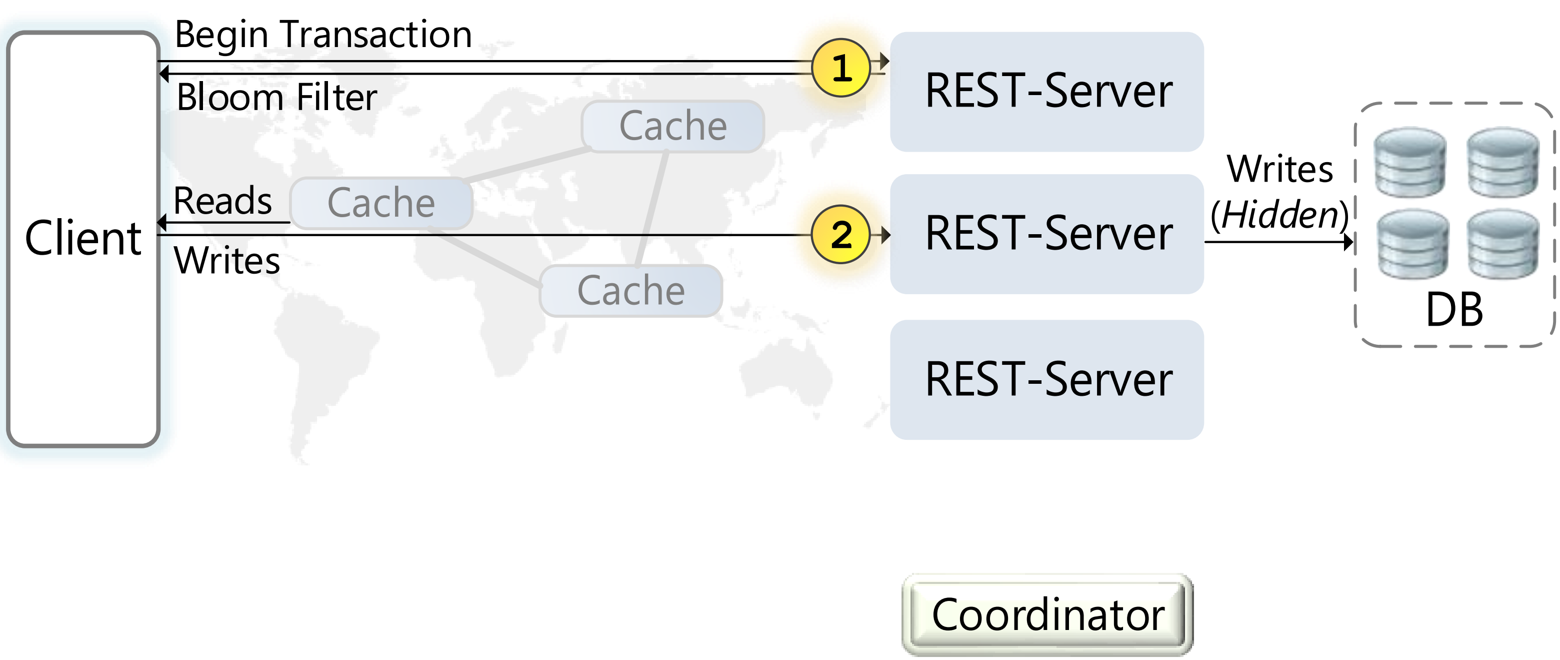

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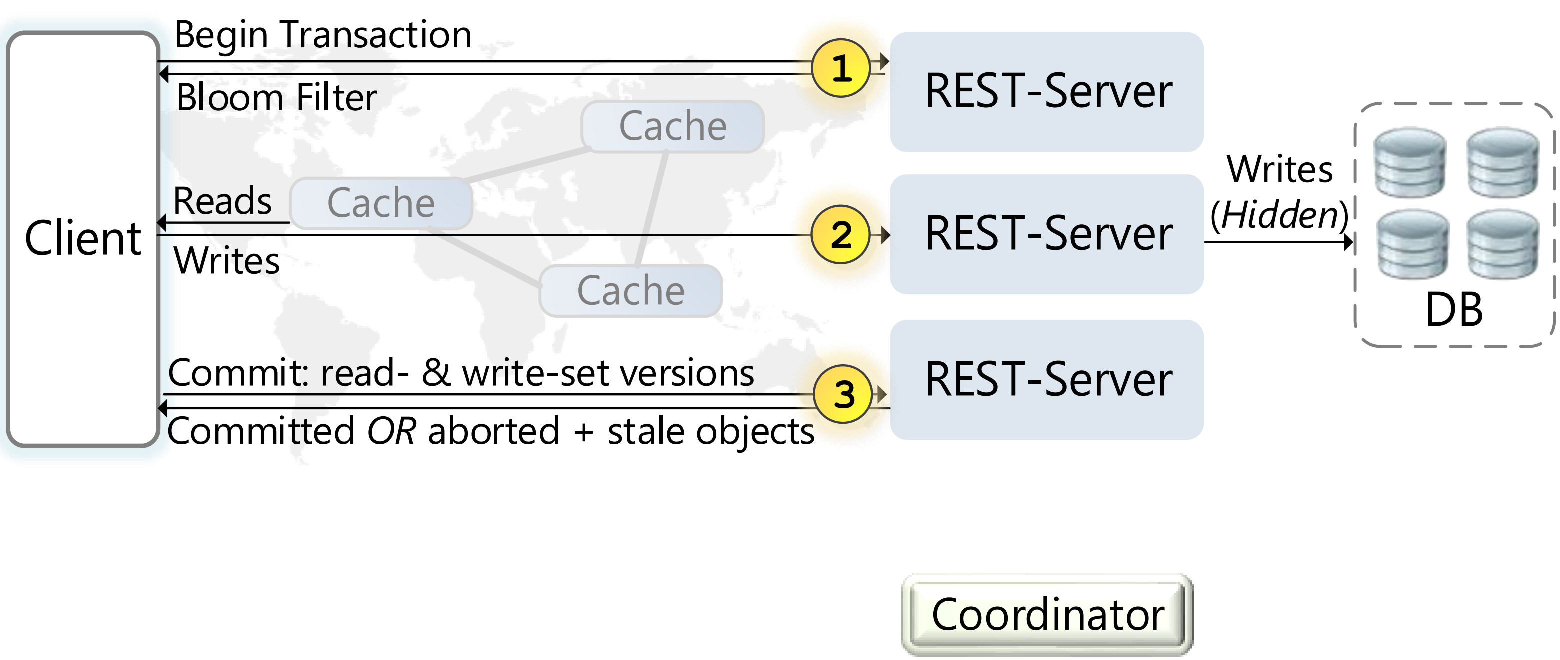

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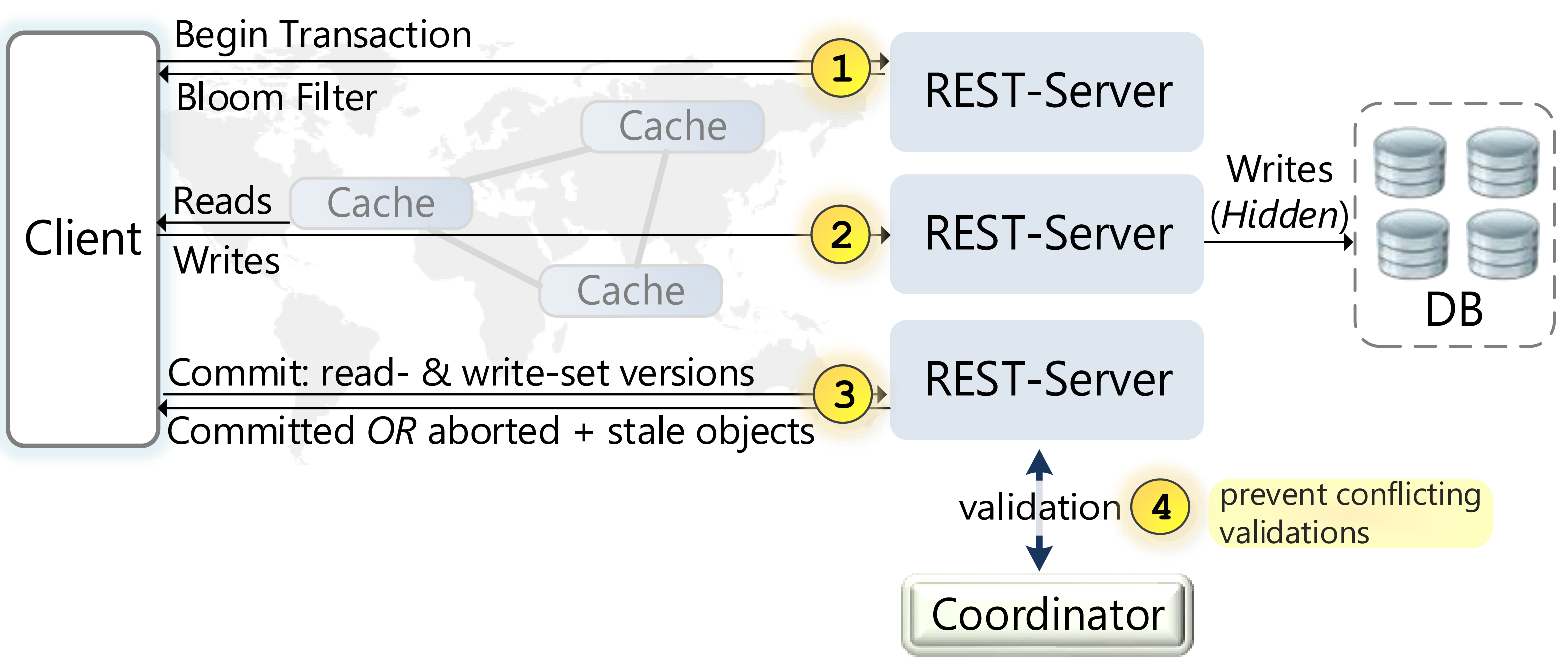

