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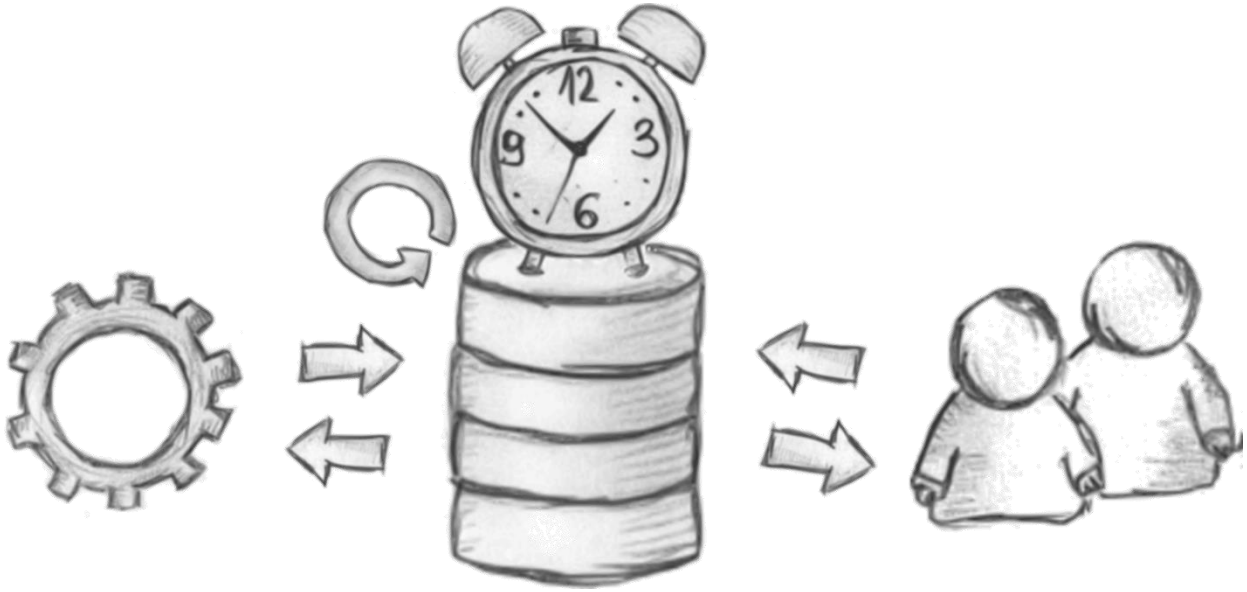
Real-Time Databases Explained: Why Meteor, RethinkDB, Parse and Firebase Don't Scale

Infrastructure & DevOps

September 28, 2017

Real-Time Databases Explained

Why Meteor, RethinkDB, Parse and Firebase Don‘t Scale



Wolfram Wingerath
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September 28, 2017

Who I Am

Research & Teaching

Wolfram Wingerath

Software Development

PhD studies:

- Real-Time Databases
- Stream Processing
- NoSQL Databases
- Database Benchmarking
- …

Universität Hamburg

Baqend:
High-Performance Backend-as-a-Service

www.baqend.com

Outline

Push-Based Data Access
Why Real-Time Databases?

- Pull-based data access
- Self-maintaining results

Real-Time Databases
System survey

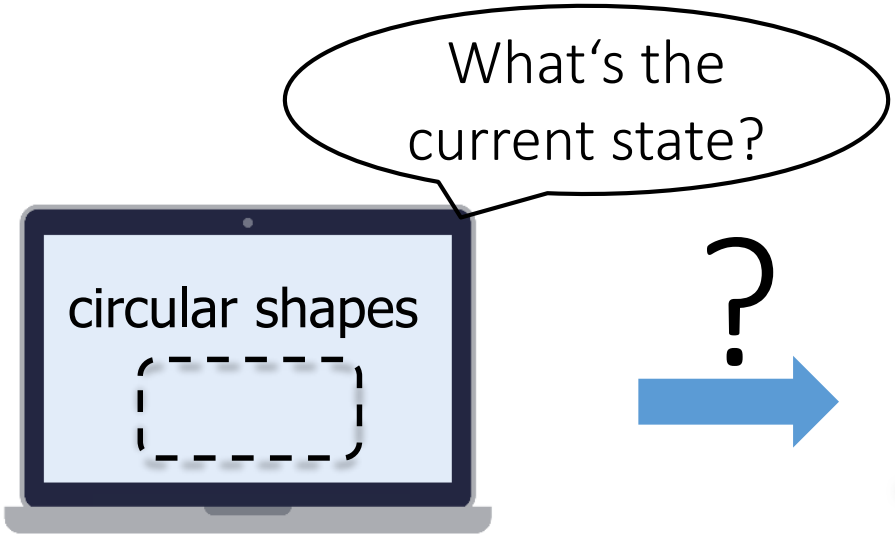
Discussion
What are the bottlenecks?

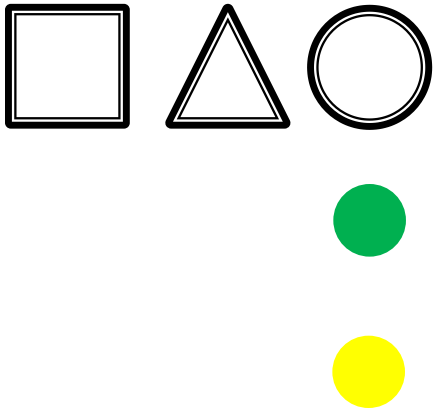
Baqend Real-Time Queries
How do they scale?

Push-Based Data Access

Traditional Databases

No Request? No Data!





Query maintenance: periodic polling

→ Inefficient

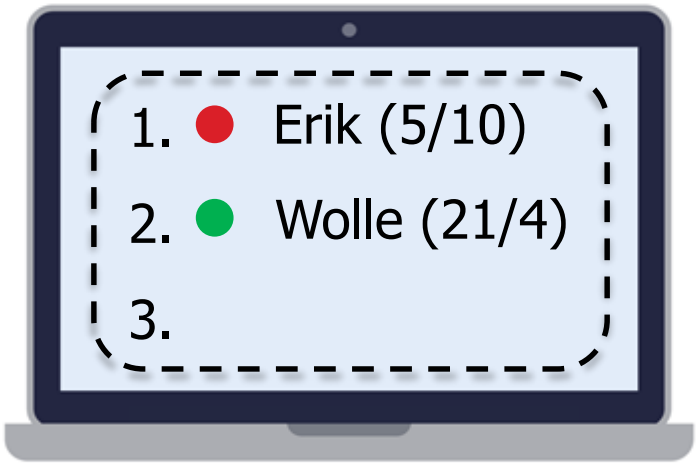
→ Slow

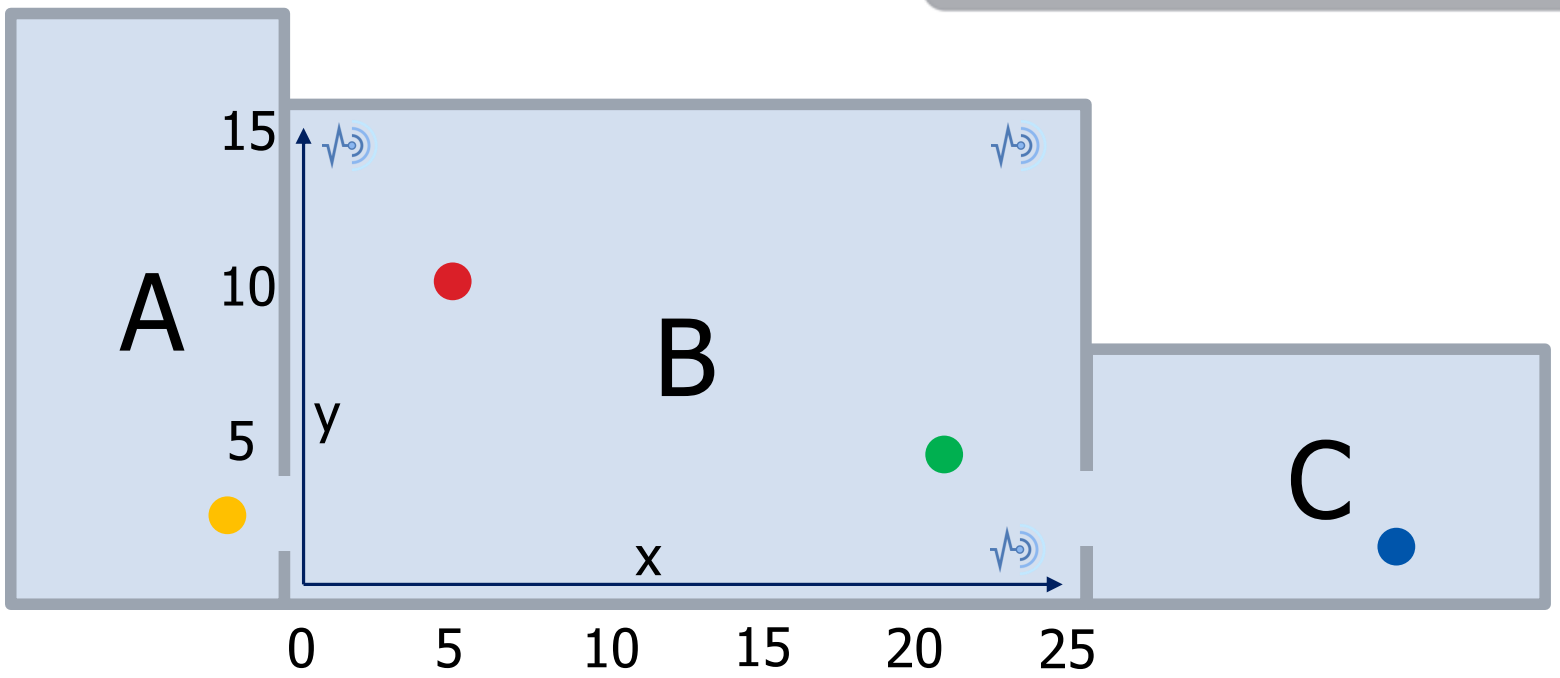
Ideal: Push-Based Data Access

Self-Maintaining Results

Find people in Room B:

```
db.User.find()
    .equal('room','B')
    .ascending('name')
    .limit(3)
    .resultStream()
```





Outline

Push-Based Data Access
Why Real-Time Databases?

Real-Time Databases
System survey

- Meteor
- RethinkDB
- Parse
- Firebase
- Others

Discussion
What are the bottlenecks?

Baqend Real-Time Queries
How do they scale?

