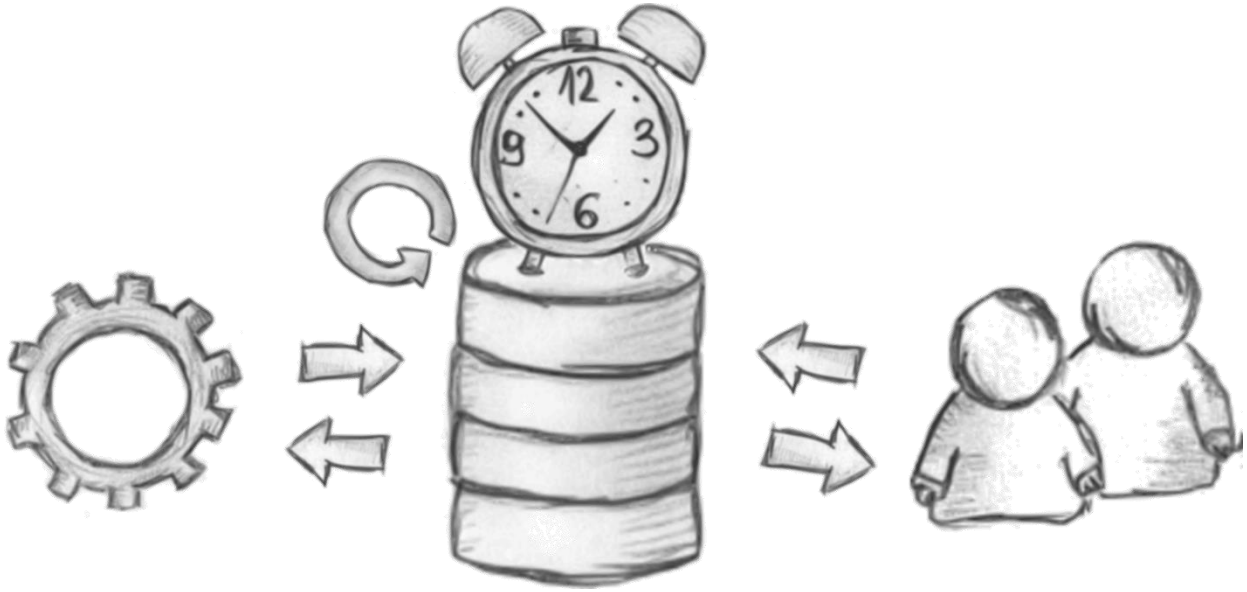
Real-Time Databases Explained

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



Wolfram Wingerath
ww@baqend.com
October 26, 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

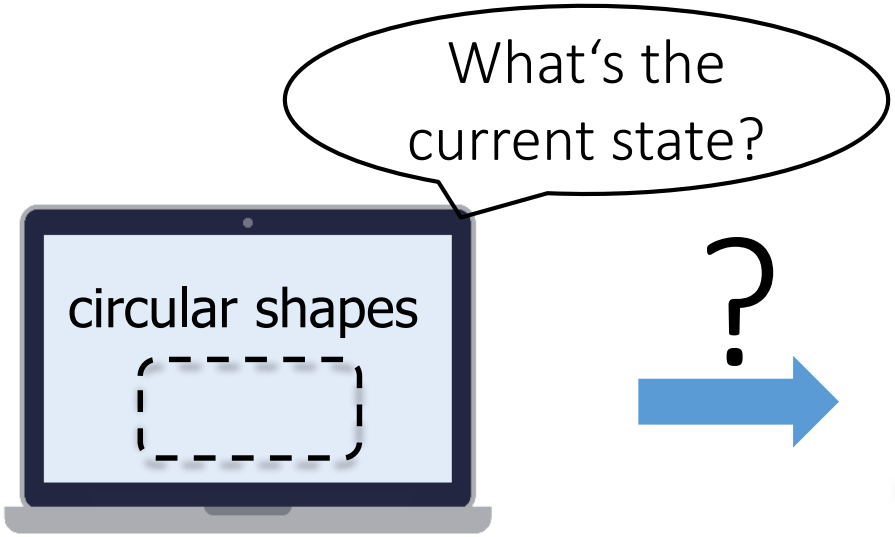
Discussion
What are the bottlenecks?

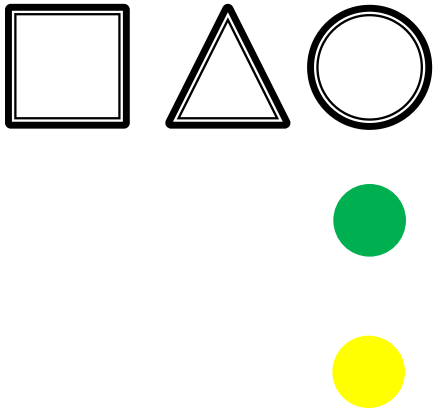
Baqend Real-Time Queries
How do they scale?

Push-Based Data Access

Traditional Databases

No Request? No Data!