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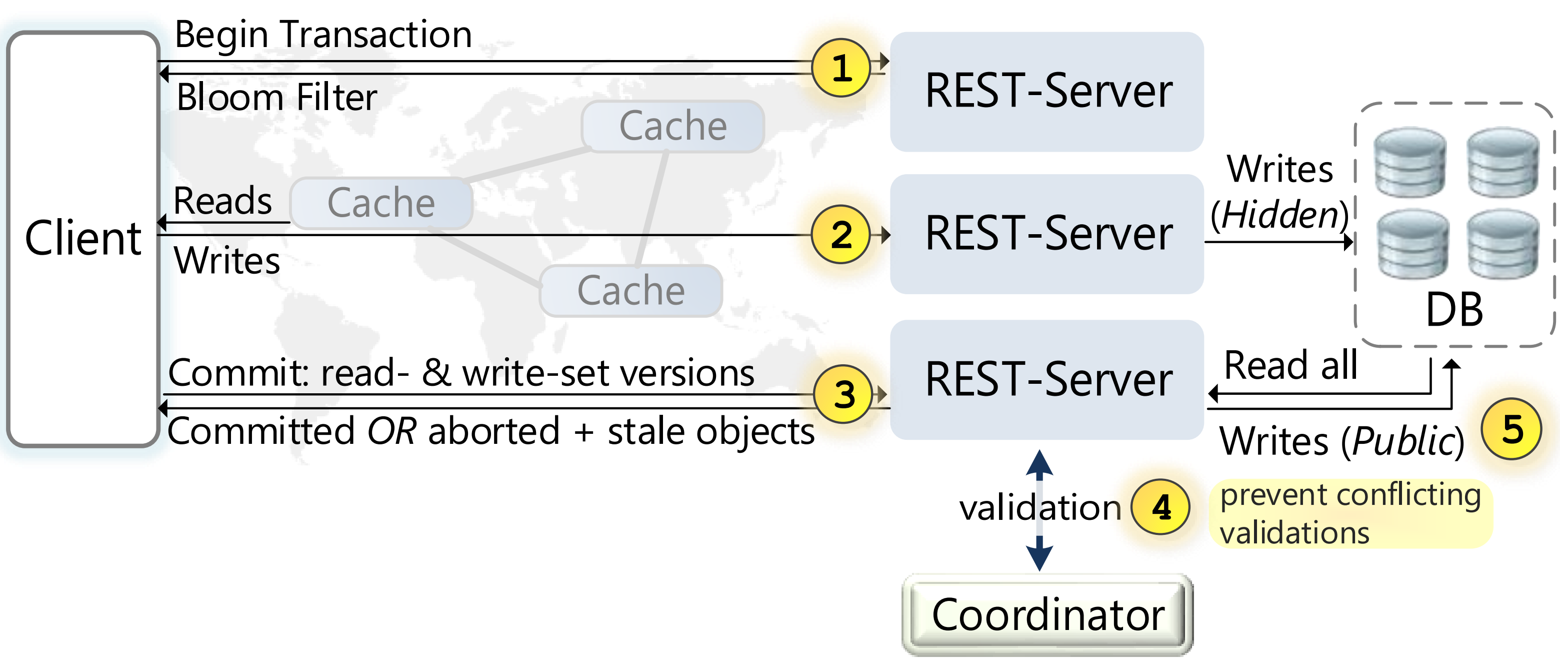

The Server Cache Sketch

- Goal: Efficient *Generation of Cache Sketch* and *Invalidation Minimization*
- **Counting Bloom Filter** and **key** → **expiration** mapping

Add key_x if
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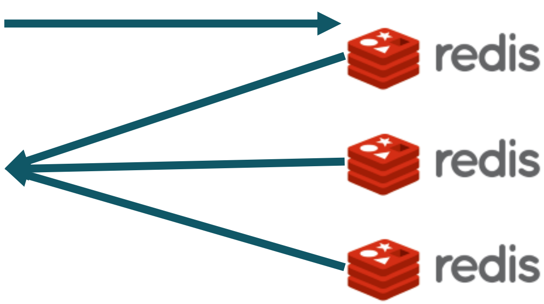

Cache Sketch
for Table **A**

… **B**

… **C**

Get Cache Sketch:
Union
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https://github.com/Baqend/Orestes-Bloomfilter

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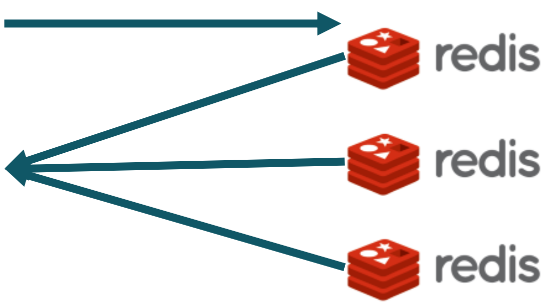

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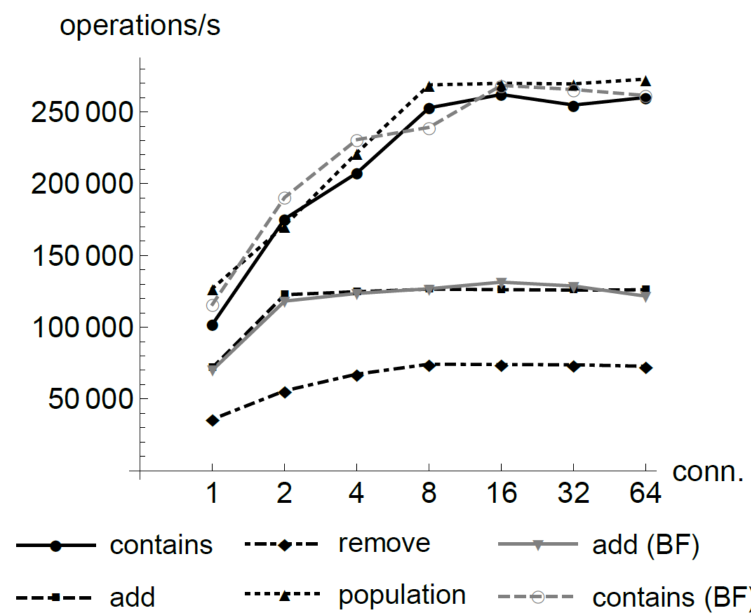

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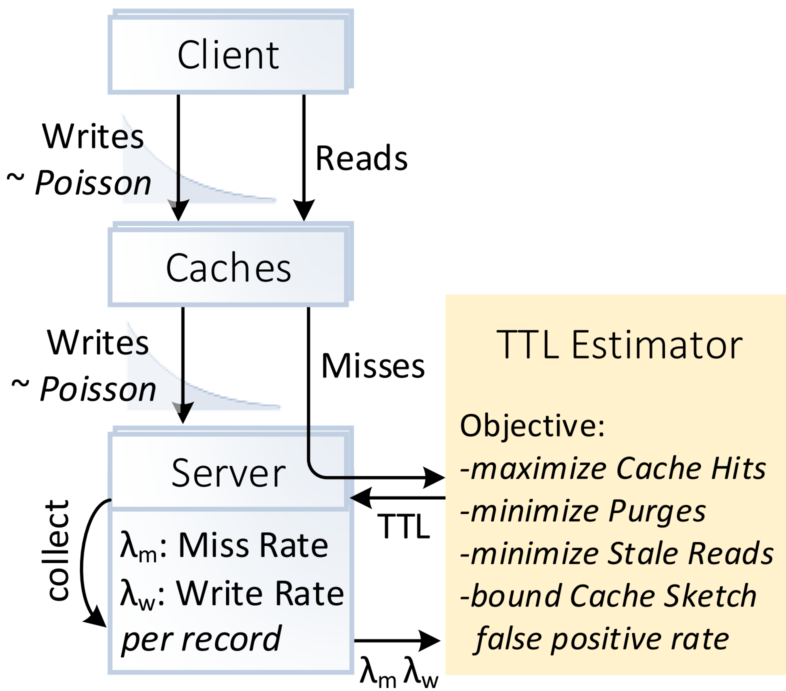
TTL Estimation

- **Problem**: if TTL ≪ time to next write, then it is contained in Cache Sketch unnecessarily long
- **TTL Estimator**: finds „best“ TTL



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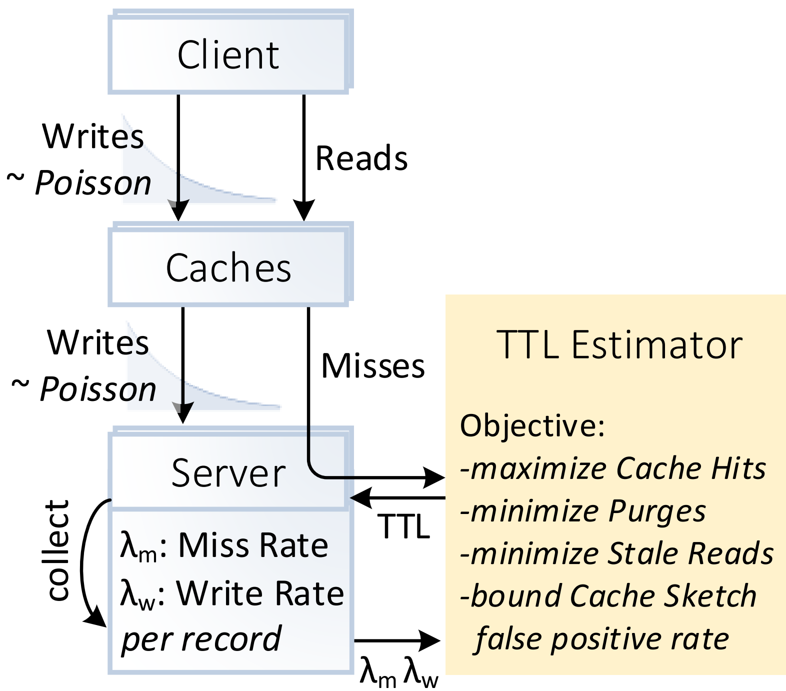