Real-Time Databases

Meteor

Overview:

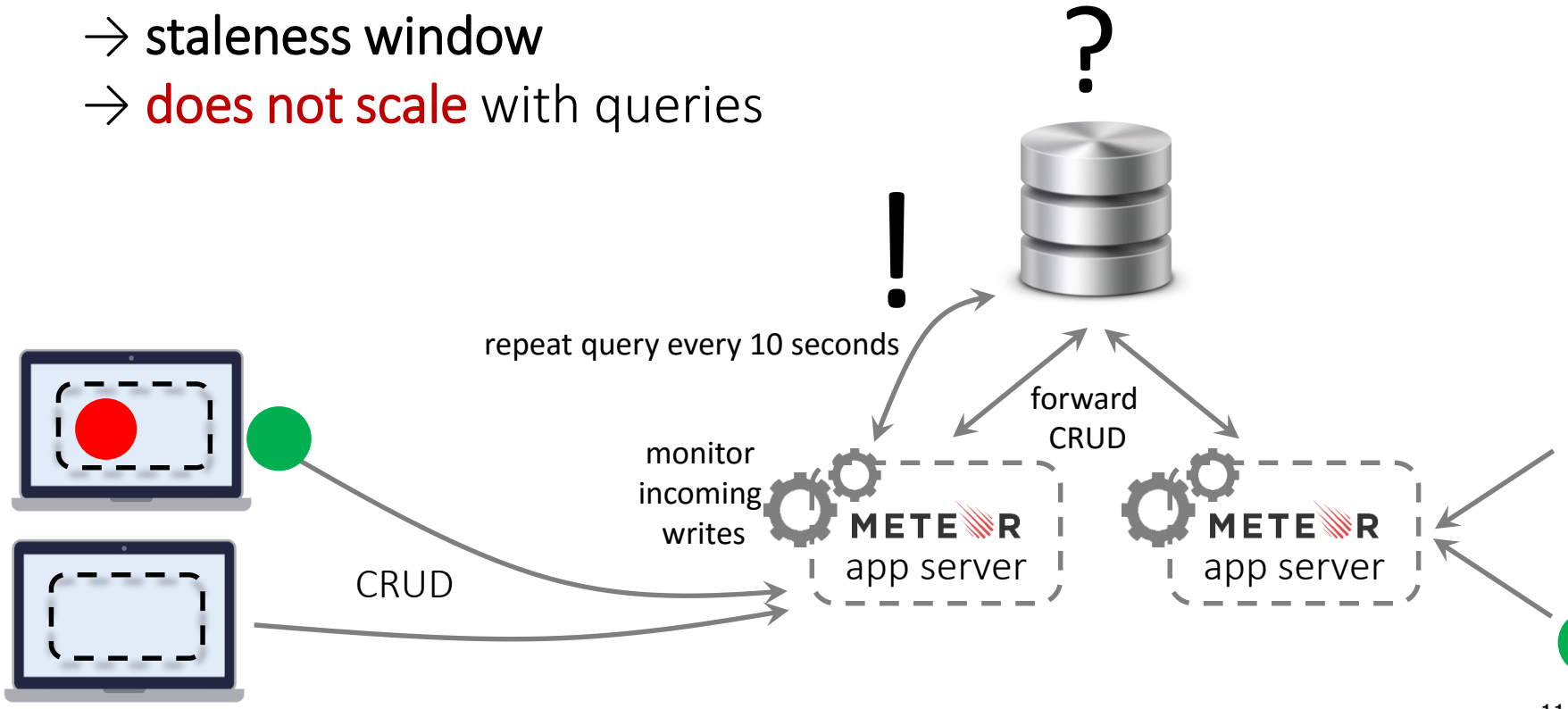
- **JavaScript Framework** for interactive apps and websites
  - **MongoDB** under the hood
  - **Real-time** result updates, full MongoDB expressiveness
- **Open-source**: MIT license
- **Managed service**: Galaxy (Platform-as-a-Service)

History:

- 2011: *Skybreak* is announced
- 2012: Skybreak is renamed to Meteor
- 2015: Managed hosting service Galaxy is announced

Live Queries
Poll-and-Diff

- **Change monitoring**: app servers detect relevant changes
  → *incomplete* in multi-server deployment
- **Poll-and-diff**: queries are re-executed periodically
  → **staleness window**
  → does not scale with queries

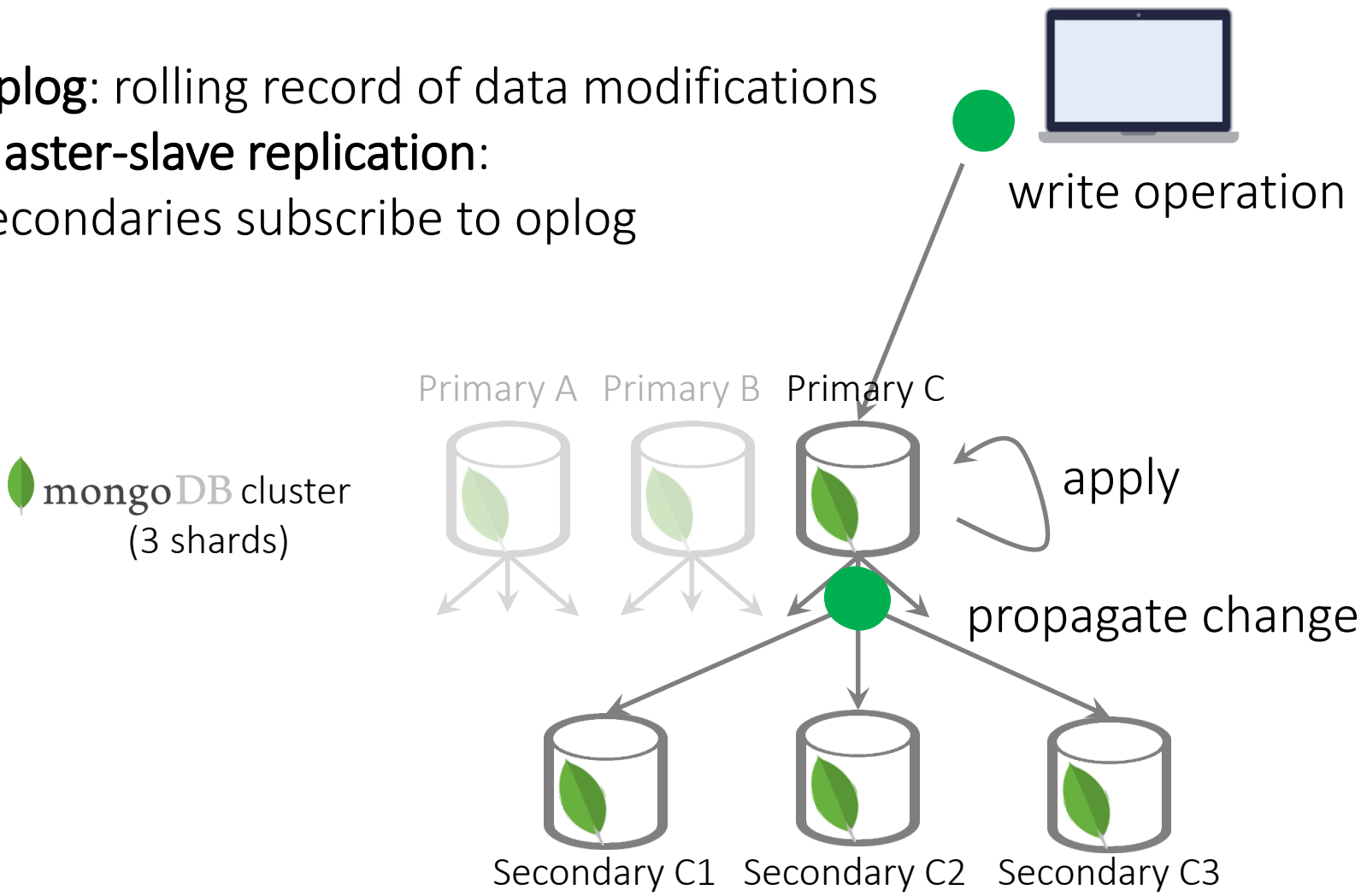


Oplog Tailing

Basics: MongoDB Replication

METEOR

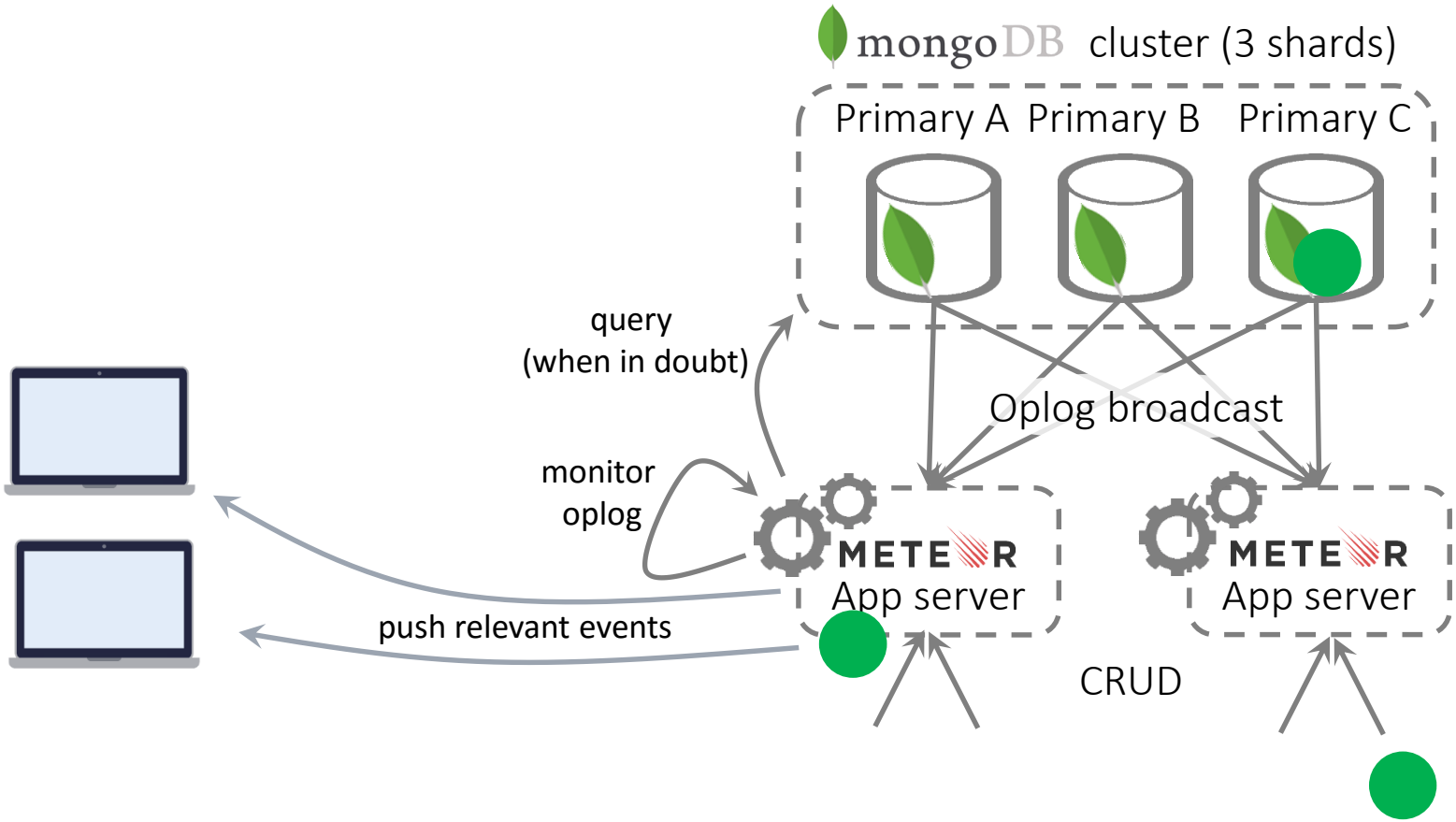
- **Oplog**: rolling record of data modifications
- **Master-slave replication**:
  Secondaries subscribe to oplog