Query maintenance: periodic polling

→ Inefficient

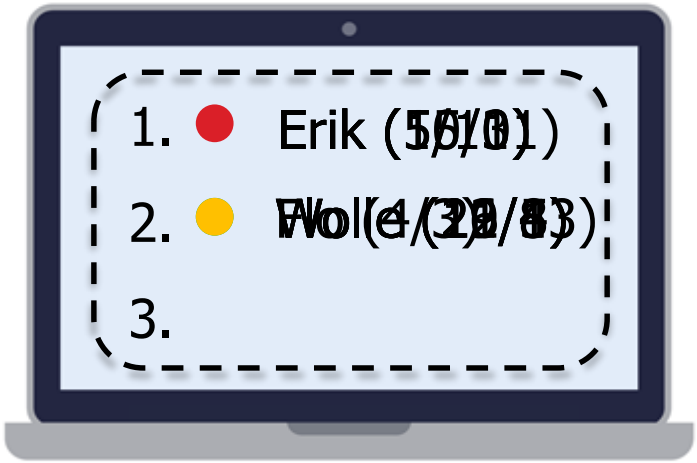
→ Slow

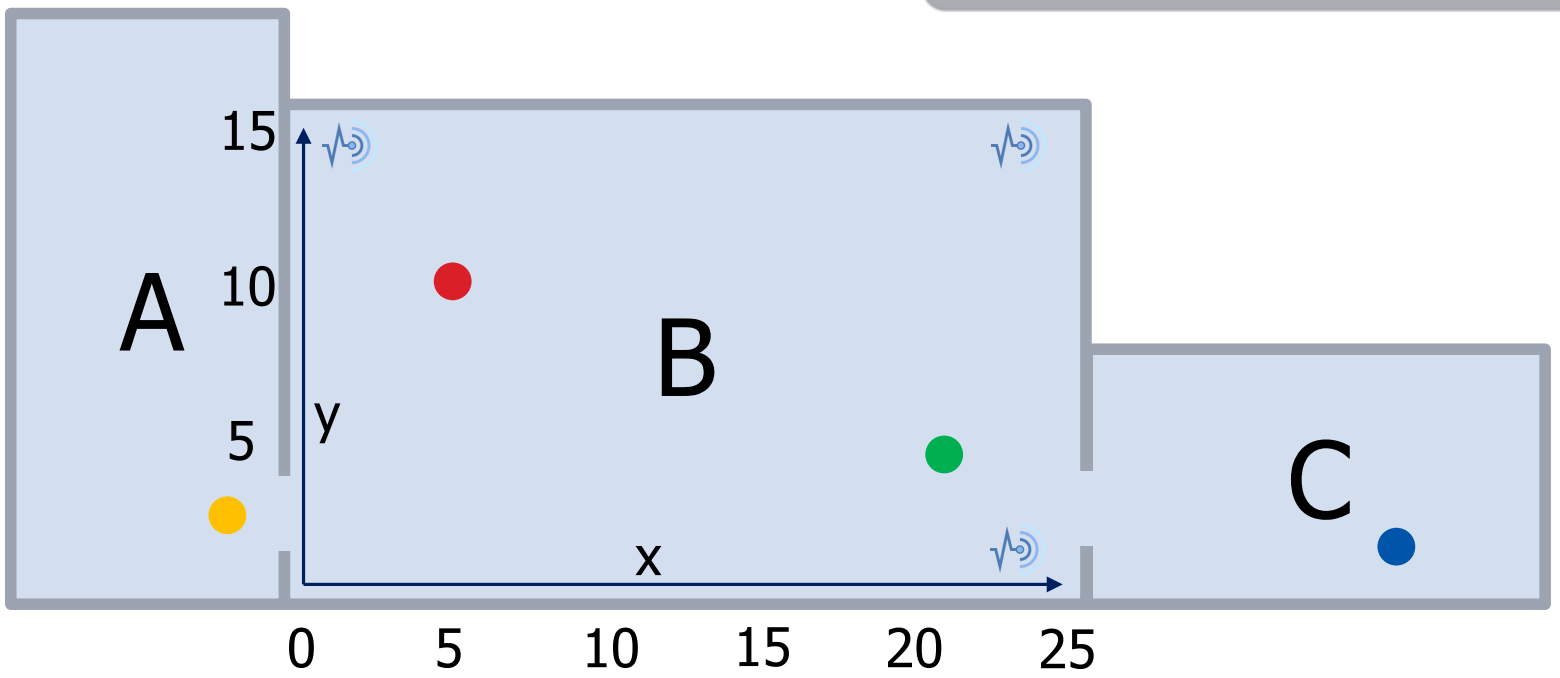
Ideal: Push-Based Data Access

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:

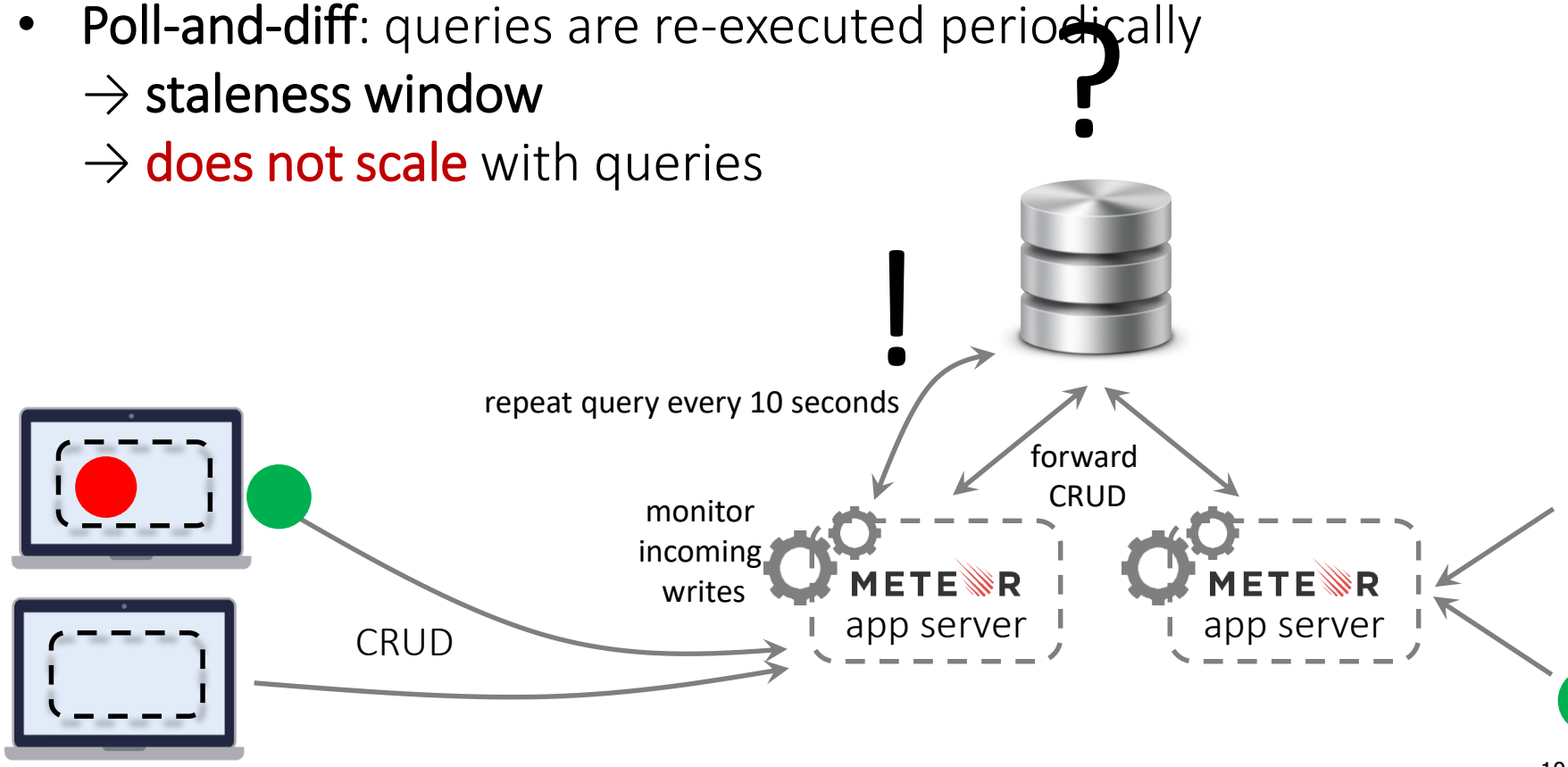
- **JavaScript Framework** for interactive apps and websites
  - **MongoDB** under the hood
  - **Real-time** result updates, full MongoDB expressiveness
- **Open-source**: MIT license
- **Managed service**: Galaxy (Platform-as-a-Service)