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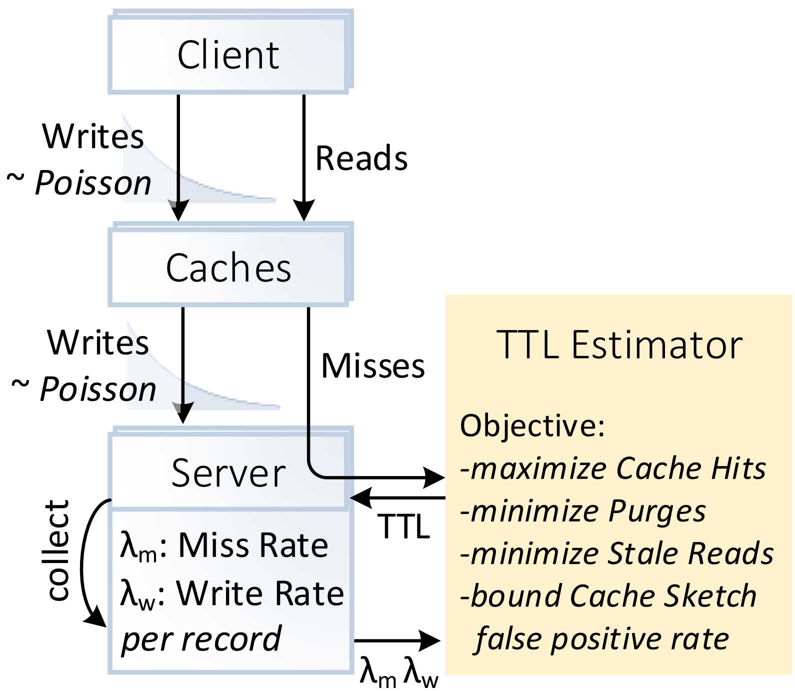
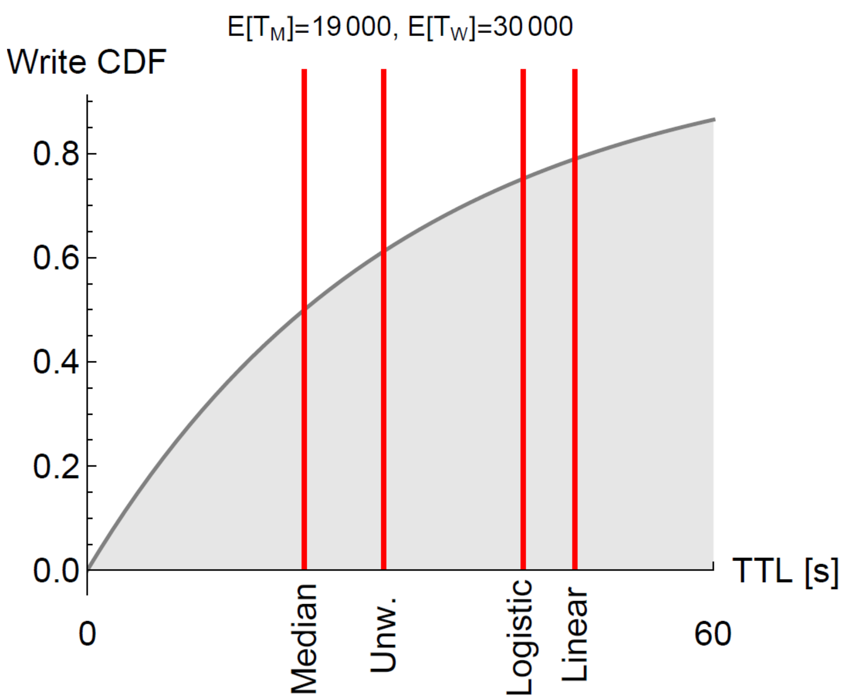
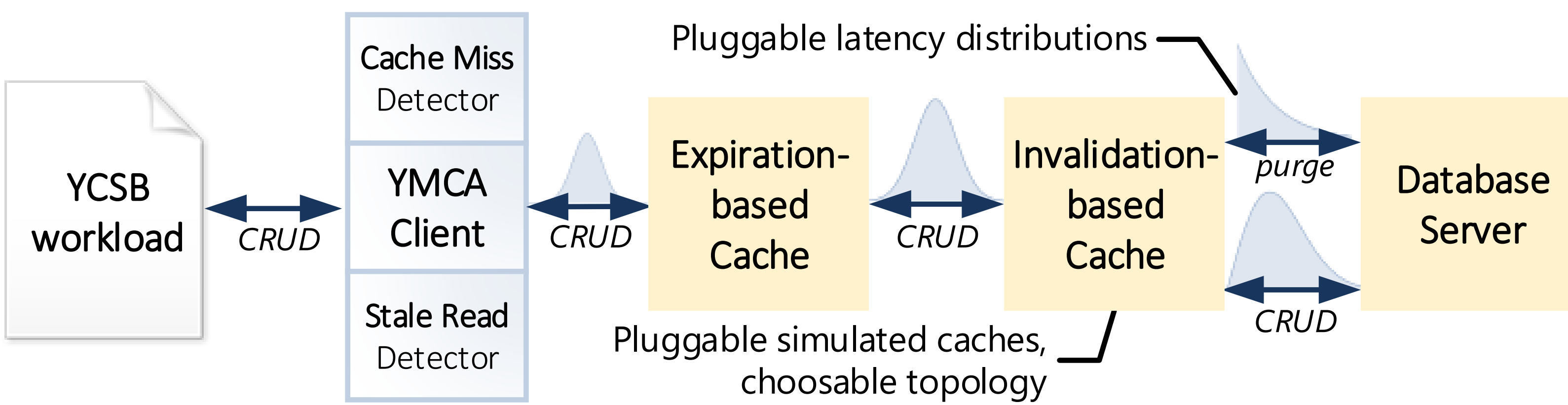




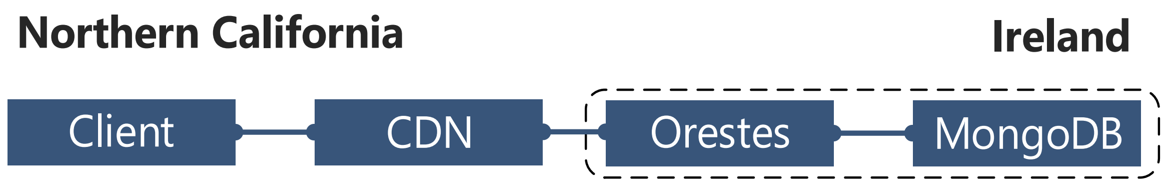
YCSB Monte Carlo Caching Simulator (YMCA)

- Goal: Analysis of arbitrary caching architectures using the standard **YCSB** benchmark
  - **Metrics**: *Latency, TP, Cache Hits, Stale Reads, Invalidations*
  - **Training of TTL Estimator**: Hill Climber finds optimal params

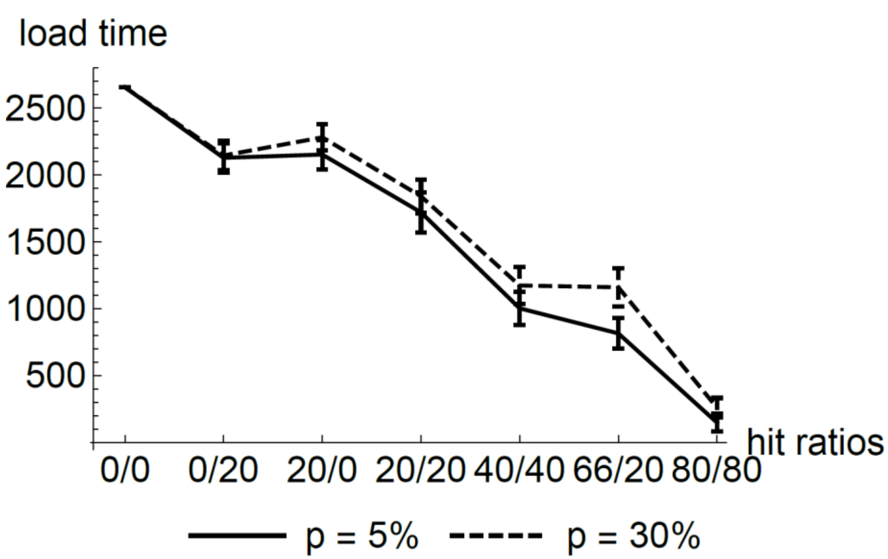


Results: Simulation & real-world

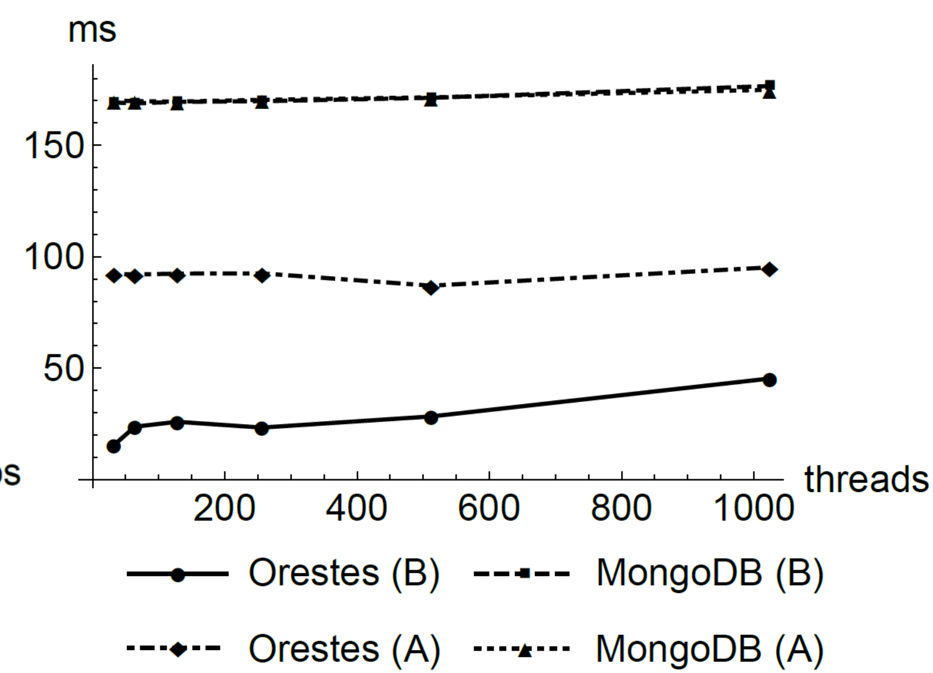
Setup:



Page load times with **cached initialization** (YMCA):



Average Latency for YCSB Workloads A and B (real):



Outline

- Motivation
- Cache Sketch Approach
- **Polyglot Persistence Mediator**
  - Idea
  - Process
  - Evaluation
- Wrap-up and future work

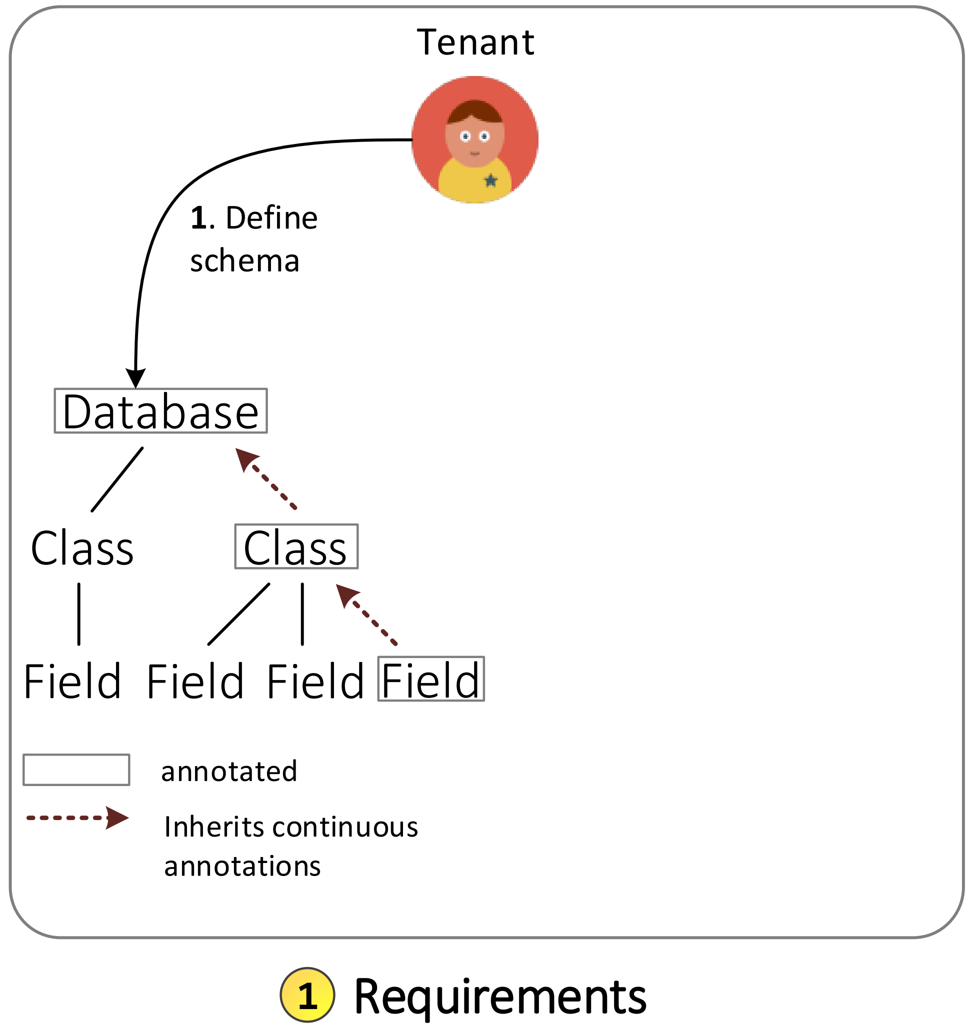
The Polyglot Persistence Mediator

- Fully transparent choice of DB, based on requirements (SLAs)
- 3-step-process:

  1. Requirements

  2. Resolution

  3. Mediation



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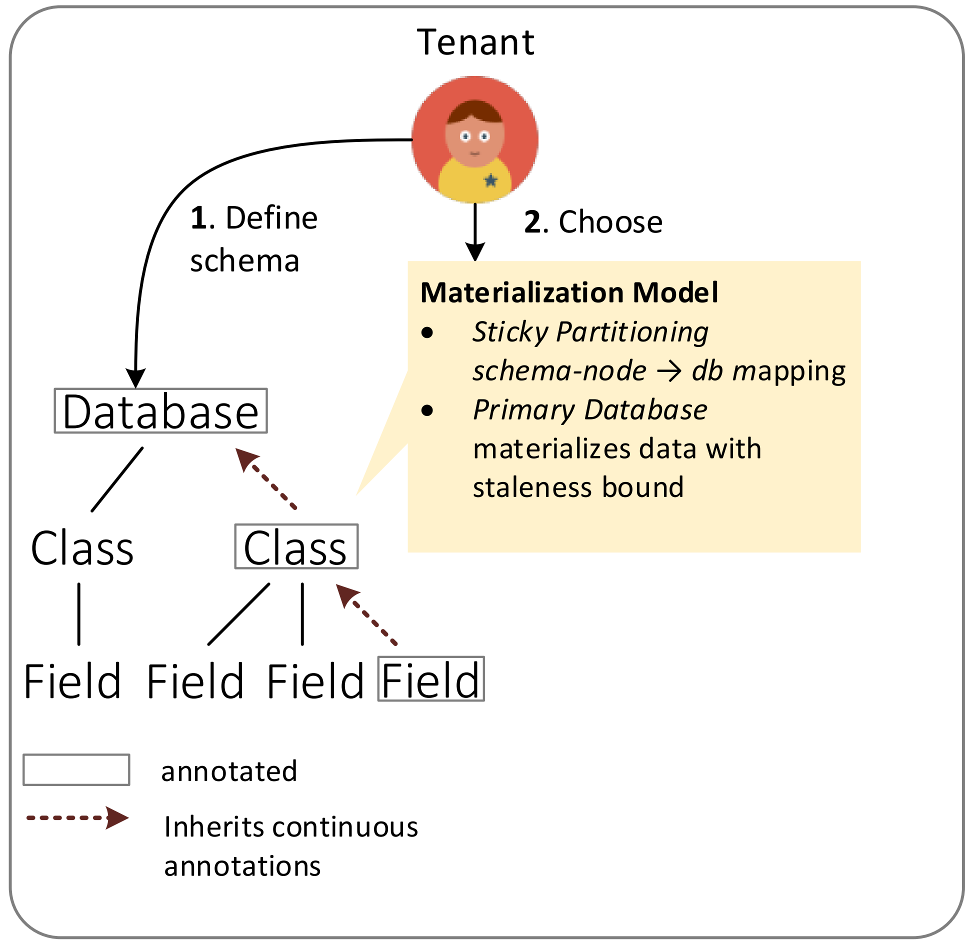

1 Requirements

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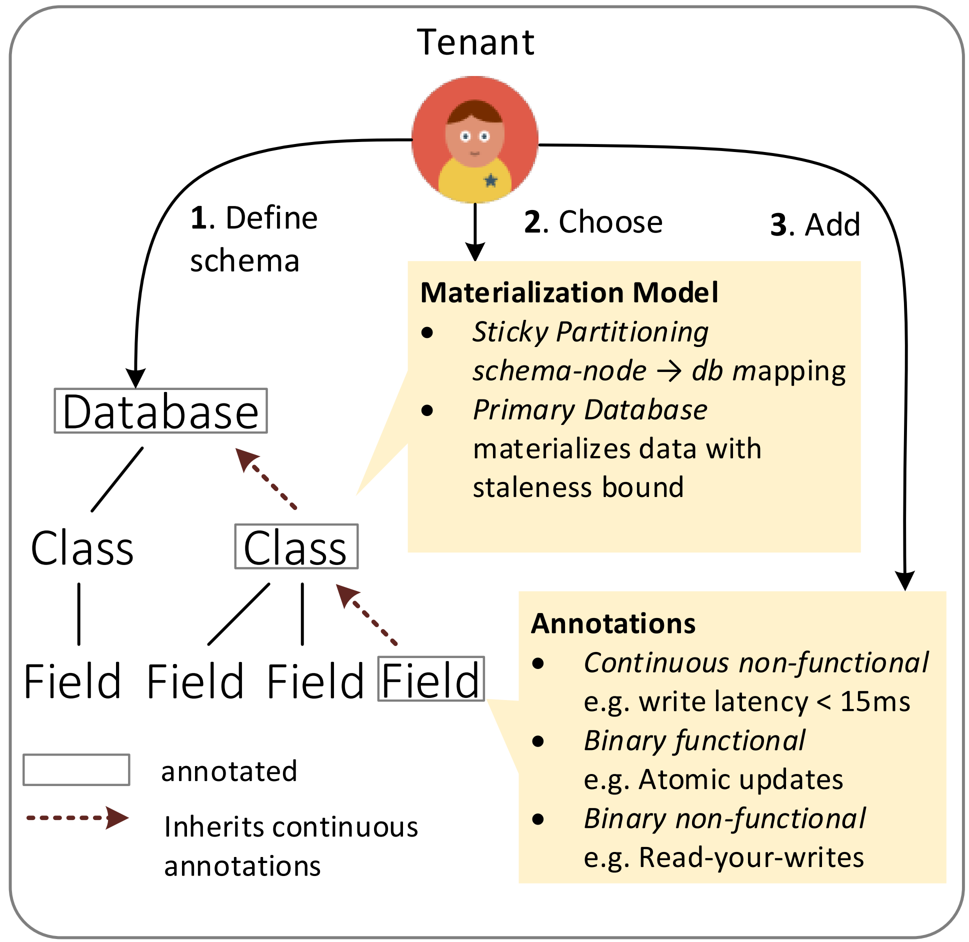