Oplog Tailing

Tapping into the Oplog

METEOR



Oplog Tailing

Oplog Info is Incomplete

METEOR

What game does Bobby play?

→ if baccarat, he takes first place!

→ if something else, nothing changes!

Partial update from oplog:

```
{ name: „Bobby“, score: 500 } // game: ???
```

Baccarat players sorted by high-score

METEOR

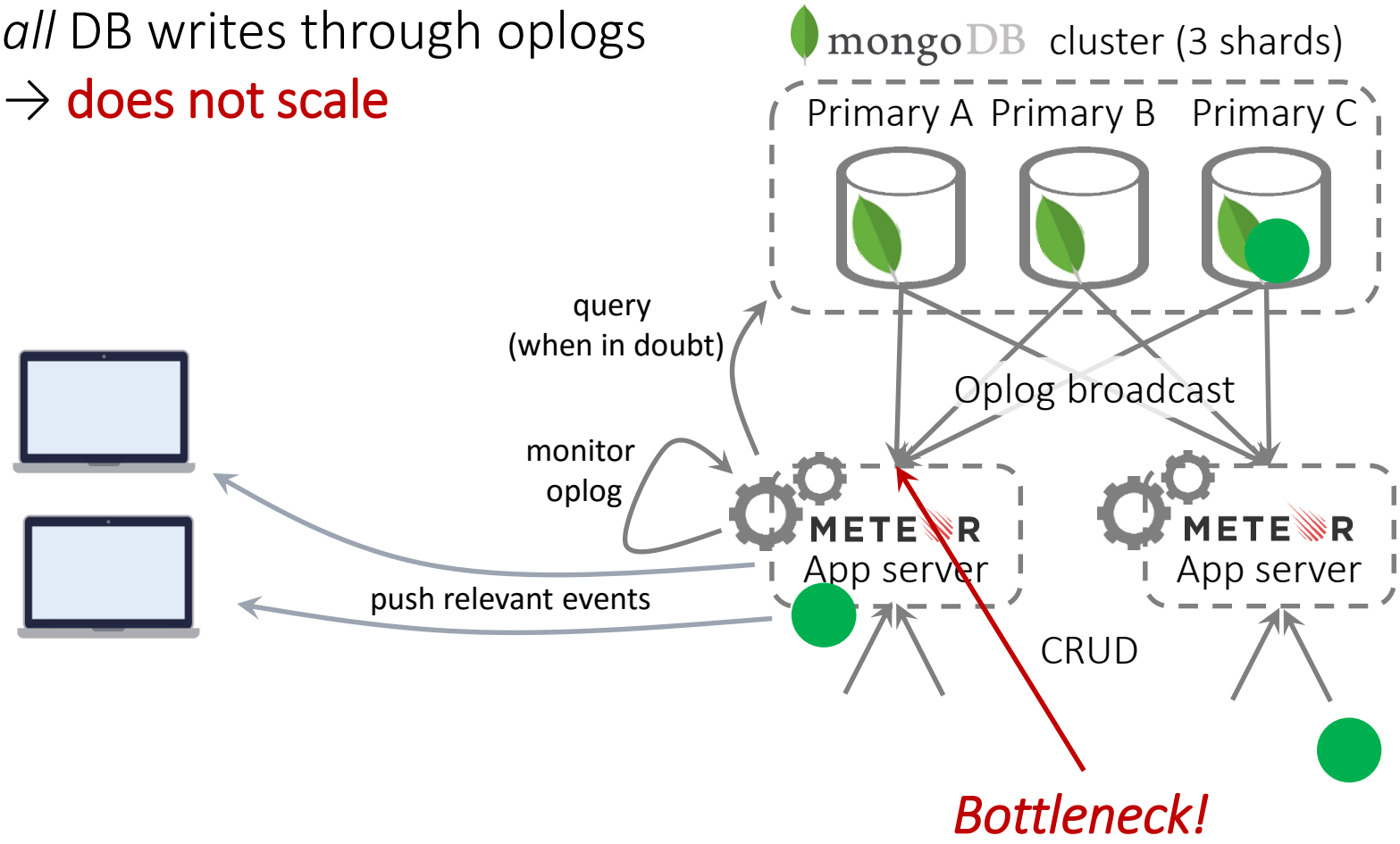
```
1. { name: „Joy“, game: „baccarat“, score: 100 }
2. { name: „Tim“, game: „baccarat“, score: 90 }
3. { name: „Lee“, game: „baccarat“, score: 80 }
```

Oplog Tailing

Tapping into the Oplog

METEOR

- *Every* Meteor server receives *all* DB writes through oplogs
  → does not scale



RethinkDB

Overview:

- **„MongoDB done right“**: comparable queries and data model, but also:
  - **Push-based queries** (filters only)
  - **Joins** (non-streaming)
  - **Strong consistency**: linearizability
- **JavaScript SDK** (*Horizon*): open-source, as managed service
- **Open-source**: Apache 2.0 license

History:

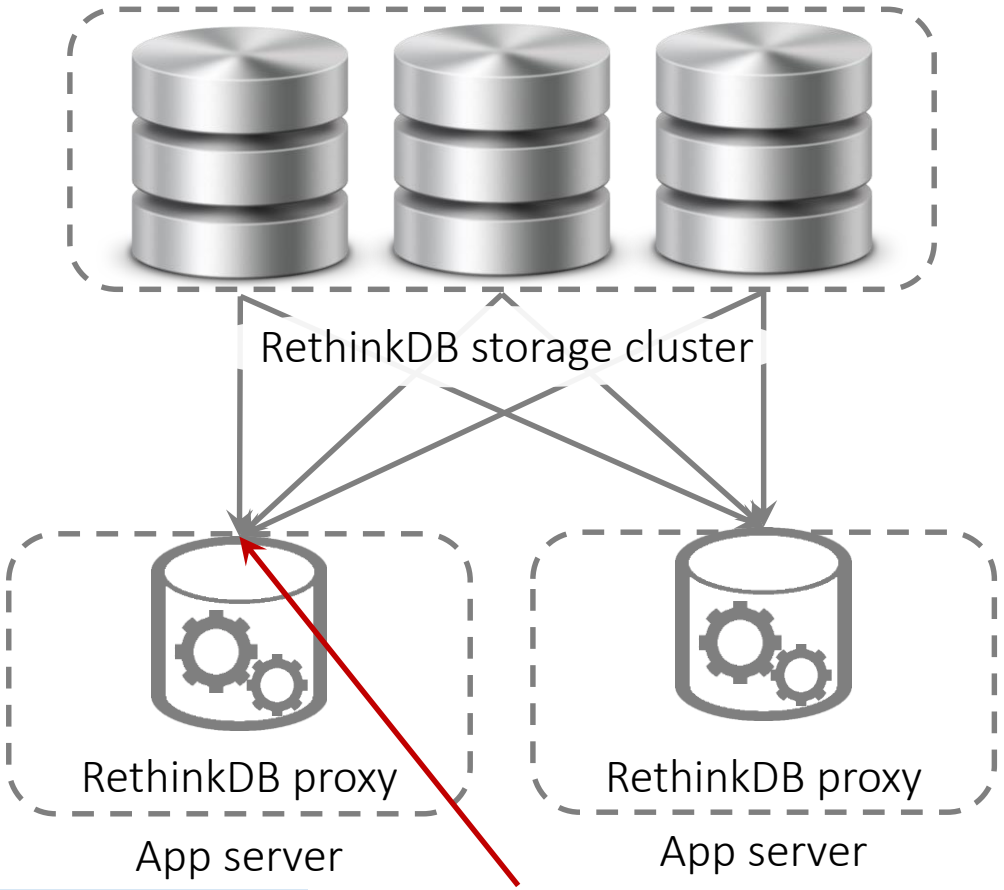
- 2009: RethinkDB is founded
- 2012: RethinkDB is open-sourced under AGPL
- 2016, May: first official release of Horizon (JavaScript SDK)
- 2016, October: RethinkDB announces shutdown
- 2017: RethinkDB is relicensed under Apache 2.0

RethinkDB

Changefeed Architecture

- Range-sharded data
- **RethinkDB proxy**: support node without data
  - Client communication
  - Request routing
  - Real-time query matching

- *Every* proxy receives *all* database writes
  → does not scale



William Stein, *RethinkDB versus PostgreSQL: my personal experience* (2017)
http://blog.sagemath.com/2017/02/09/rethinkdb-vs-postgres.html (2017-02-27)

Daniel Mewes, *Comment on GitHub issue #962: Consider adding more docs on RethinkDB Proxy* (2016)
https://github.com/rethinkdb/docs/issues/962 (2017-02-27)

Parse

Overview:

- **Backend-as-a-Service** for mobile apps
  - **MongoDB:** largest deployment world-wide
  - **Easy development**: great docs, push notifications, authentication, …
  - **Real-time** updates for most MongoDB queries
- **Open-source**: BSD license
- **Managed service**: discontinued

History:

- 2011: Parse is founded
- 2013: Parse is acquired by Facebook
- 2015: more than 500,000 mobile apps reported on Parse
- 2016, January: Parse shutdown is announced
- 2016, March: **Live Queries** are announced
- 2017: Parse shutdown is finalized