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

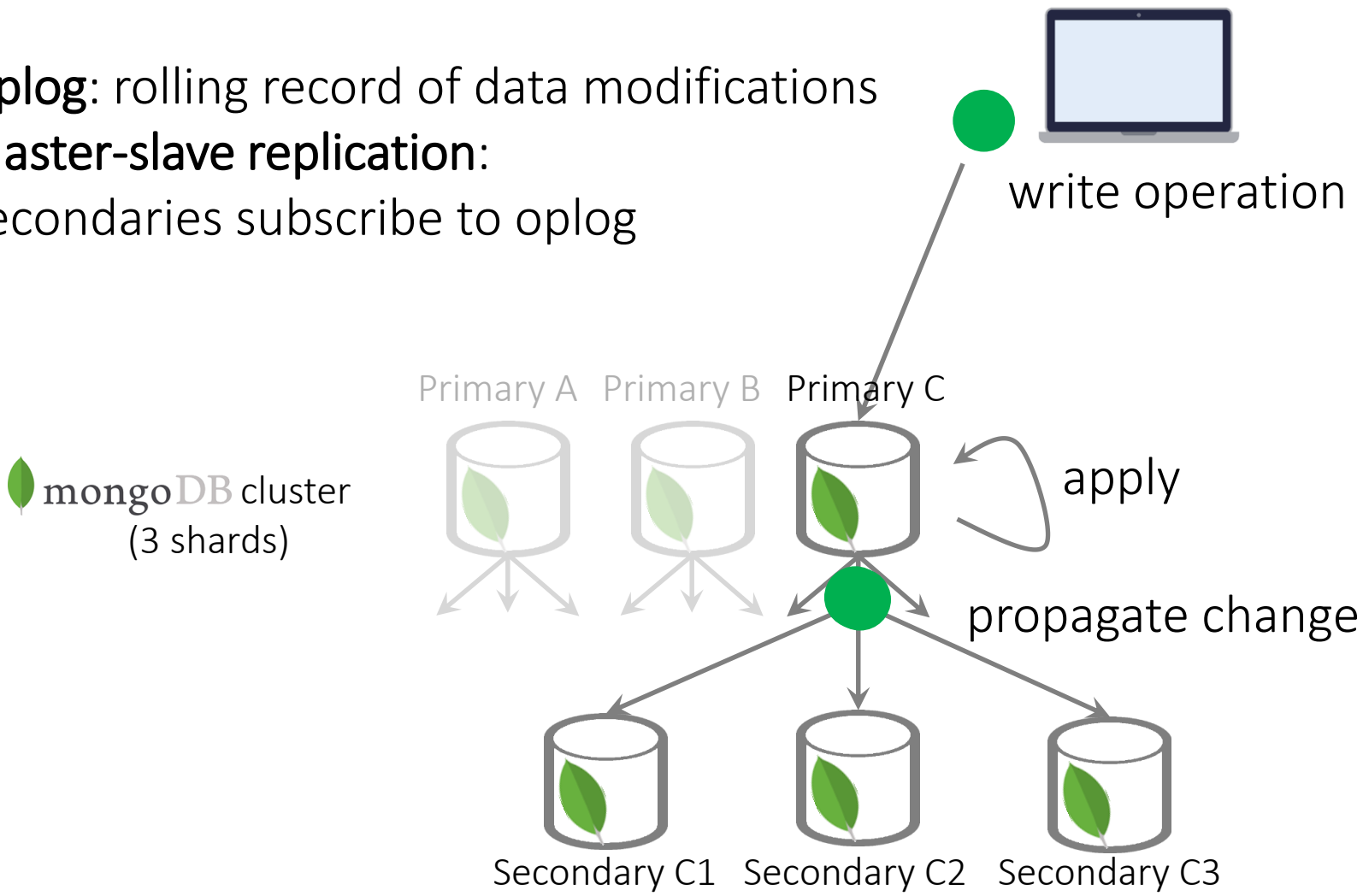


Oplog Tailing

Basics: MongoDB Replication

METEOR

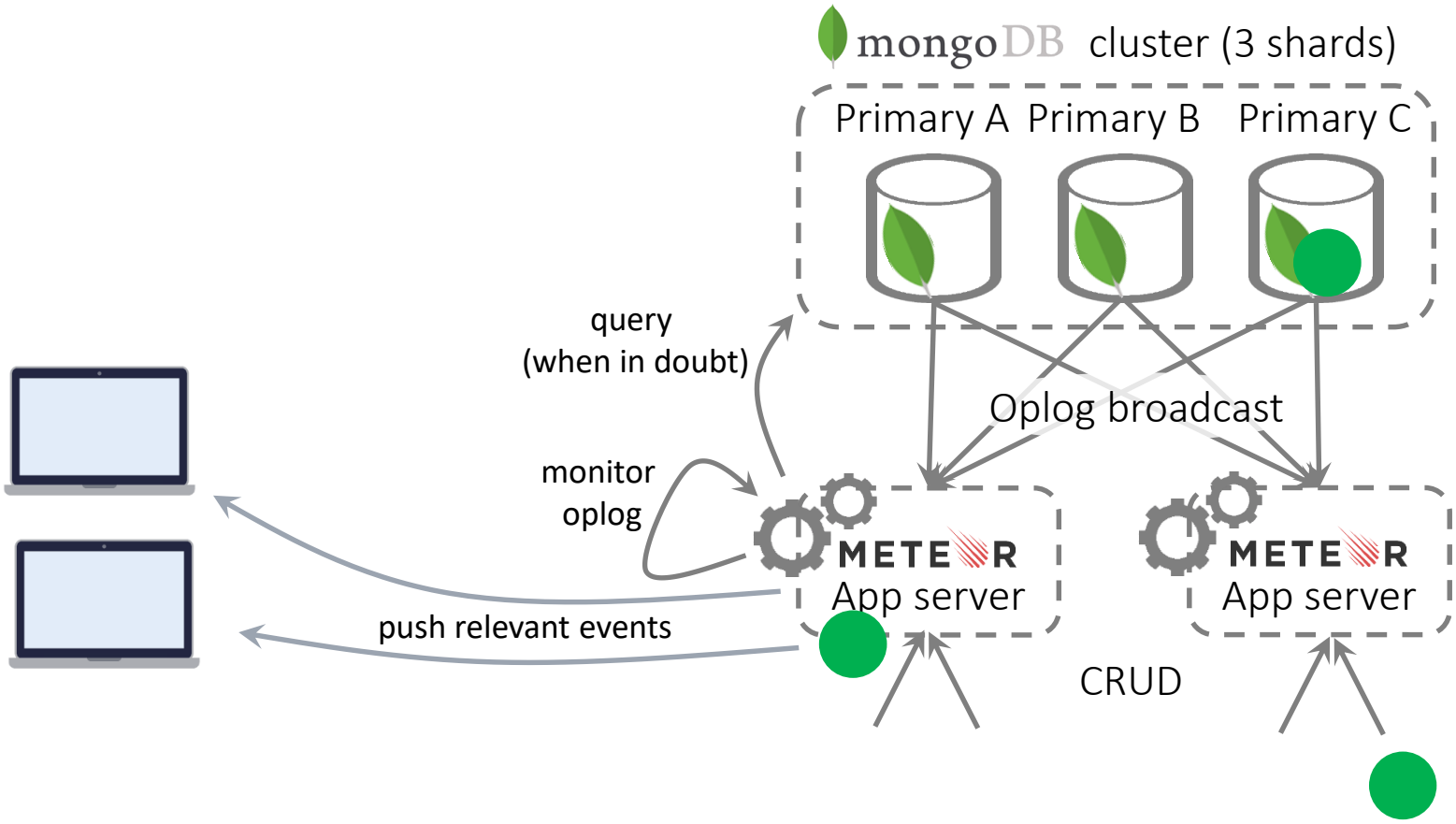
- **Oplog**: rolling record of data modifications
- **Master-slave replication**:
  Secondaries subscribe to oplog