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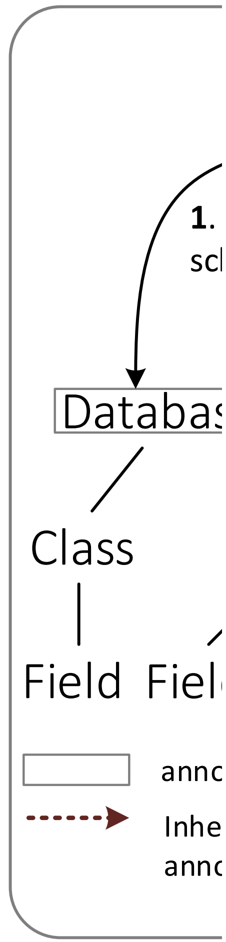
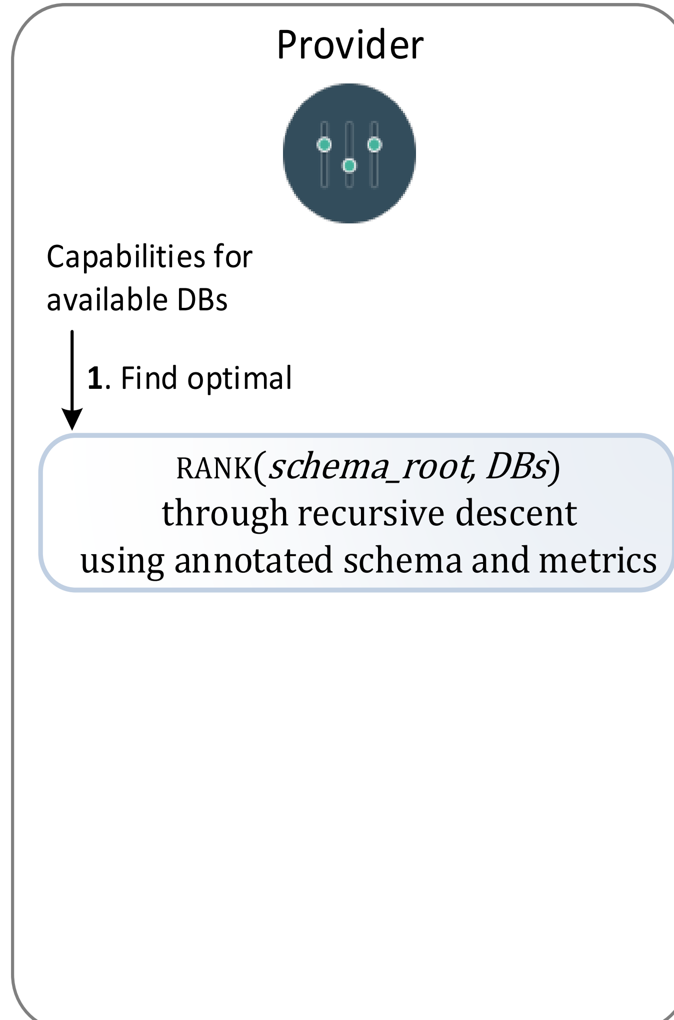


Annotation	Type	Annotated at
Read Availability	Continuous	*
Write Availability	Continuous	*
Read Latency	Continuous	*
Write Latency	Continuous	*
Write Throughput	Continuous	*
Data Vol. Scalability	Non-Functional	Field/Class/DB
Write Scalability	Non-Functional	Field/Class/DB
Read Scalabilty	Non-Functional	Field/Class/DB
Elasticity	Non-Functional	Field/Class/DB
Durability	Non-Functional	Field/Class/DB
Replicated	Non-Functional	Field/Class/DB
Linearizability	Non-Functional	Field/Class
Read-your-Writes	Non-Functional	Field/Class
Causal Consistency	Non-Functional	Field/Class
Writes follow reads	Non-Functional	Field/Class
Monotonic Read	Non-Functional	Field/Class
Monotonic Write	Non-Functional	Field/Class
Scans	Functional	Field
Sorting	Functional	Field
Range Queries	Functional	Field
Point Lookups	Functional	Field
ACID Transactions	Functional	Class/DB
Conditional Updates	Functional	Field
Joins	Functional	Class/DB
Analytics Integration	Functional	Field/Class/DB
Fulltext Search	Functional	Field
Atomic Updates	Functional	Field/Class

PPM Step 2: Resolution

- The Provider resolves the requirements
- RANK algorithm recursively analyzes schema annotations
- For each schema element:
  - Find each DB that satisfies all binary requirements
  - Pick the one that has the best score according to utility function of historic or predicted metrics



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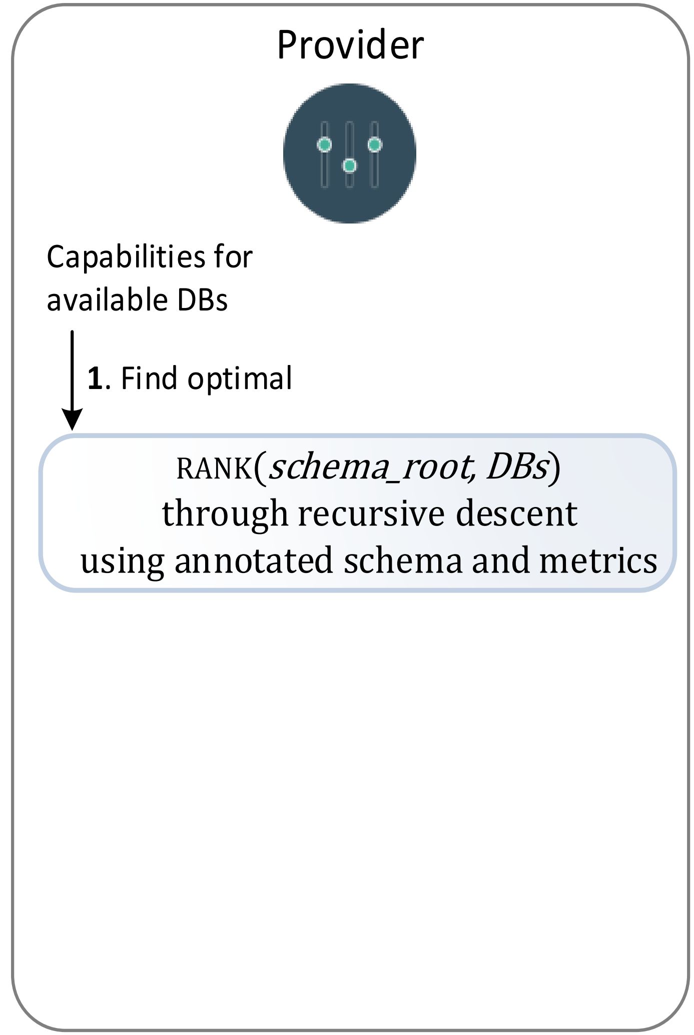

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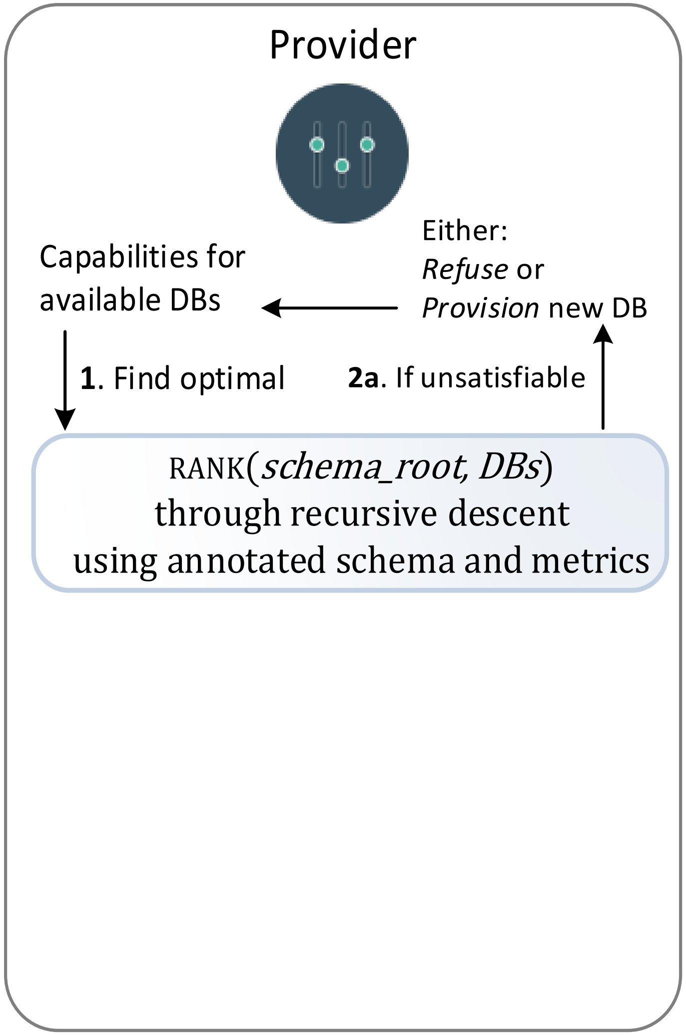