Parse

LiveQuery Architecture

- **LiveQuery Server**: no data, real-time query matching
- *Every* LiveQuery Server receives *all* database writes
  → does not scale

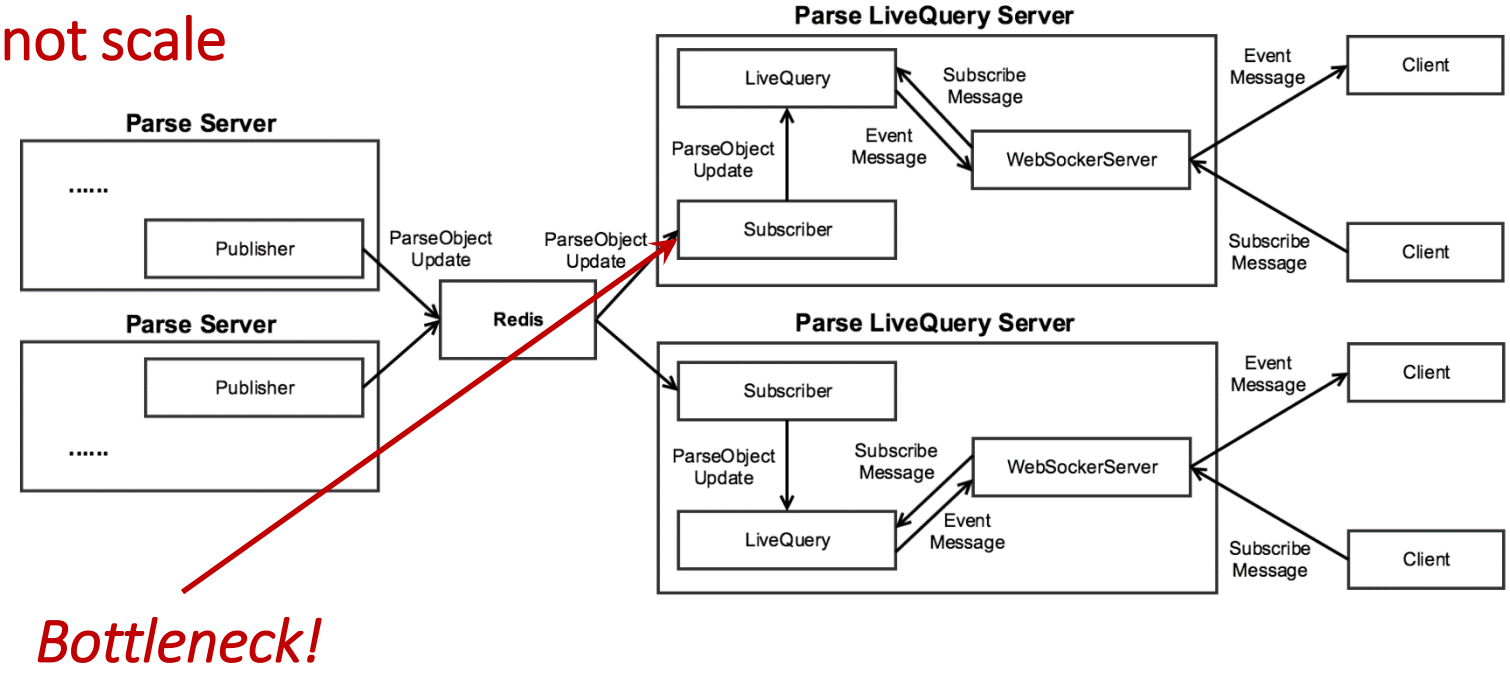


Illustration taken from:
http://parseplatform.github.io/docs/parse-server/guide/#live-queries (2017-02-22)

Firebase

Overview:

- **Real-time state synchronization** across devices
- **Simplistic data model:** nested hierarchy of lists and objects
- **Simplistic queries**: mostly navigation/filtering
- **Fully managed**, proprietary
- **App SDK** for App development, mobile-first
- **Google services integration**: analytics, hosting, authorization, …

History:

- 2011: chat service startup Envolve is founded
  → was often used for cross-device state synchronization
  → state synchronization is separated (Firebase)
- 2012: Firebase is founded
- 2013: Firebase is acquired by Google

Firebase

Real-Time State Synchronization

- **Tree data model**: application state ~JSON object
- **Subtree synching**: push notifications for specific keys only
  → Flat structure for fine granularity

→ *Limited expressiveness!*

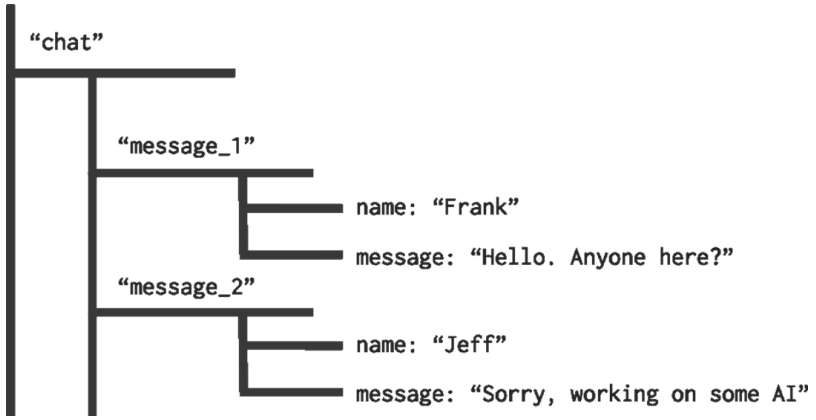
Illustration taken from: Frank van Puffelen, *Have you met the Realtime Database? (2016)* https://firebase.googleblog.com/2016/07/have-you-met-realtime-database.html (2017-02-27)

Firebase

Query Processing in the Client

- Push notifications for **specific keys** only
  - Order by a **single attribute**
  - Apply a **single filter** on that attribute

- Non-trivial query processing in client
  → does not scale!

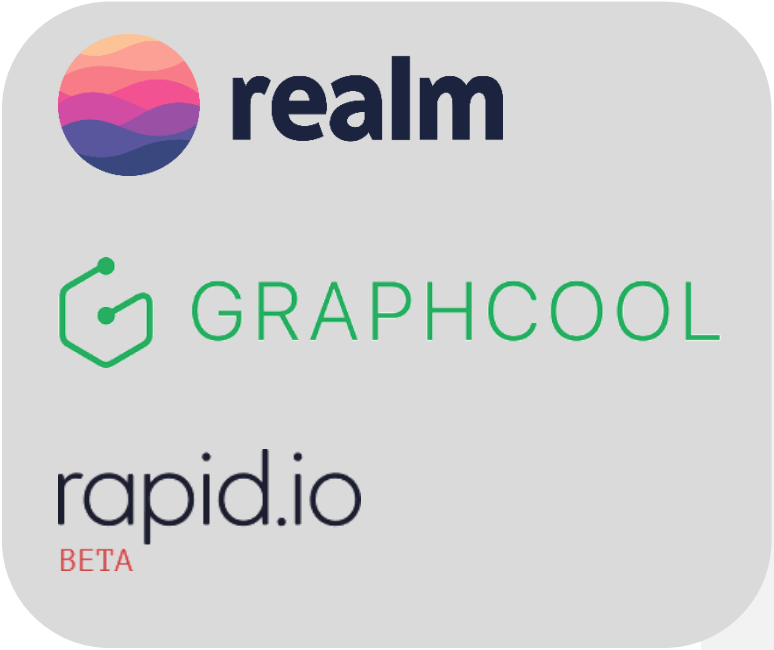


Jacob Wenger, on the Firebase Google Group *(2015)*
https://groups.google.com/forum/#!topic/firebase-talk/d-XjaBVL2Ko (2017-02-27)

Illustration taken from: Frank van Puffelen, *Have you met the Realtime Database? (2016)*
https://firebase.googleblog.com/2016/07/have-you-met-realtime-database.html (2017-02-27)

Honorable Mentions

Other Systems With Real-Time Features



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Push-Based Data Access
Why Real-Time Databases?

Real-Time Databases
System survey

Discussion
What are the bottlenecks?

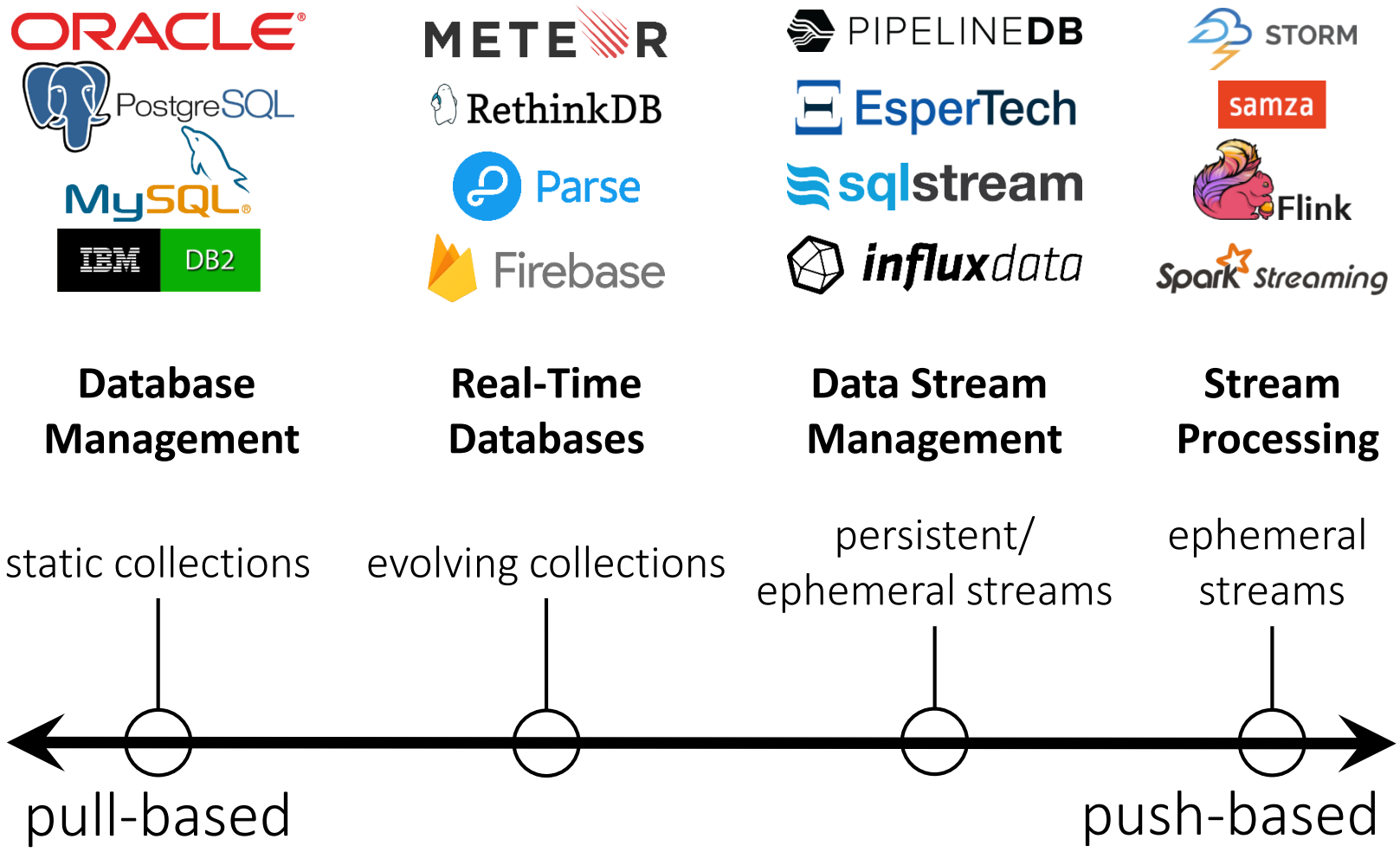
Baqend Real-Time Queries
How do they scale?