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

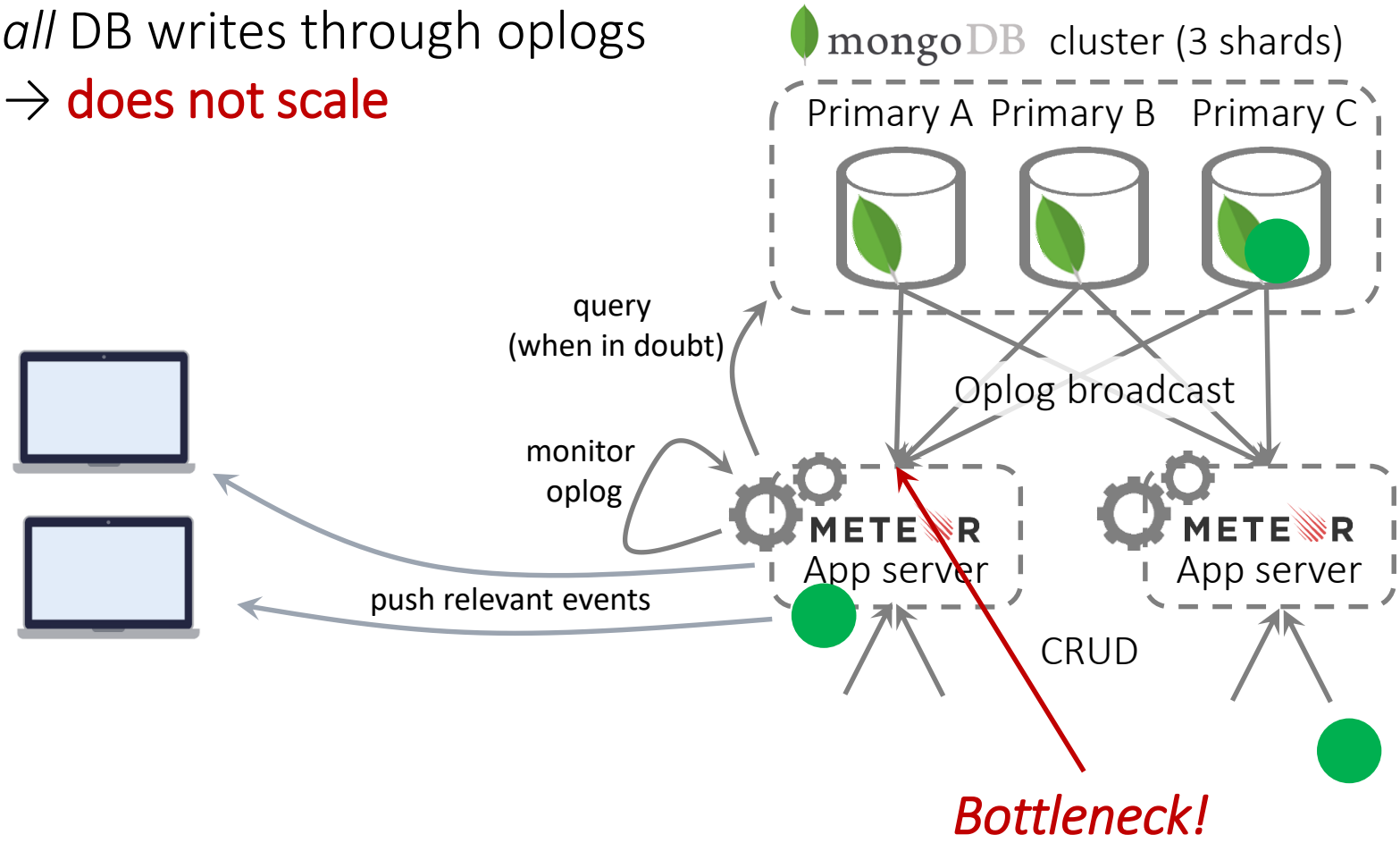
METEOR

```
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

- *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:

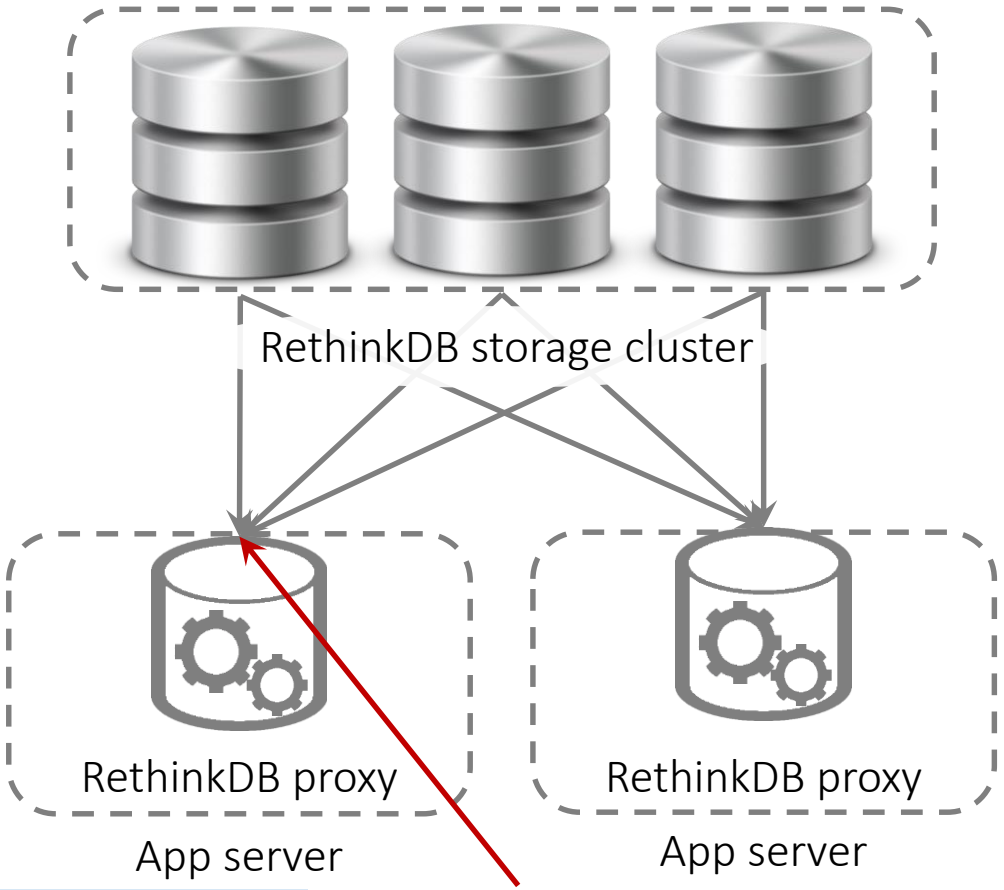
- 2009: RethinkDB is founded
- 2012: RethinkDB is open-sourced under AGPL
- 2016, May: first official release of Horizon (JavaScript SDK)
- 2016, October: RethinkDB announces shutdown