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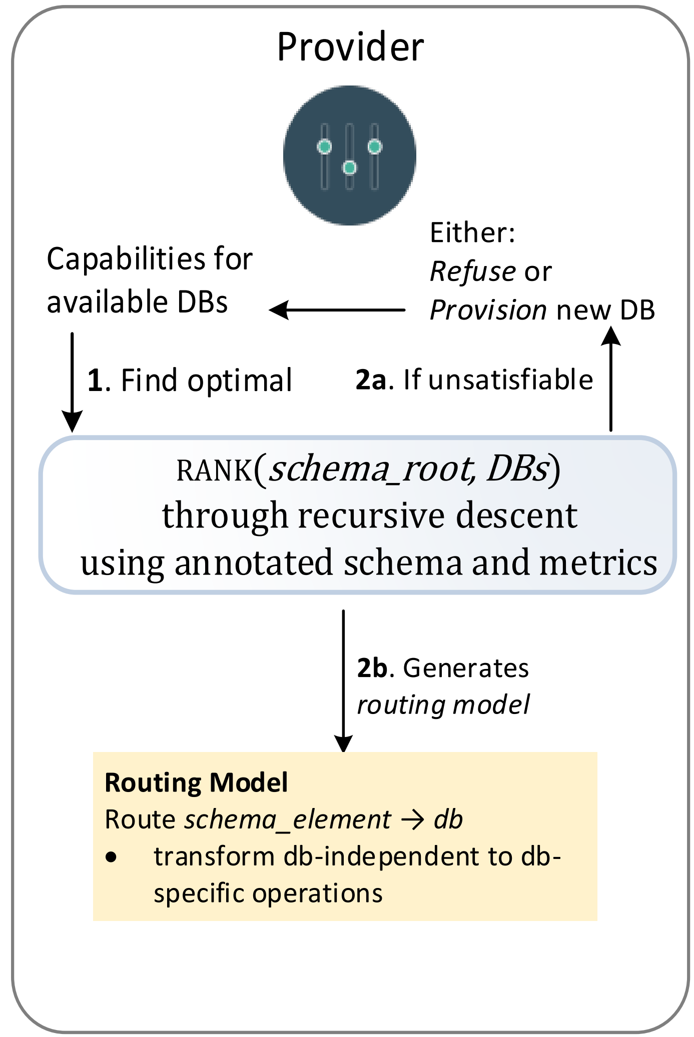
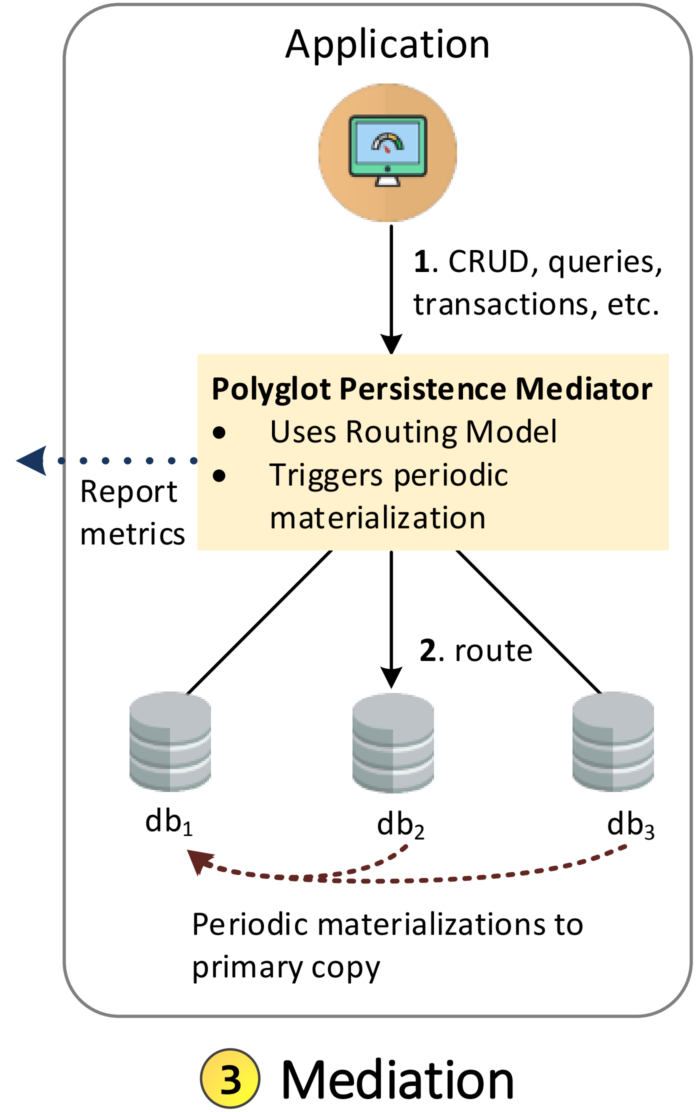


2 Resolution

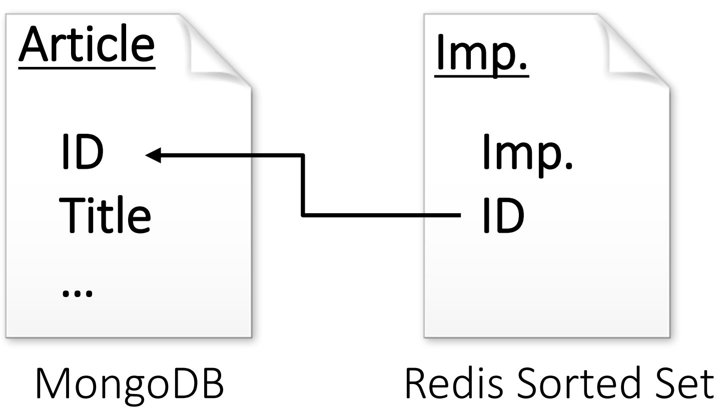
PPM Step 3: Mediation

- The PPM routes data and operations to the chosen DBs
- In the *primary database model*, it triggers periodic materializations
- Metrics (latency, availability, etc.) are reported to the resolver



Evaluation

Scenario: news articles with impression counts
Objective: low-latency top-k querys, high-throughput counts



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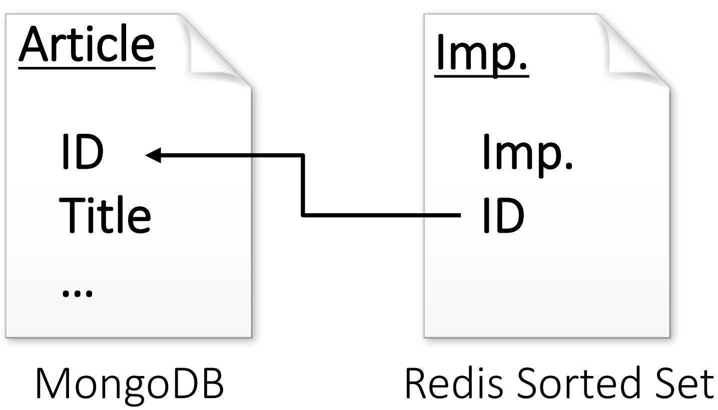

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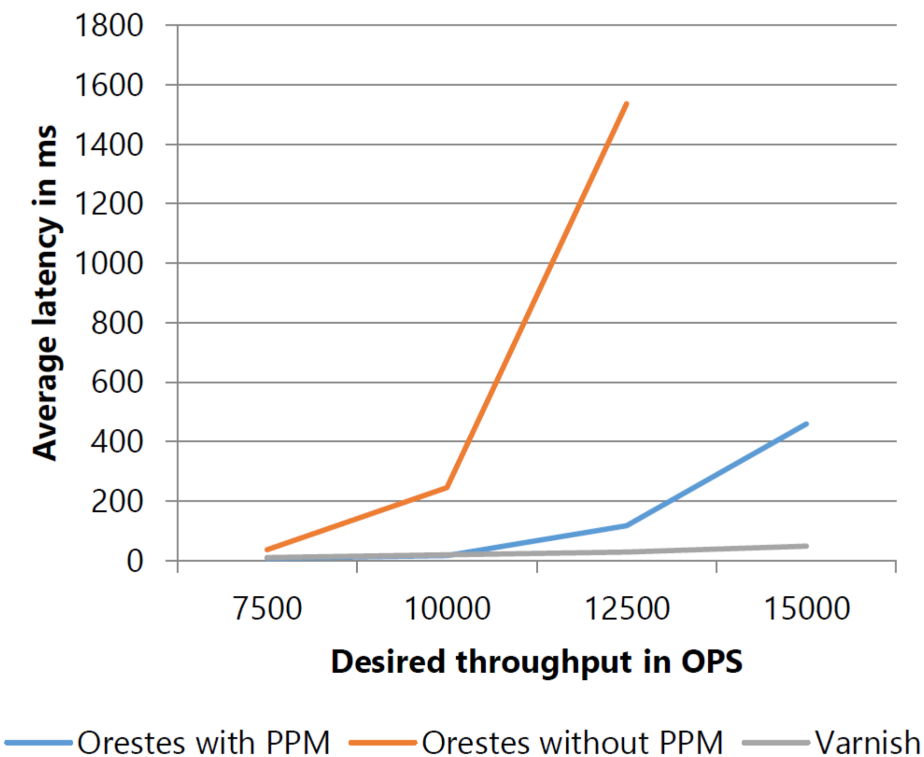