- System classification:
  - Databases
  - Real-time databases
  - Stream management
  - Stream processing
- Side-by-side comparison

Discussion

Quick Comparison

DBMS vs. RT DB vs. DSMS vs. Stream Processing



Wrap-Up

Direct Comparison

	Meteor		RethinkDB	Parse	Firebase	Baqend
	Poll-and-Diff	Oplog Tailing				
Scales with write TP	✓	✗	✗	✗	?	✓
Scales with no. of queries	✗	✓	✓	✓		✓
Composite queries (`AND`/`OR`)	✓	✓	✓	✓	✗	✓
Sorted queries	✓	✓	✓	✗	○ (single attribute)	✓
Limit	✓	✓	✓	✗	✓	✓
Offset	✓	✓	✗	✗	✓	✓

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What are the bottlenecks?

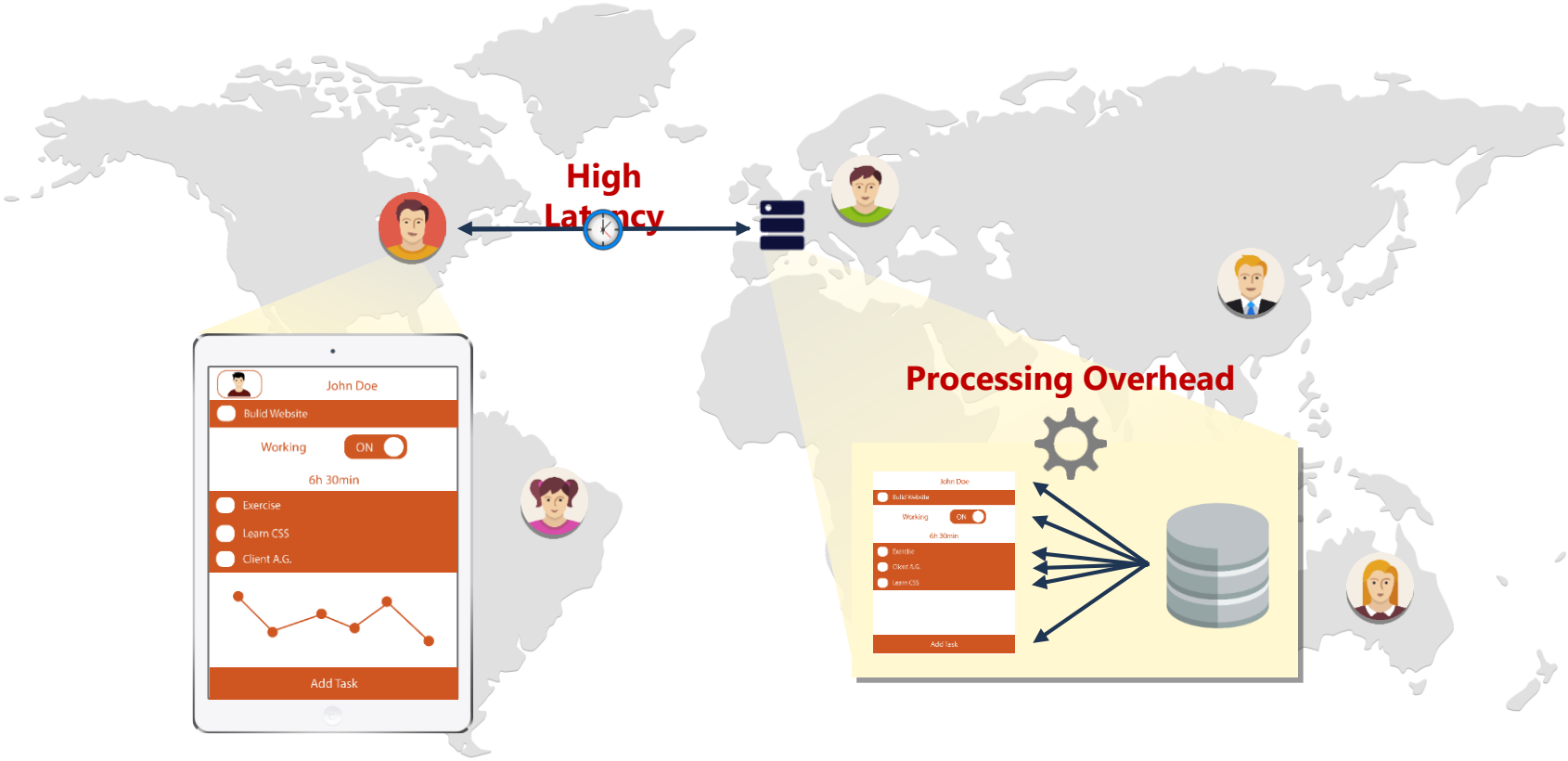
Baqend Real-Time Queries
How do they scale?

- InvaliDB: opt-in real-time queries
- System architecture
- Query expressiveness
- Performance & scalability
- Example app: Twoogle