- 2017: RethinkDB is relicensed under Apache 2.0

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

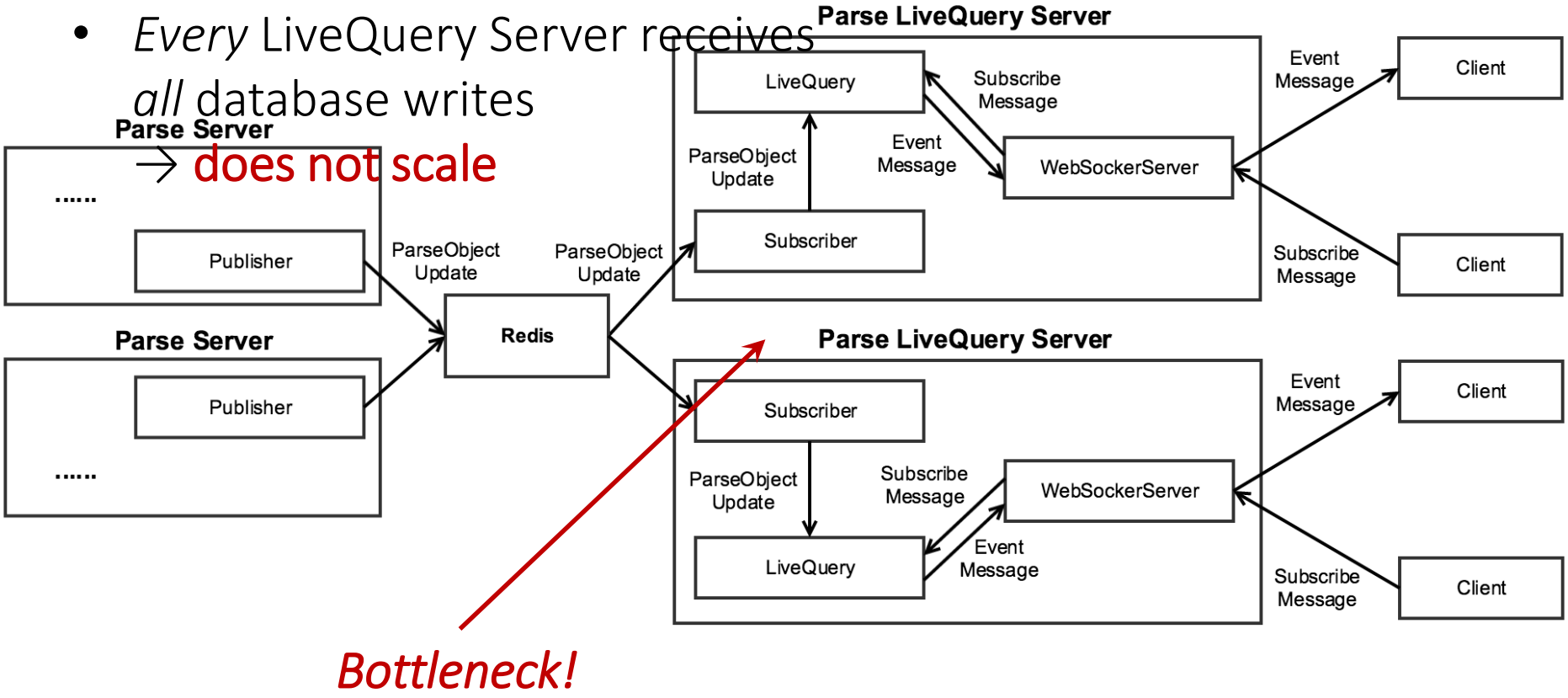


Illustration taken from:
http://parseplatform.github.io/docs/parse-server/guide/#live-queries (2017-02-22)

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

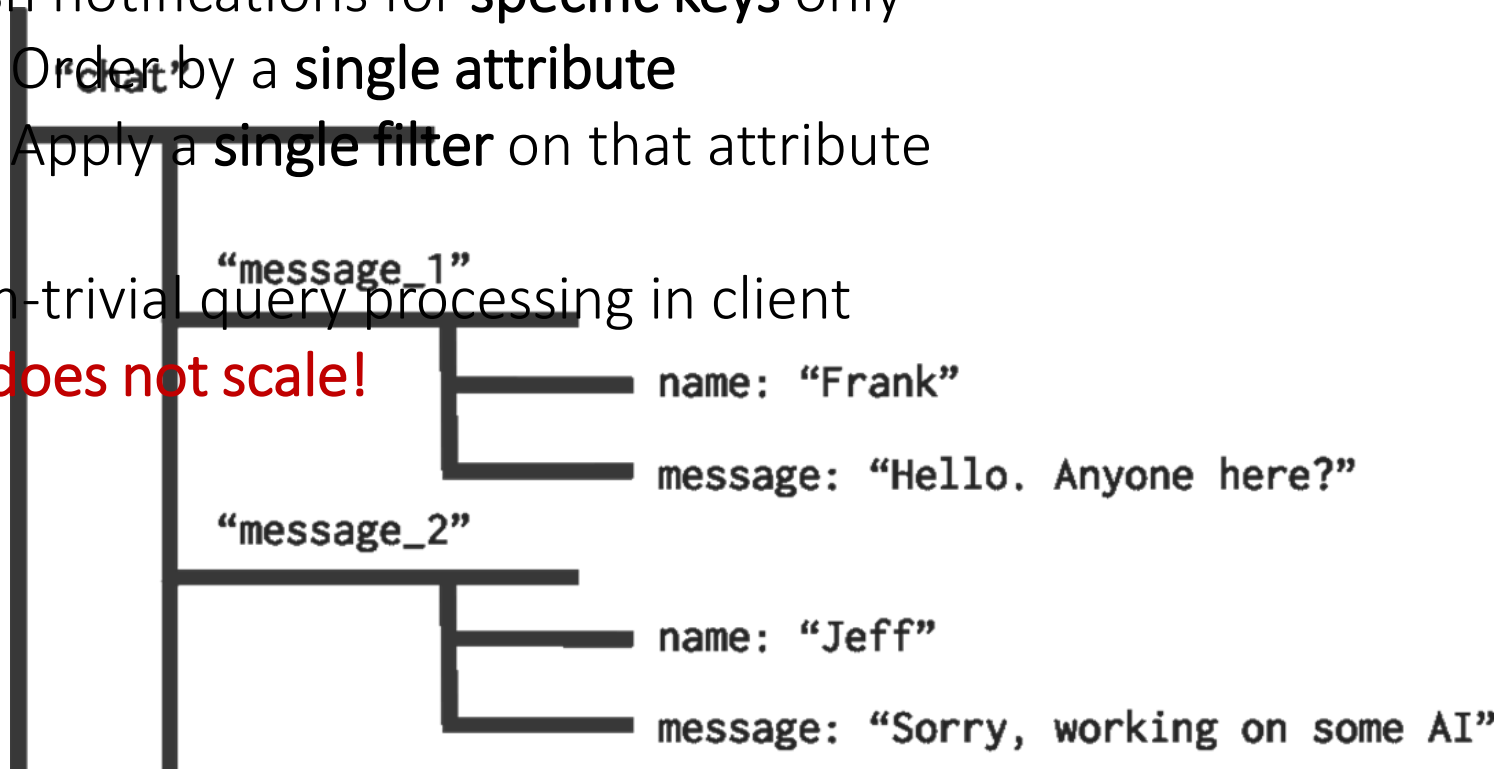
→ *Limited expressiveness!*

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!

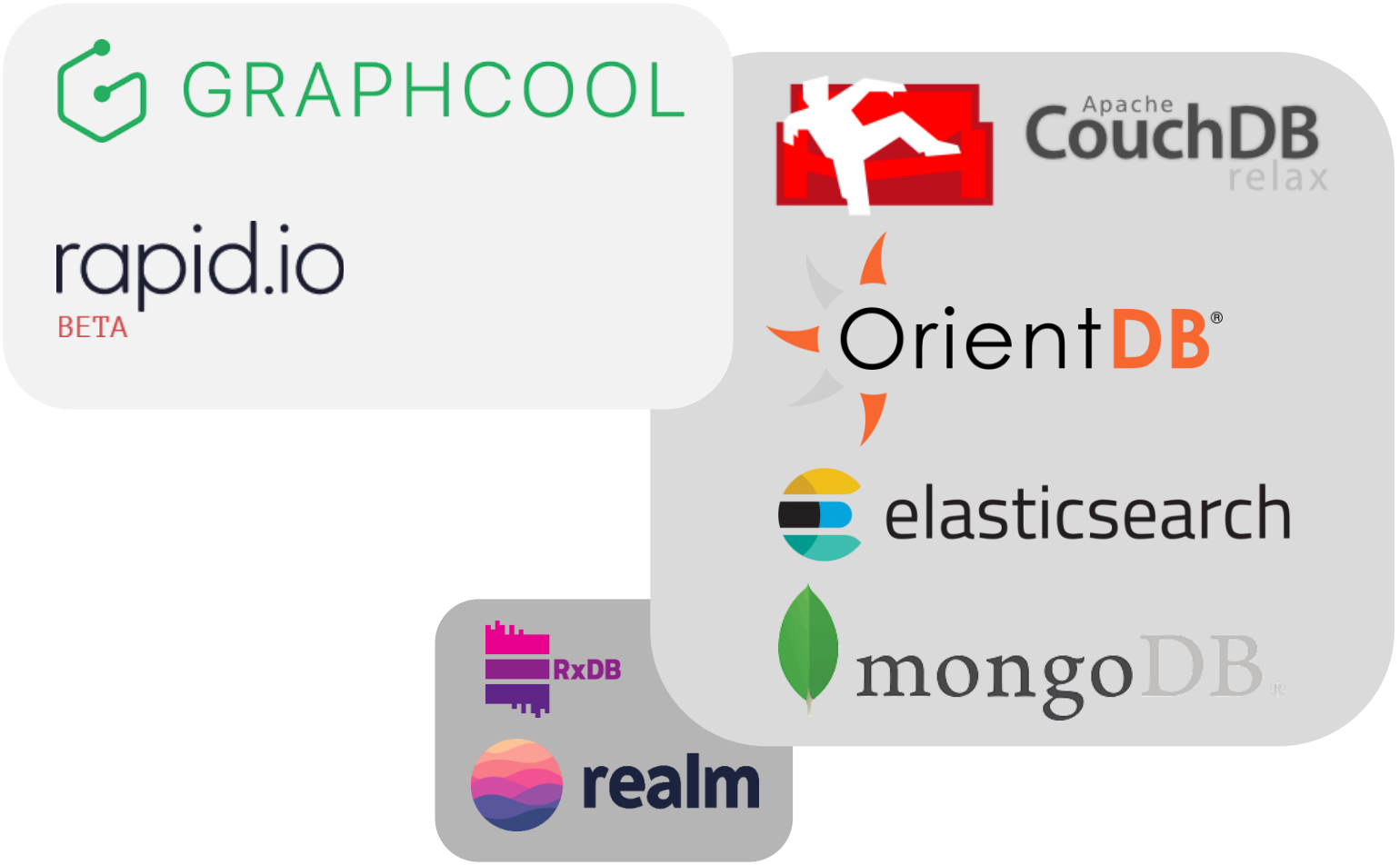