Outline

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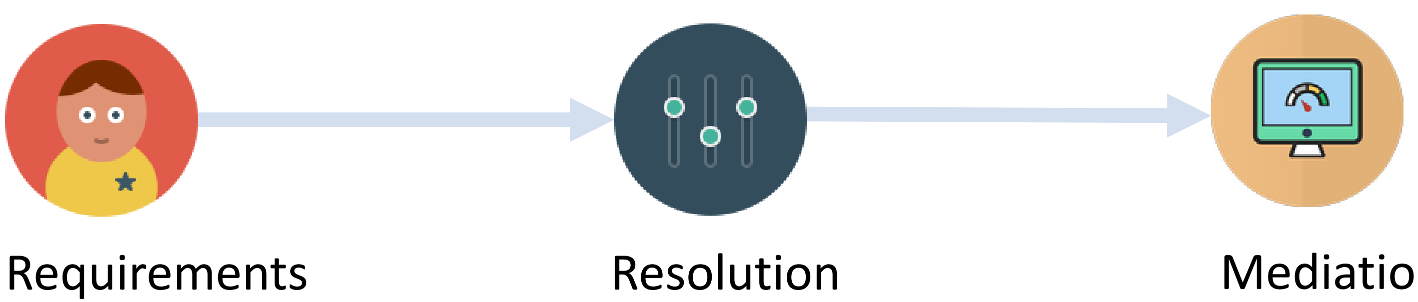
- Cache Sketch Approach
- Polyglot Persistence Mediator
- **Wrap-up and future work**
  - Summary
  - Research areas
  - Baqend

Summary

- **Cache Sketch**: dual approach to web caching for database services
  - Consistent (Δ-atomic) *expiration-based* caching
  - *Invalidation-based* caching with minimal purges

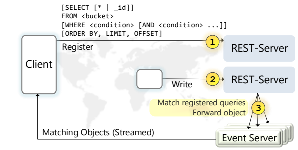
Cached Initialization	Δ-Bounded Staleness	Conflict-Avoidant Transactions	Invalidation Minimization

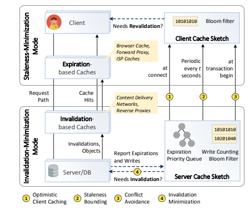
- **Polyglot Persistence Mediator**: SLA-driven, fine-grained selection of database systems

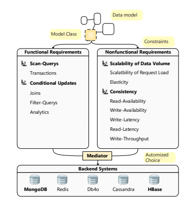


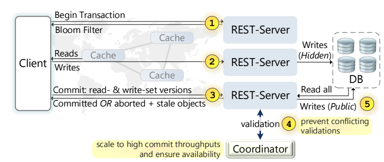
Future & Current Work

- **Cache Sketch**:
  - Online learning of best *TTL estimation*
  - Quantify *COT* properties
  - *Query* result caching
  - Extend *YMCA* to replication and sharding architectures
- **Polyglot Persistence**:
  - Common requirements/SLA „*library*“
  - Implementation of *Resolution*
  - *Live Migration*
  - Scalable *metrics* aggregation

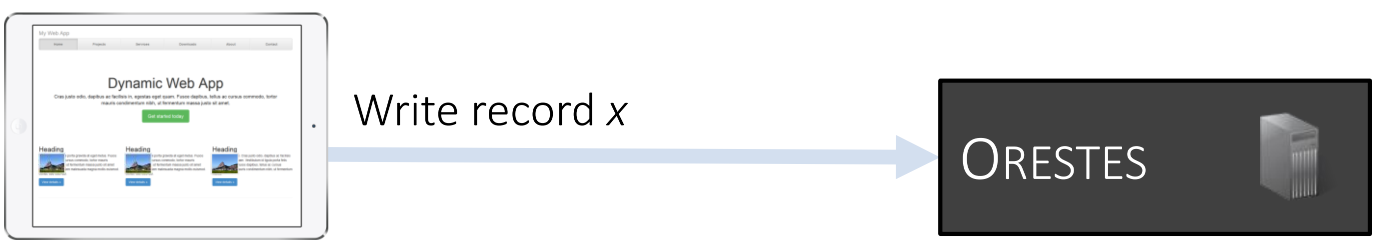








Future Work: Query Caching



Future Work: Query Caching

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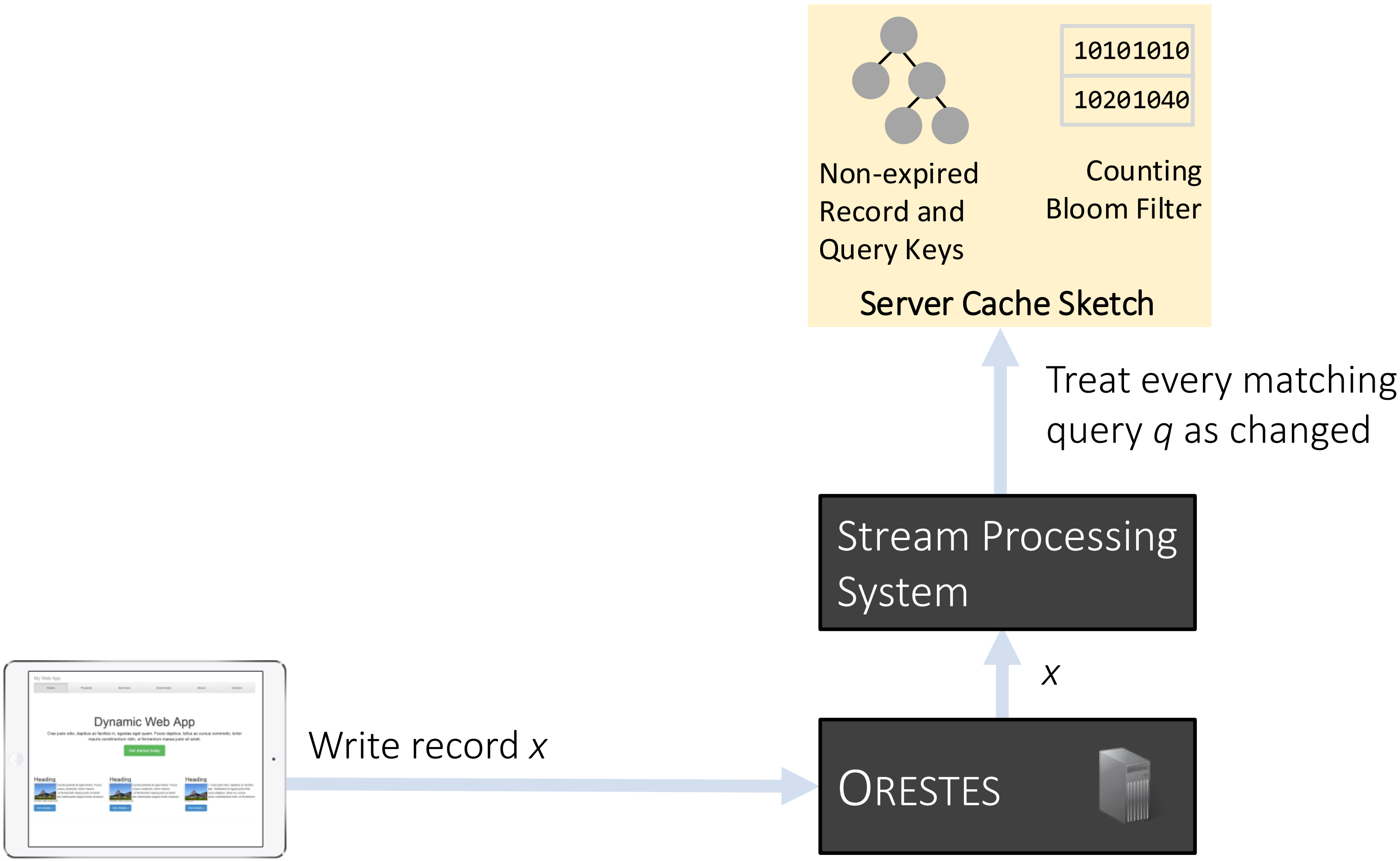