Baqend Real-Time Queries

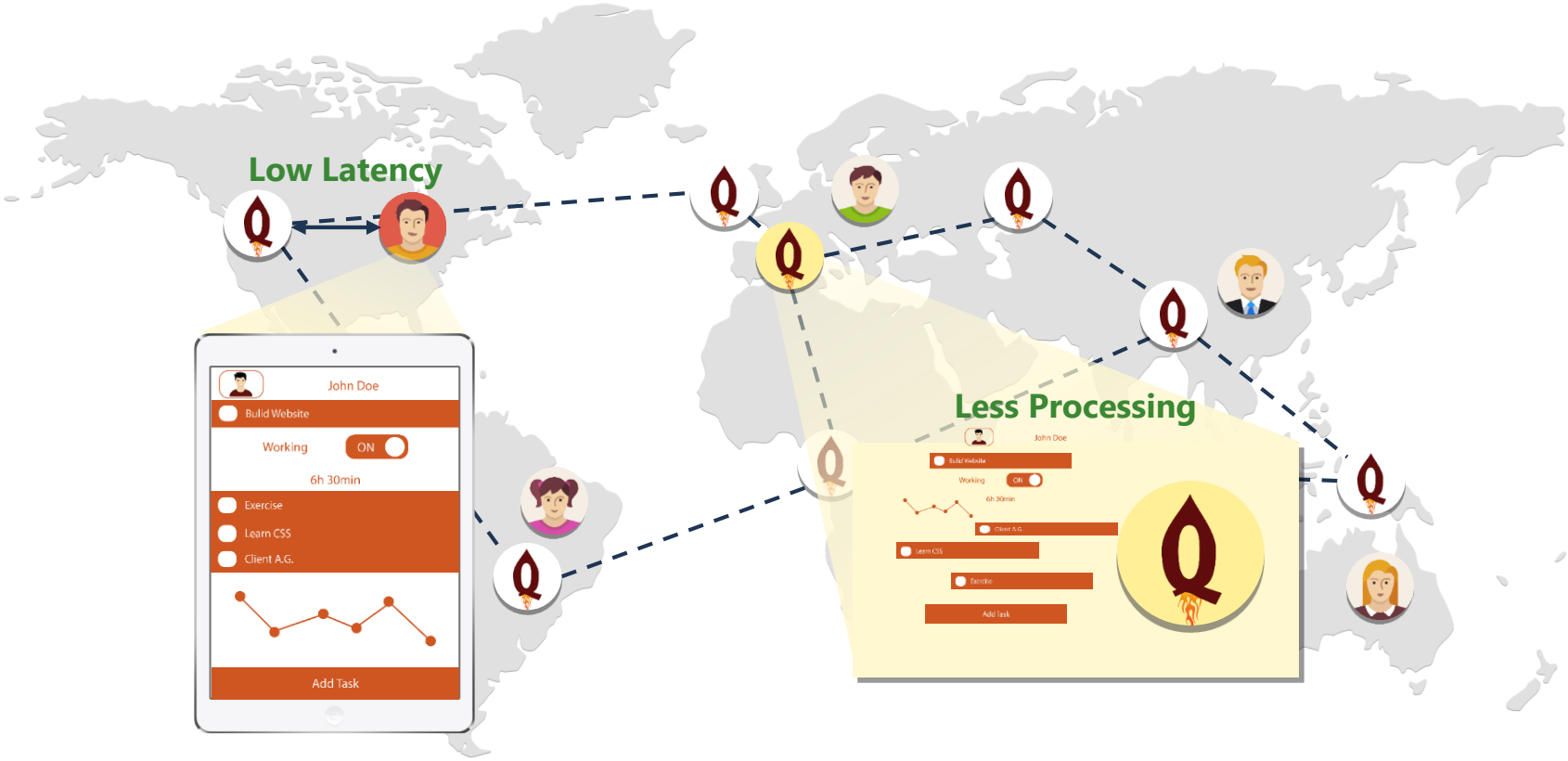
Problem: Slow Websites

Two Bottlenecks: Latency and Processing



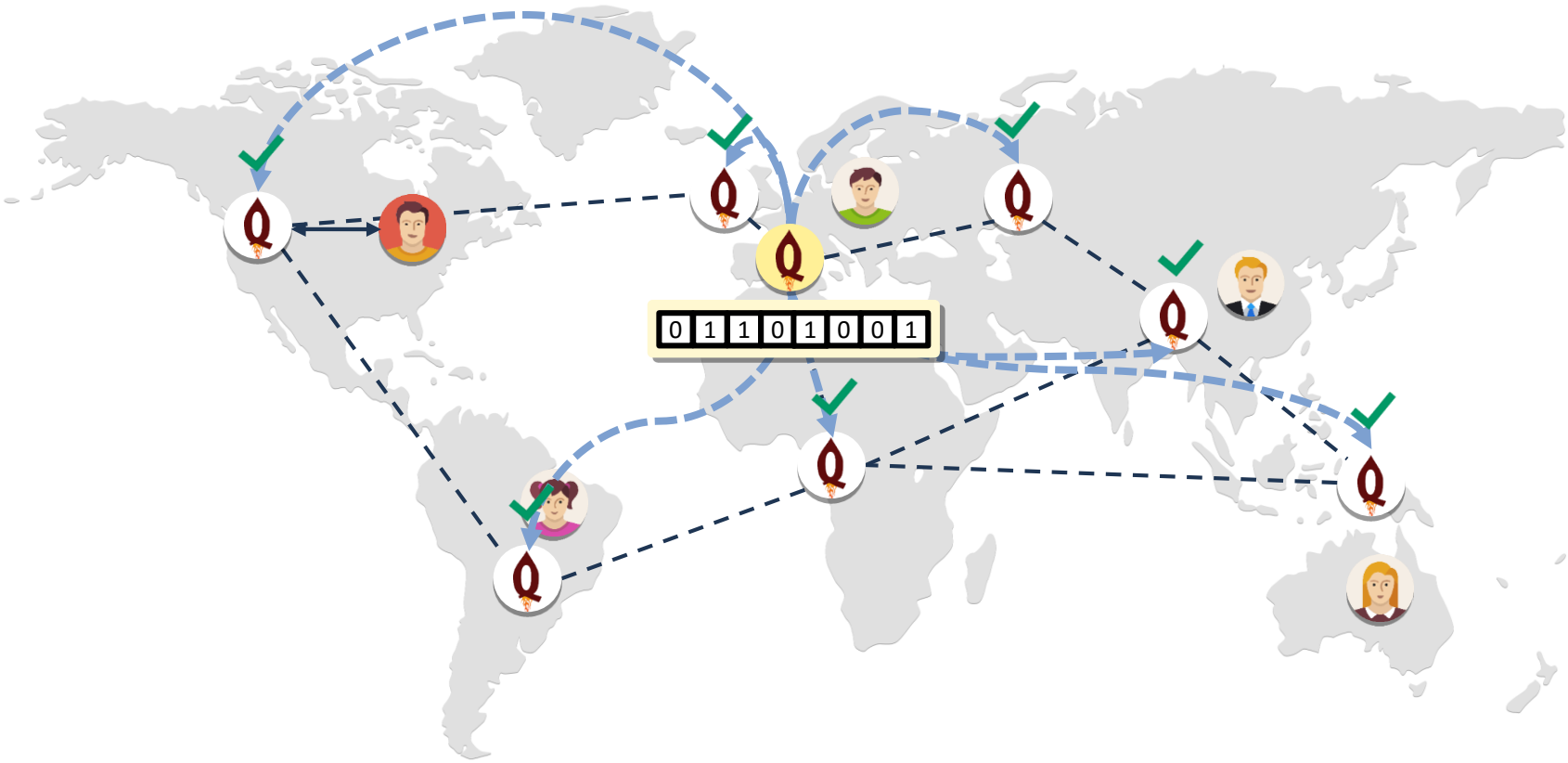
Solution: Global Caching

Fresh Data From Distributed Web Caches



New Caching Algorithms

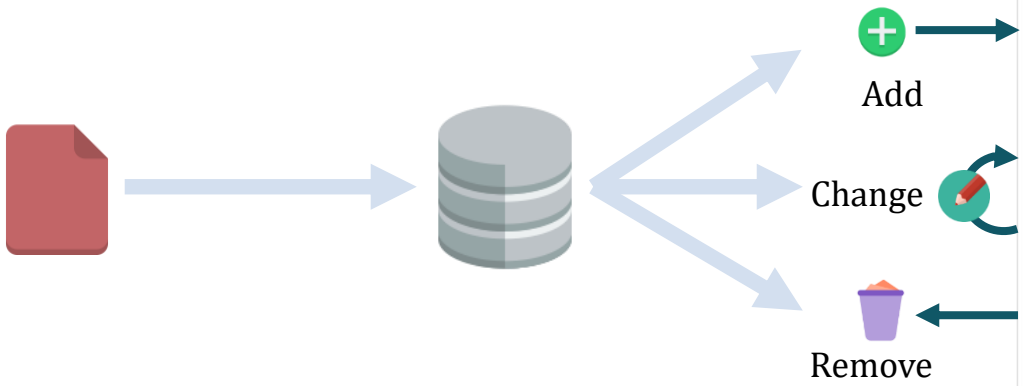
Solve Consistency Problem

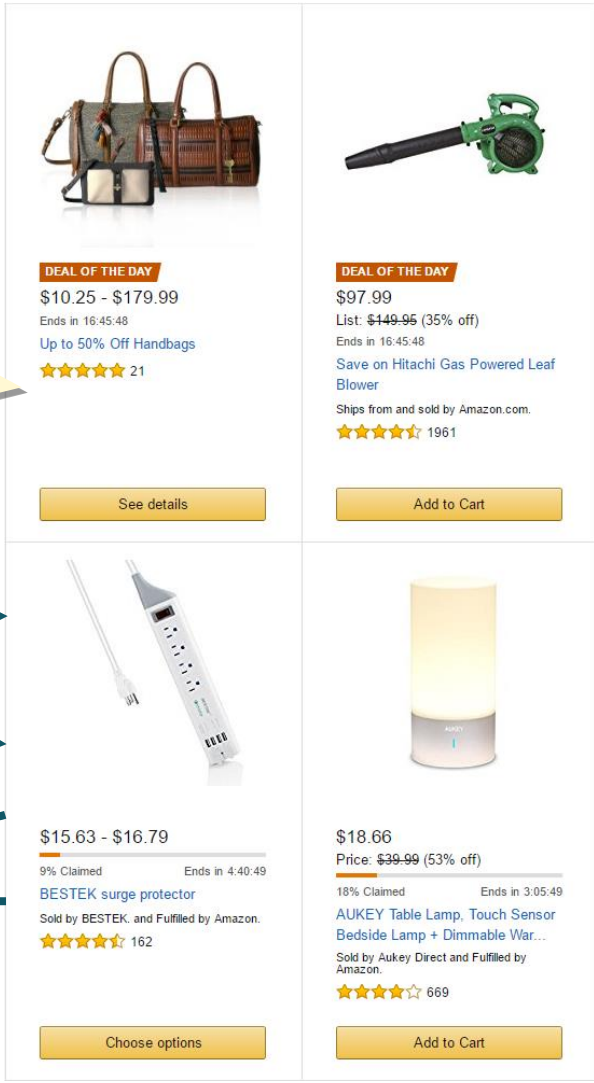


InvaliDB

Invalidating DB Queries

How to **detect changes to query results**:
„Give me the most popular products that are in stock.“