Jacob Wenger, on the Firebase Google Group *(2015)*
https://groups.google.com/forum/#!topic/firebase-talk/d-XjaBVL2Ko (2017-02-27)

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



Outline

Push-Based Data Access
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Real-Time Databases
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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

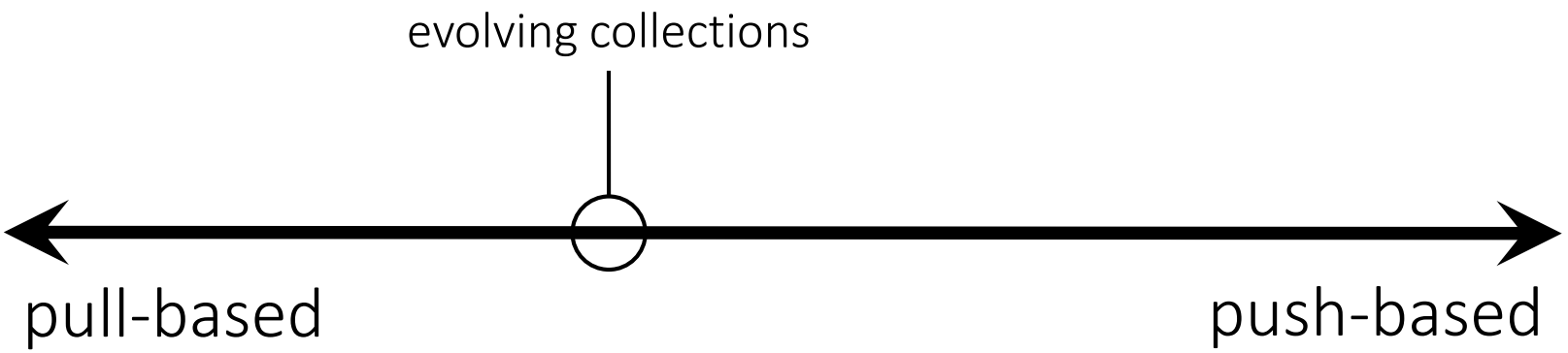
METEOR