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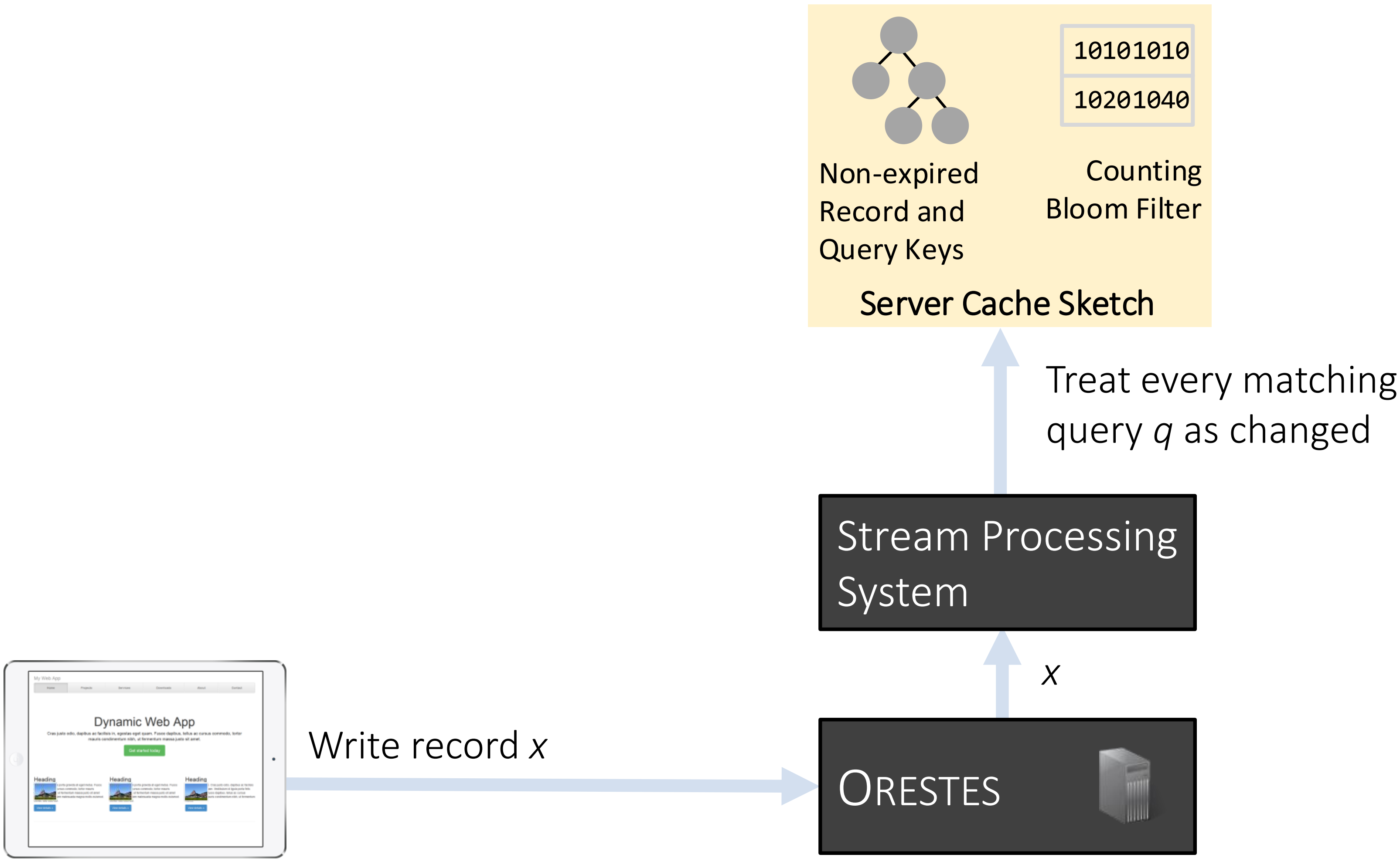

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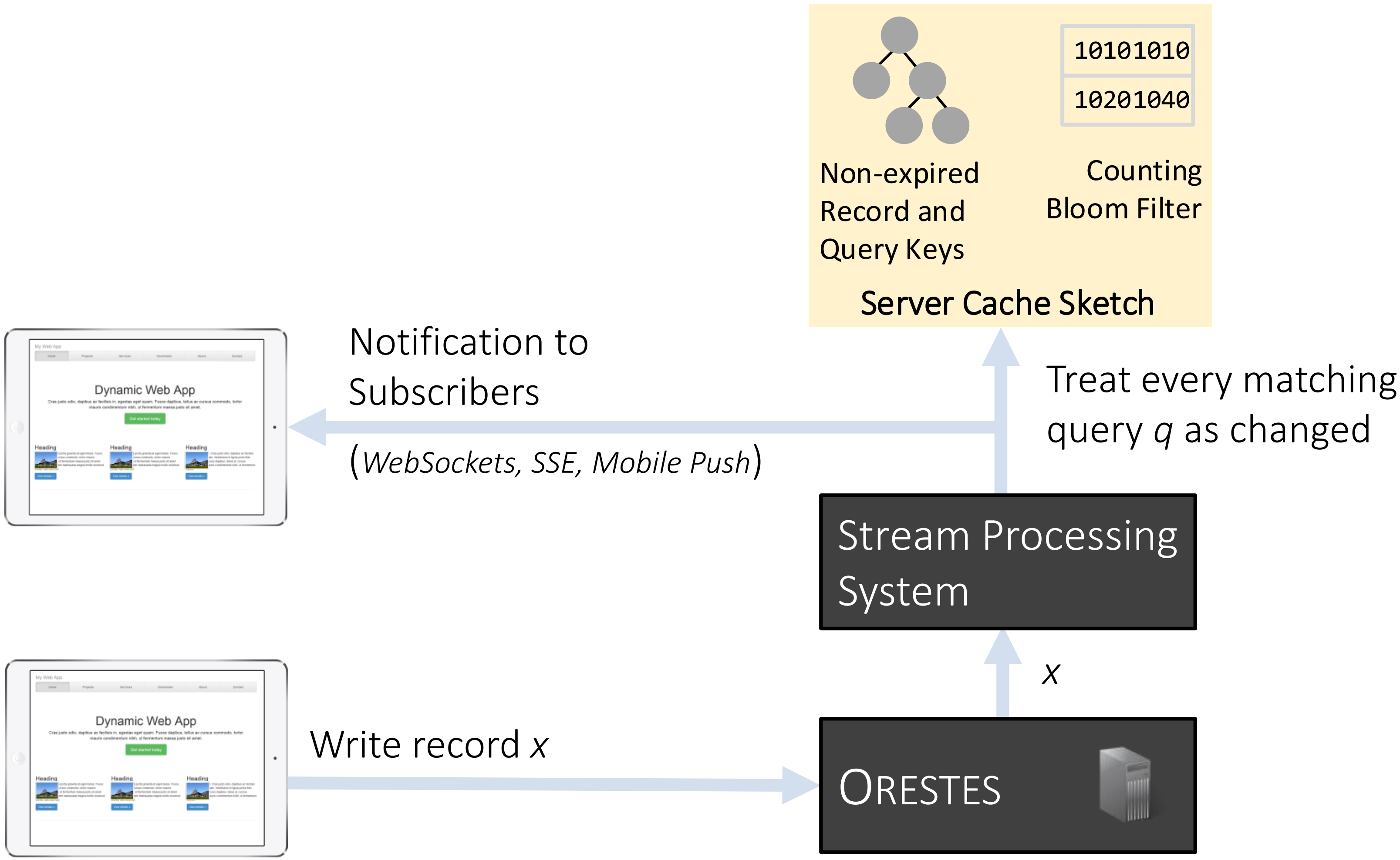


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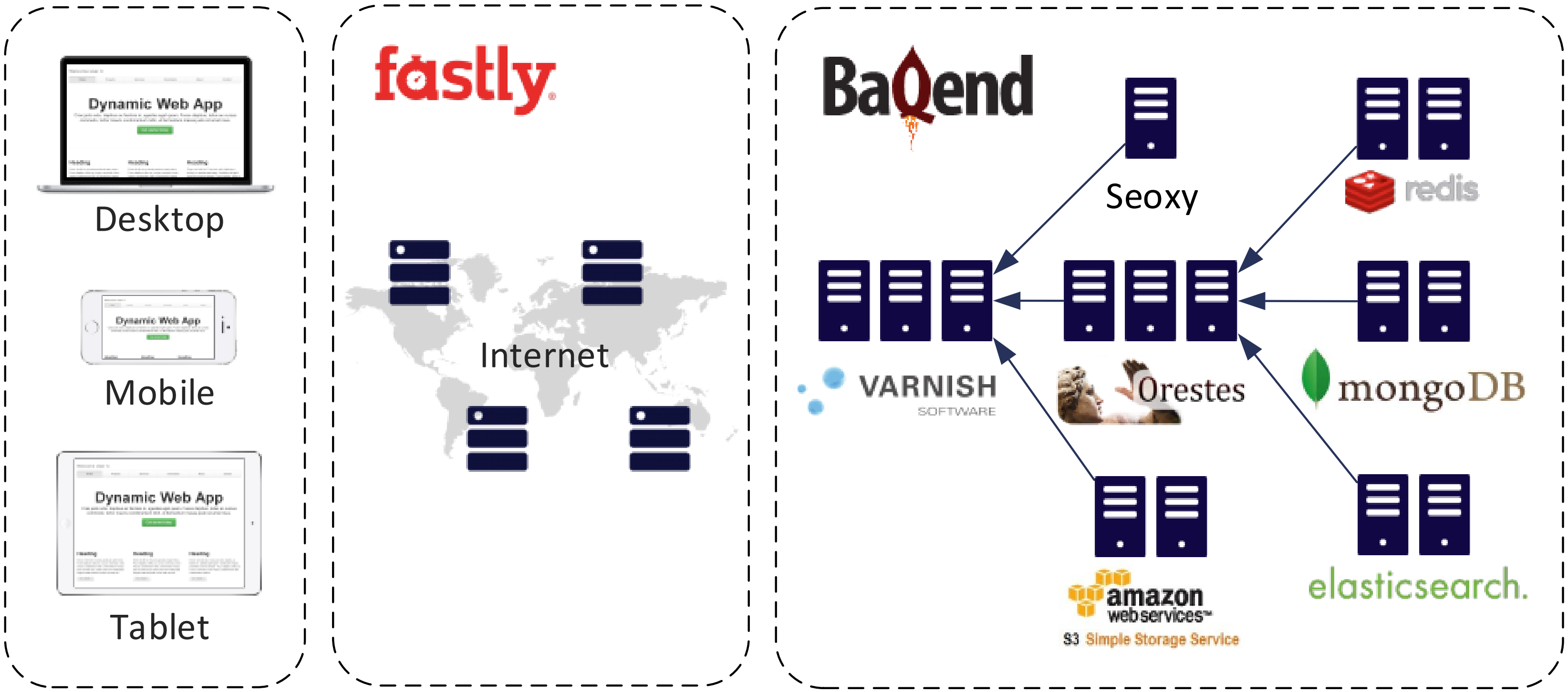
- Orestes as a startup, funded since March 2014



Thank you

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gessert@informatik.uni-hamburg.de

http://orestes.info

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