InvaliDB

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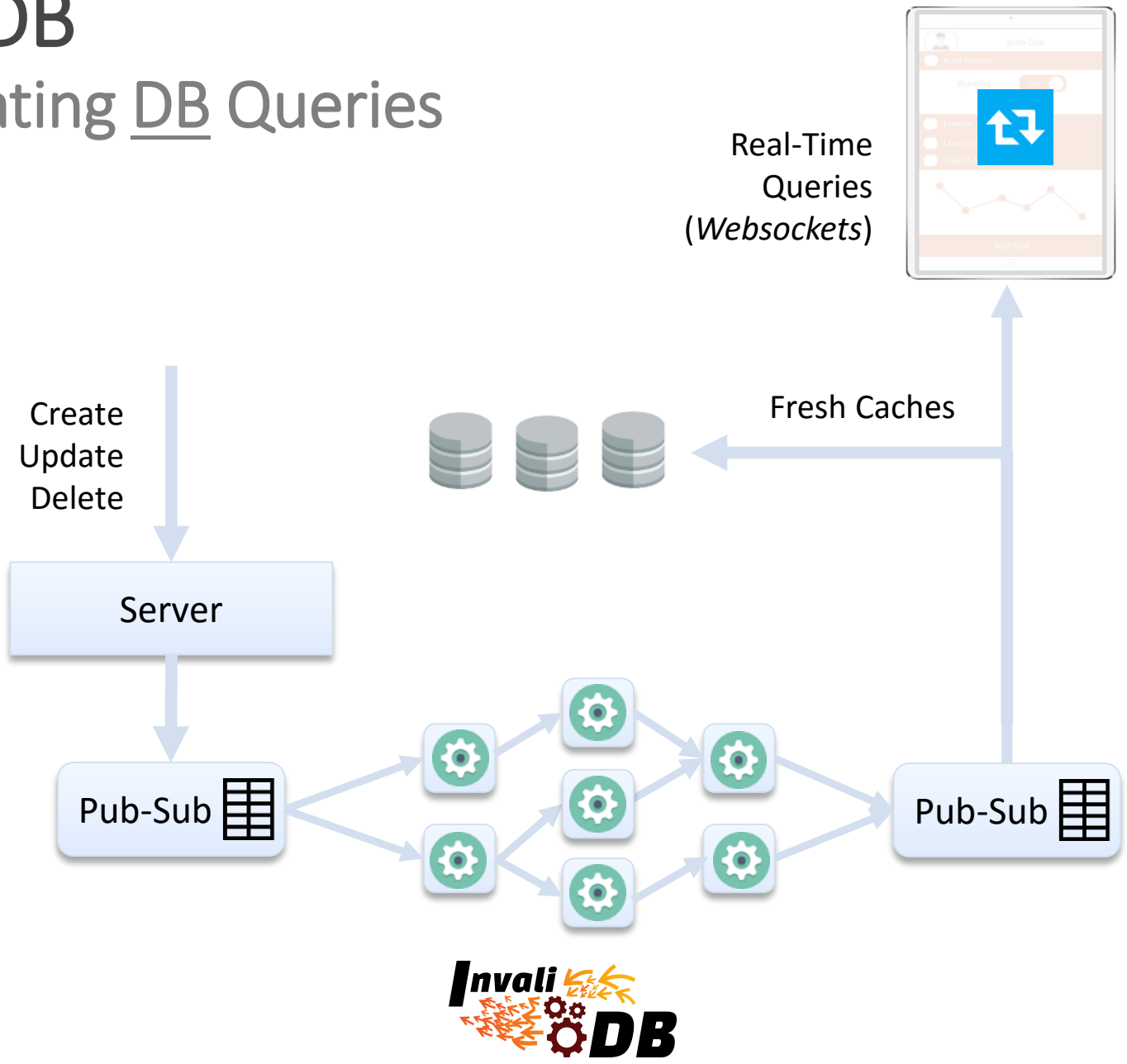
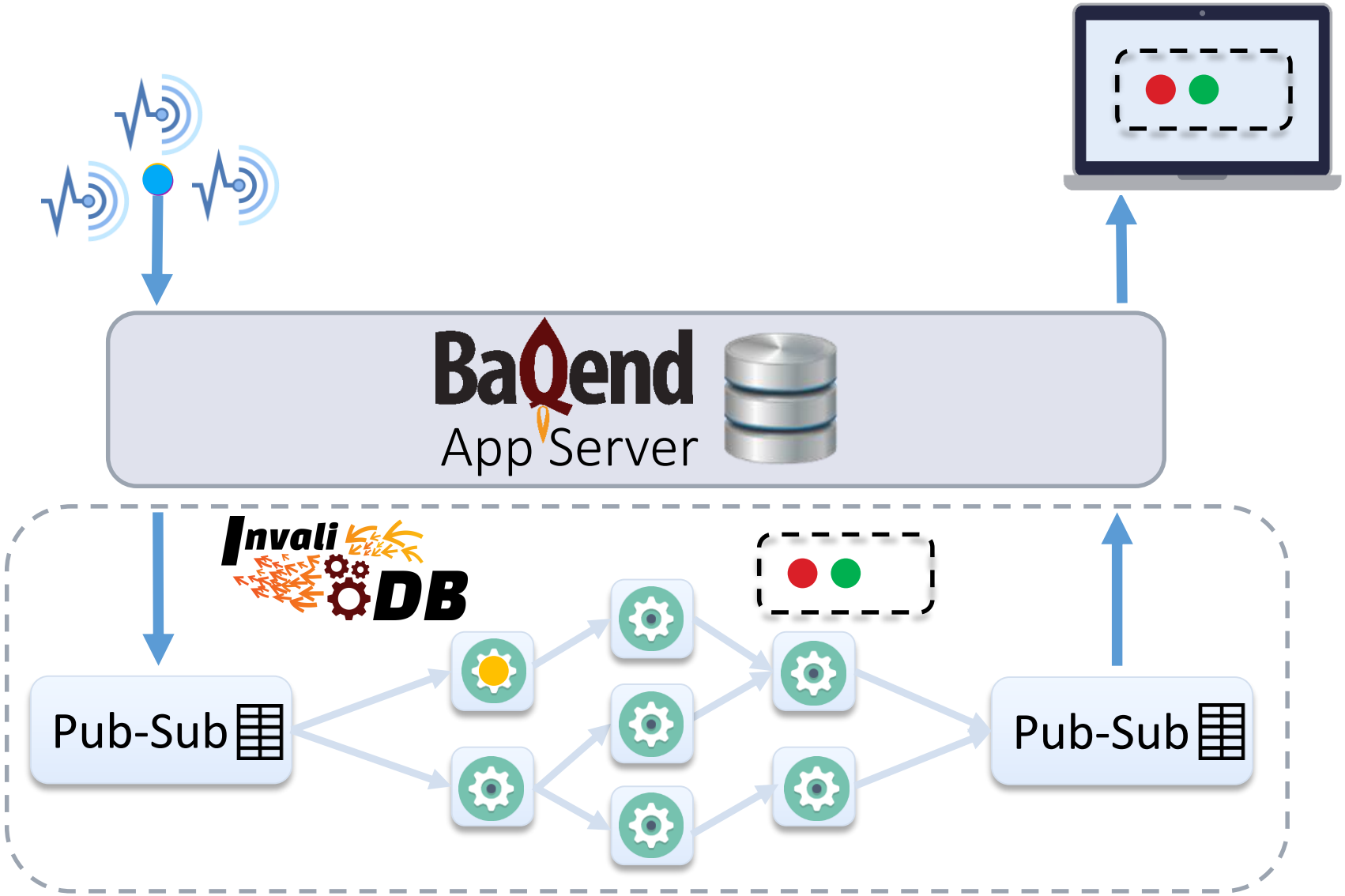


Baqend Real-Time Queries

Real-Time Decoupled

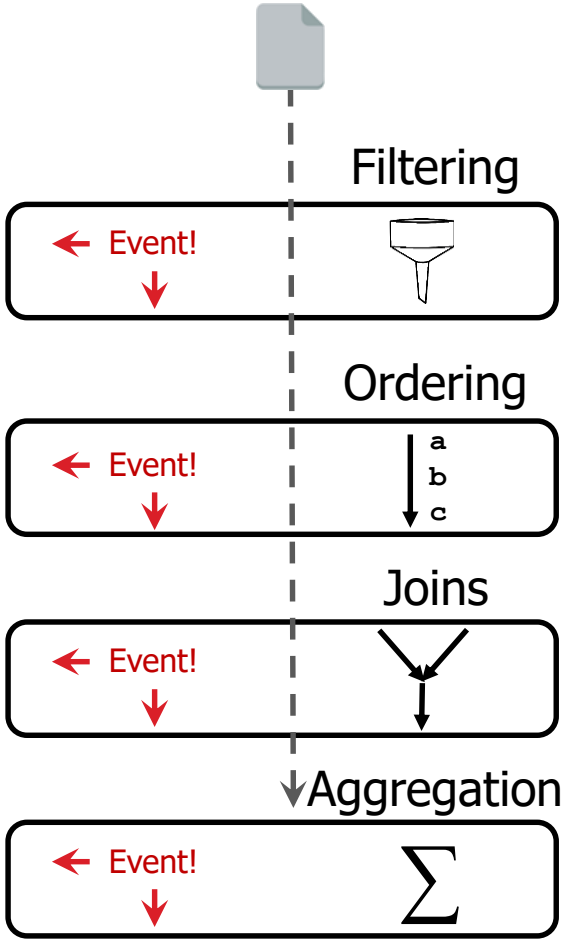


Baqend Real-Time Queries

Staged Real-Time Query Processing

Change notifications go through up to 4 query processing stages:

1. **Filter queries**: track matching status
   → *before*- and after-images
2. **Sorted queries**: maintain result order
3. **Joins**: combine maintained results
4. **Aggregations**: maintain aggregations



Baqend Real-Time Queries

Filter Queries: Distributed Query Matching

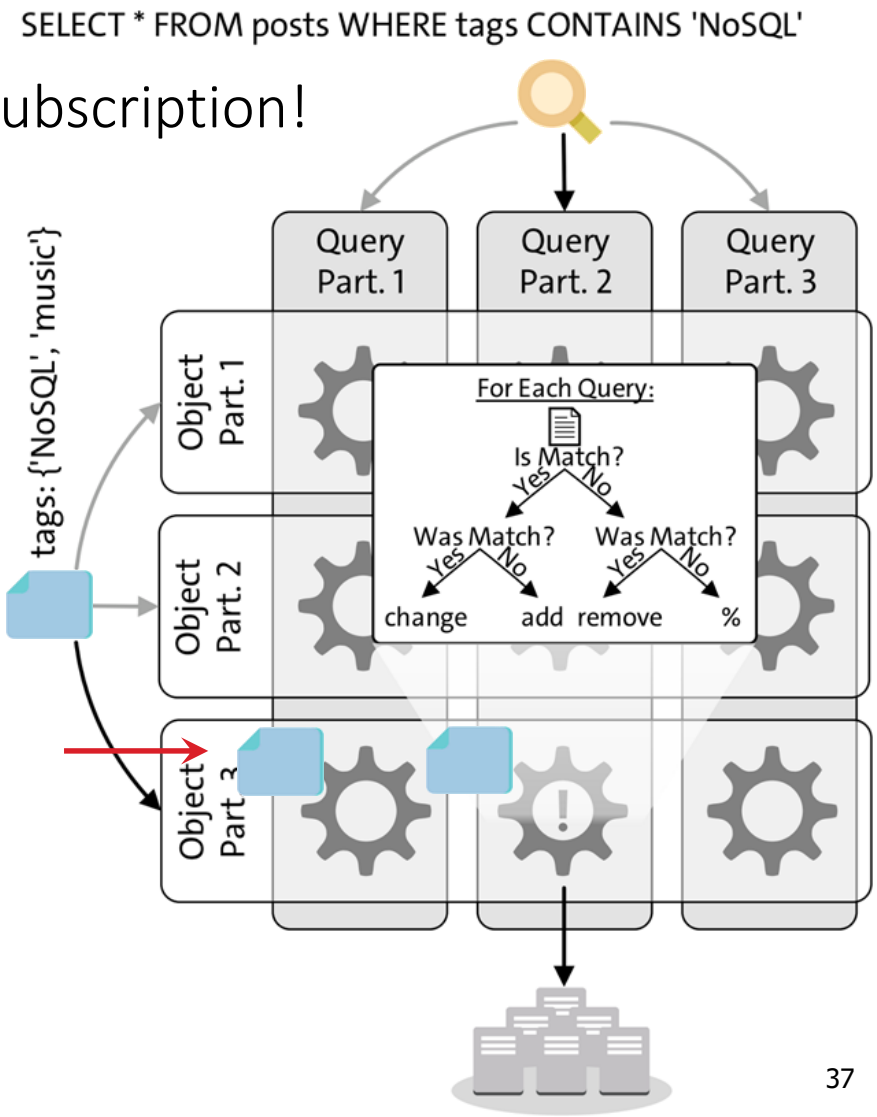
Two-dimensional partitioning:

- *by Query*
- *by Object*

→ scales with queries and writes

Implementation:

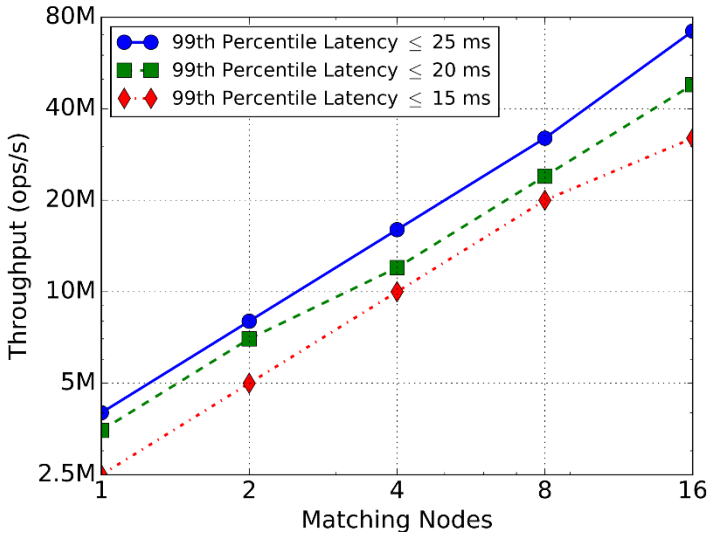
- Apache Storm
- Topology in Java
- MongoDB query language
- **Pluggable query engine**