RethinkDB

Parse

Firebase

Real-Time Databases



Wrap-Up

Direct Comparison

	Meteor		RethinkDB	Parse	Firebase
	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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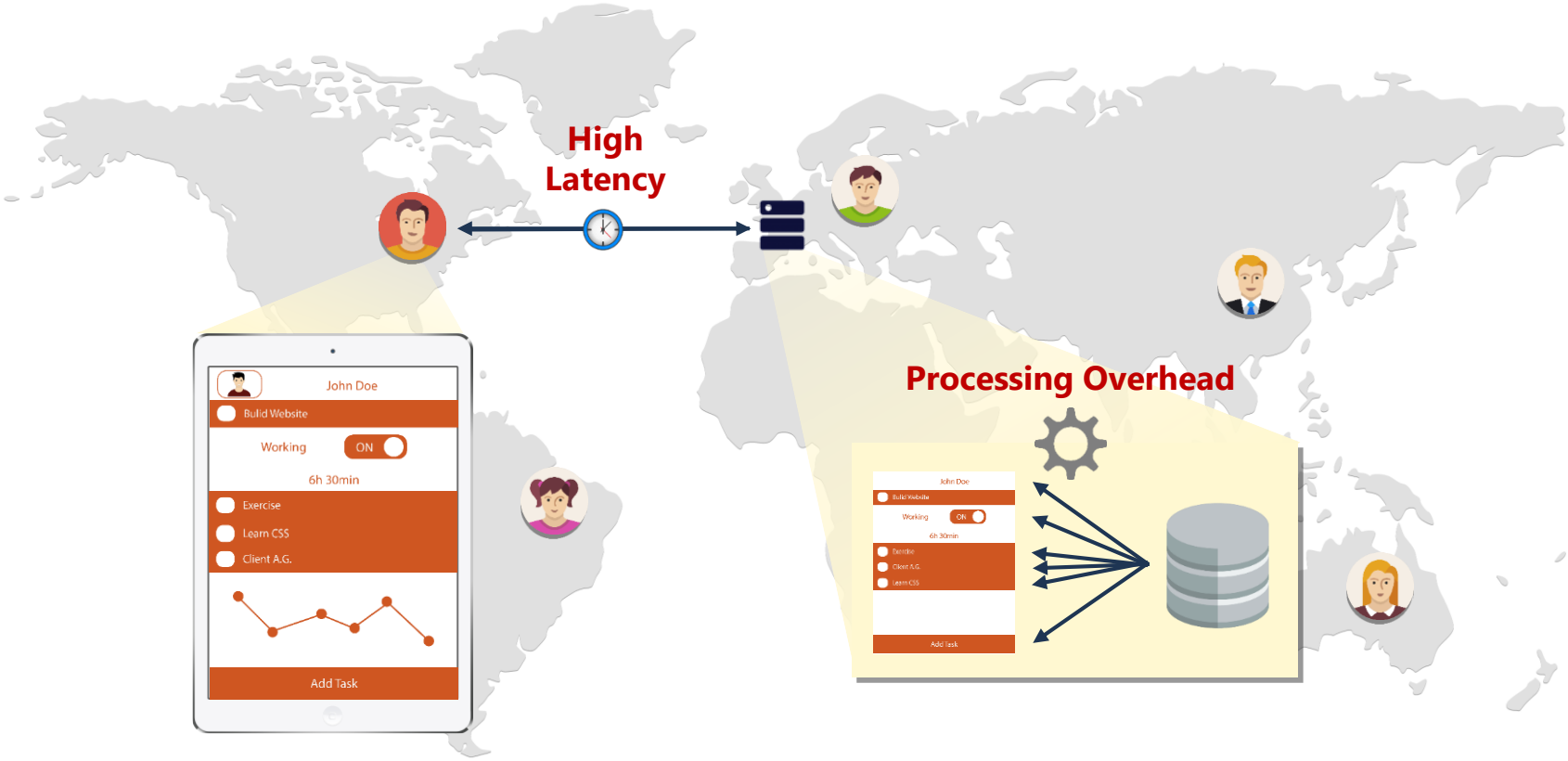
Baqend Real-Time Queries
How do they scale?

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

Baqend Real-Time Queries

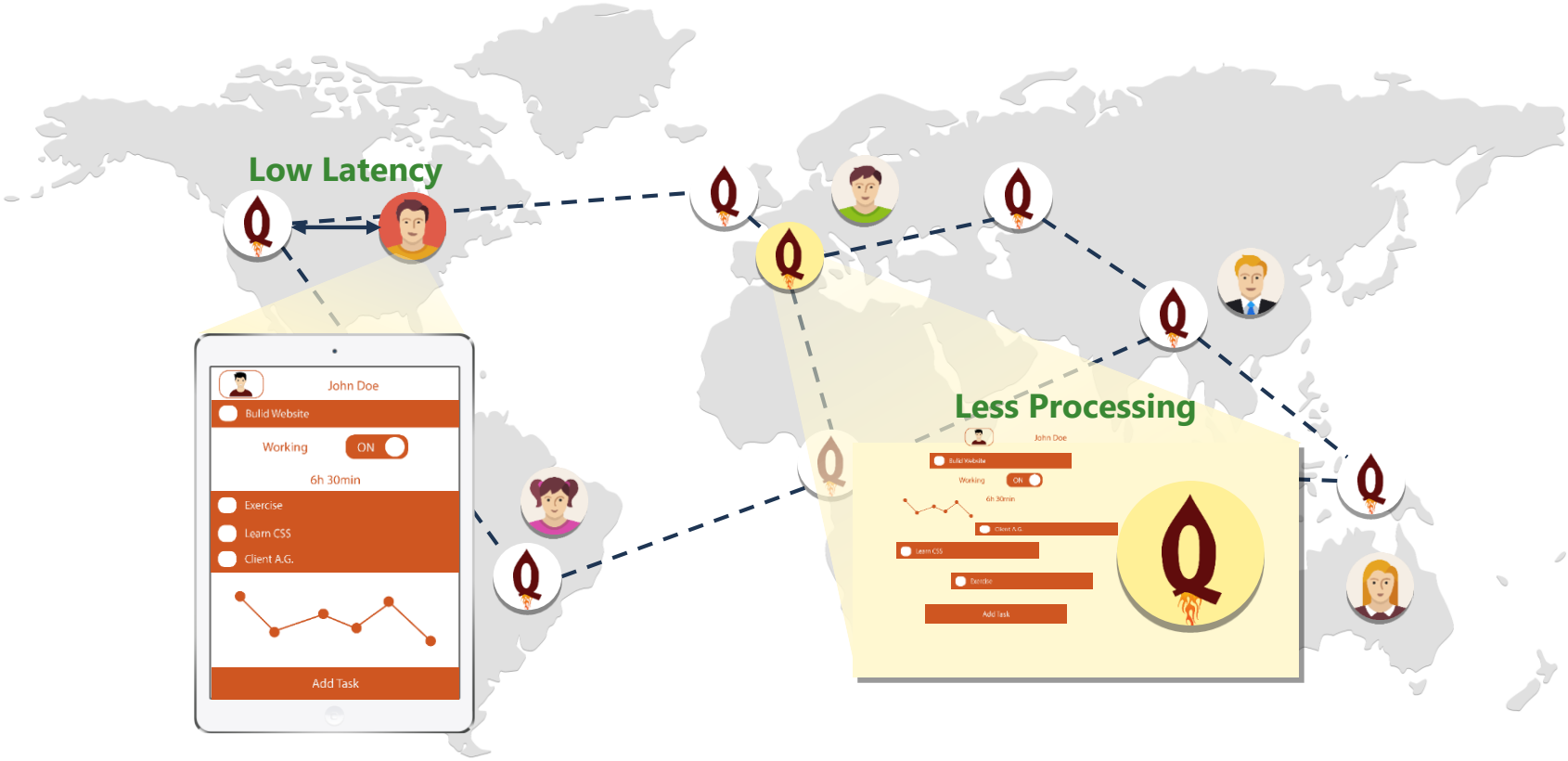
Problem: Slow Websites