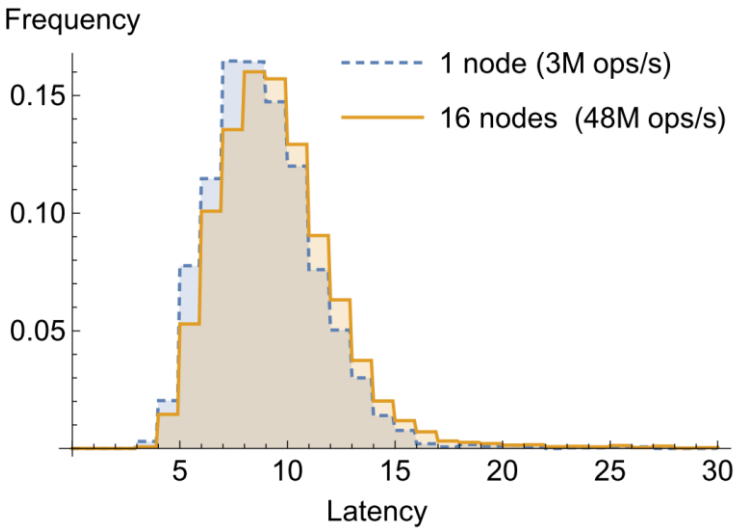
Baqend Real-Time Queries

Low Latency + Linear Scalability

Linear Scalability



Stable Latency Distribution



Quaestor: Query Web Caching for Database-as-a-Service Providers
VLDB '17

Programming Real-Time Queries

JavaScript API

```
var query = DB.Tweet.find()
              .matches('text', /my filter/)
              .descending('createdAt')
              .offset(20)
              .limit(10);
```

Static Query

```
query.resultList(result => ...);
```

Google

Real-Time Query

```
query.resultStream(result => ...);
```

Twoogle

Twoogle

Filter word, e.g. "http", "Java", "Baqend"

Real-Time Static

Last result update at 15:51:21 (less than a second ago)

1. Conju.re (conju_re, 3840 followers) tweeted:
https://twitter.com/conju_re/status/859767327570702336

Congress Saved the Science Budget—And That's the Problem https://t.co/UdrjNidakc https://t.co/xlNjpEpKZG

2. ねぼすけゆーだい (Yuuu___key, 229 followers) tweeted:
https://twitter.com/Yuuu___key/status/859767323384623104

けいきさんと PENGUIN　RESEARCHのけいたくん がリプのやり取りしてる…

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holy..... waiting for it so long💋 ☺ https://t.co/UdXcHJb7X3

4. Lisa Schmid (LisaMSchmid, 67 followers) tweeted on #teamscs, and #scs...
https://twitter.com/LisaMSchmid/status/859767317311500290

Congrats to Matthew Kent, winner of the 26th #TeamSCS Coding Challenge. https://t.co/vx1o0WgJrZ #SCSchallenge

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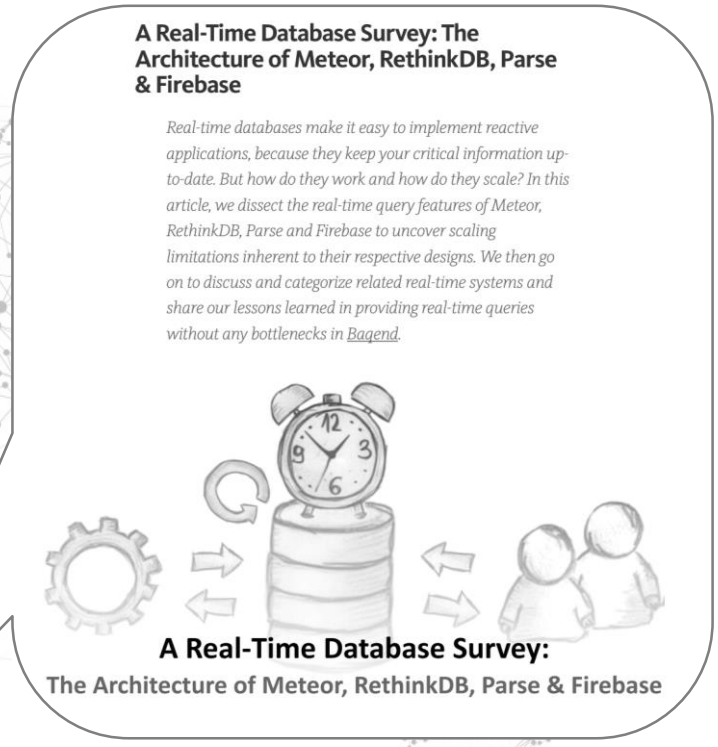
Wrap-up

- **Push-based Data Access**
  - Natural for many applications
  - Hard to implement on top of traditional (pull-based) databases
- **Real-time Databases**
  - Natively push-based
  - Not legacy-compatible
  - Barely scalable
- **Baqend Real-Time Queries**
  - No impact on OLTP workload
  - Linear scalability
  - Low latency
  - Filter, sorting, joins, aggregations

Our Related Publications

Scientific Papers:

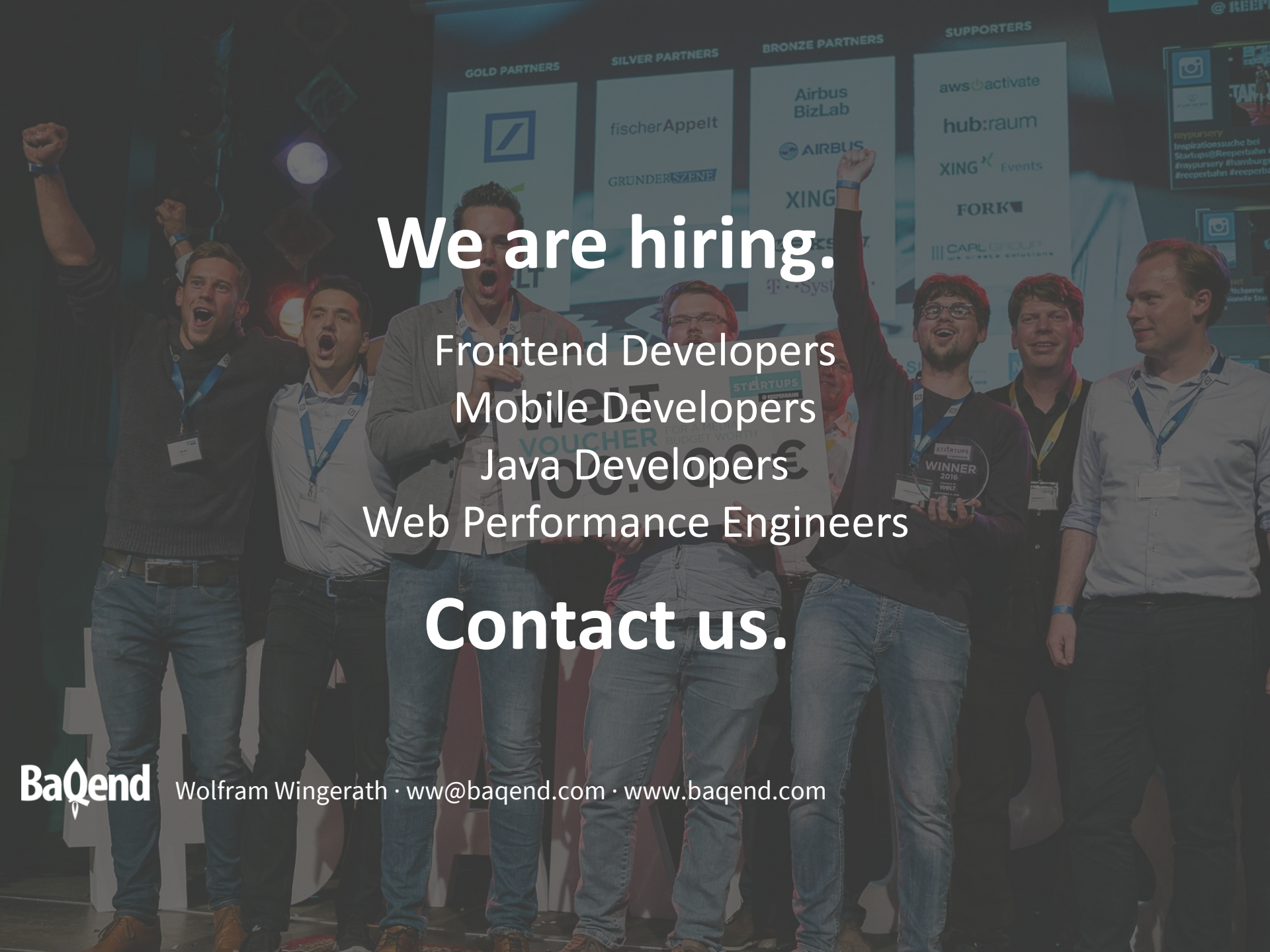
- *Quaestor: Query Web Caching for Database-as-a-Service Providers*
  VLDB ‘17
- *NoSQL Database Systems: A Survey and Decision Guidance*
  SummerSOC ‘16
- *Real-time stream processing for Big Data*
  it - Information Technology 58 (2016)
- *The Case For Change Notifications in Pull-Based Databases*
  BTW ‘17



Blog Posts:

- *Real-Time Databases Explained: Why Meteor, RethinkDB, Parse and Firebase Don't Scale*
  Baqend Tech Blog (2017): https://medium.com/p/822ff87d2f87

Learn more at blog.baqend.com!



We are hiring.

Frontend Developers
Mobile Developers
Java Developers
Web Performance Engineers

Contact us.

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Questions?

Fr. 10:00 Real-Time Anwendungen mit React und React Native entwickeln

Fr. 14:00 AMP, PWAs, HTTP/2 and Service Workers: A new Era of Web Performance?

Fr. 17:00 Wie man ein Backend-as-a-Service entwickelt: Lessons Learned

Wolfram Wingerath wingerath@informatik.uni-hamburg.de