Two Bottlenecks: Latency and Processing



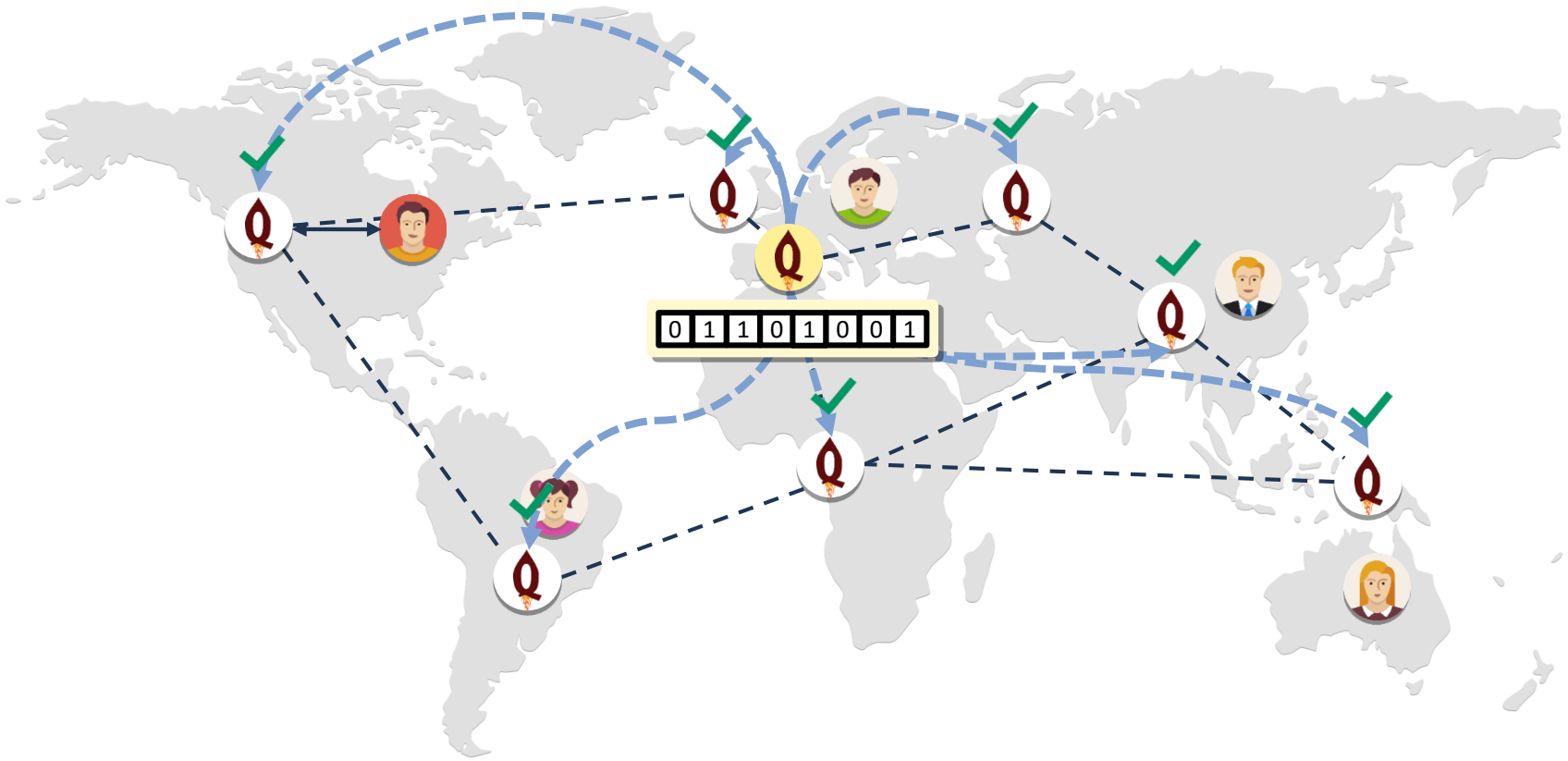
Solution: Global Caching

Fresh Data From Distributed Web Caches



New Caching Algorithms

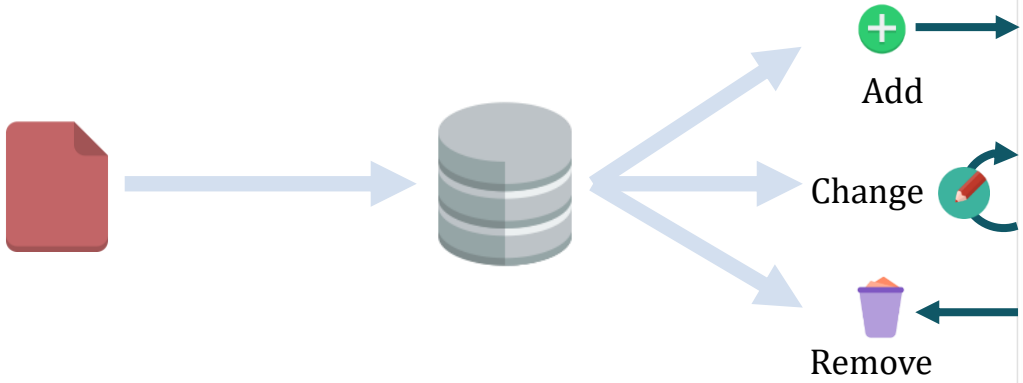
Solve Consistency Problem

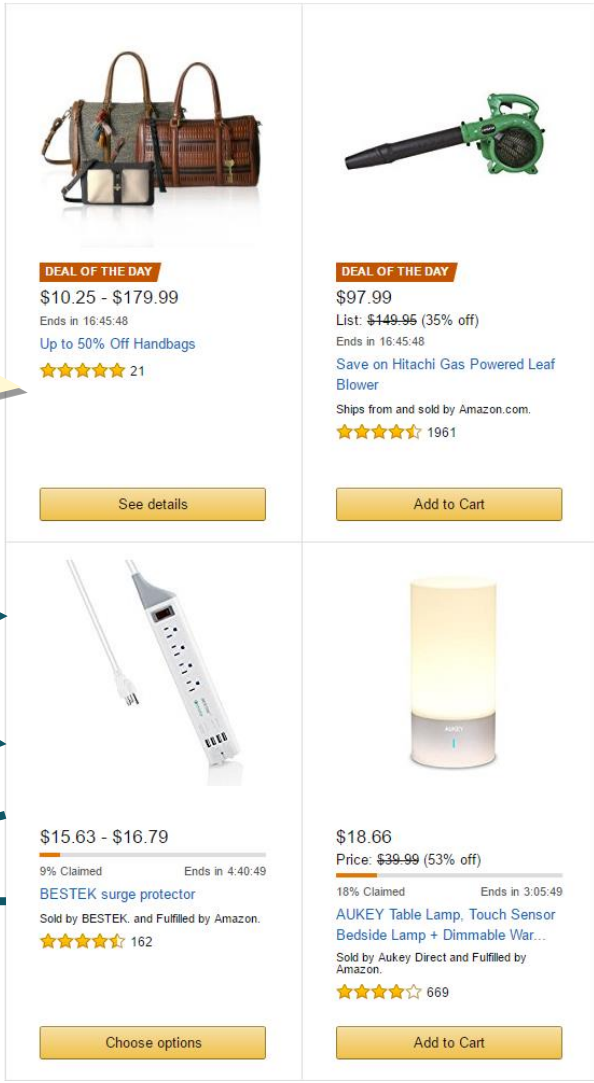


InvaliDB

Invalidating DB Queries

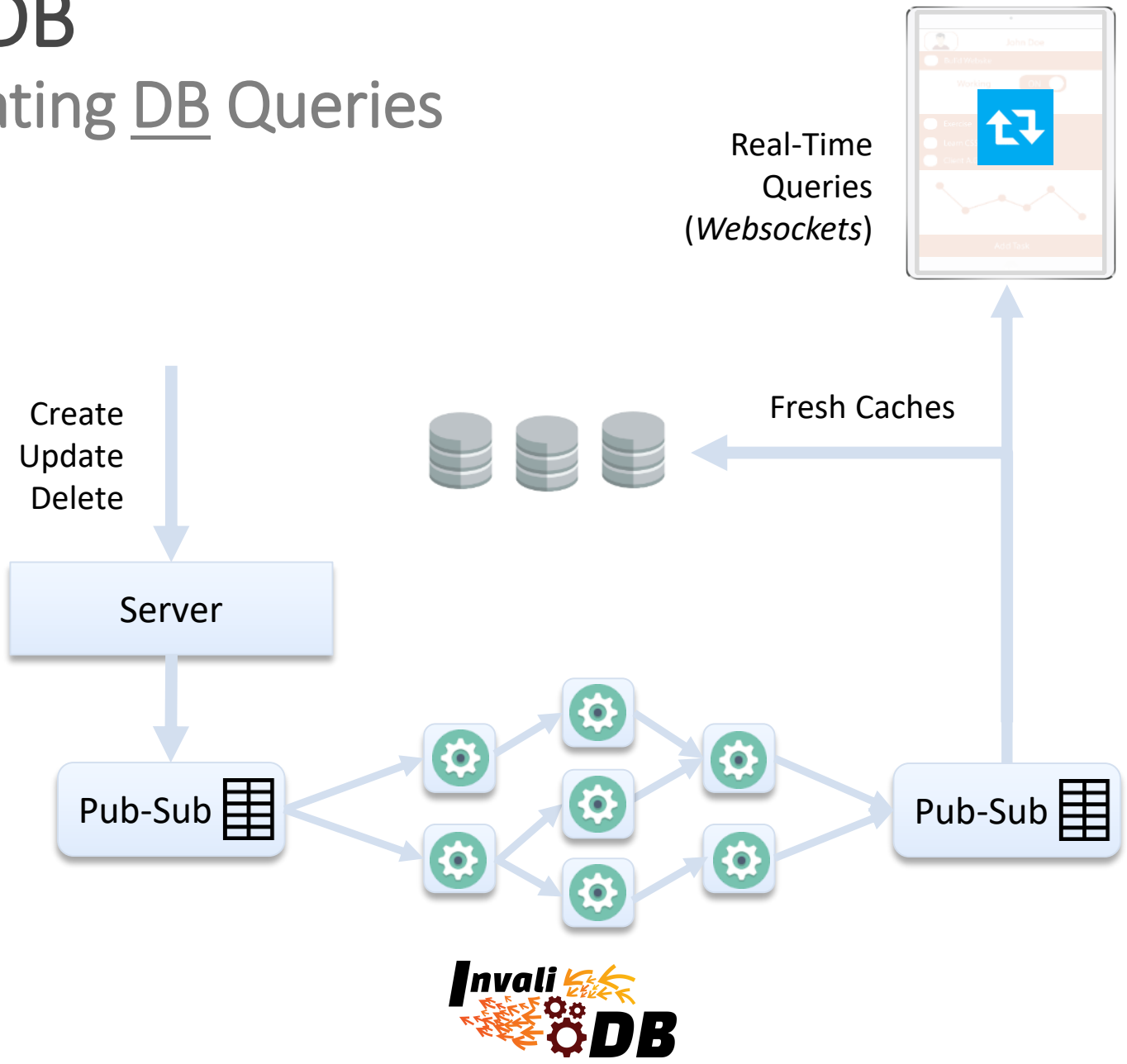
How to **detect changes to query results**:
„Give me the most popular products that are in stock.“





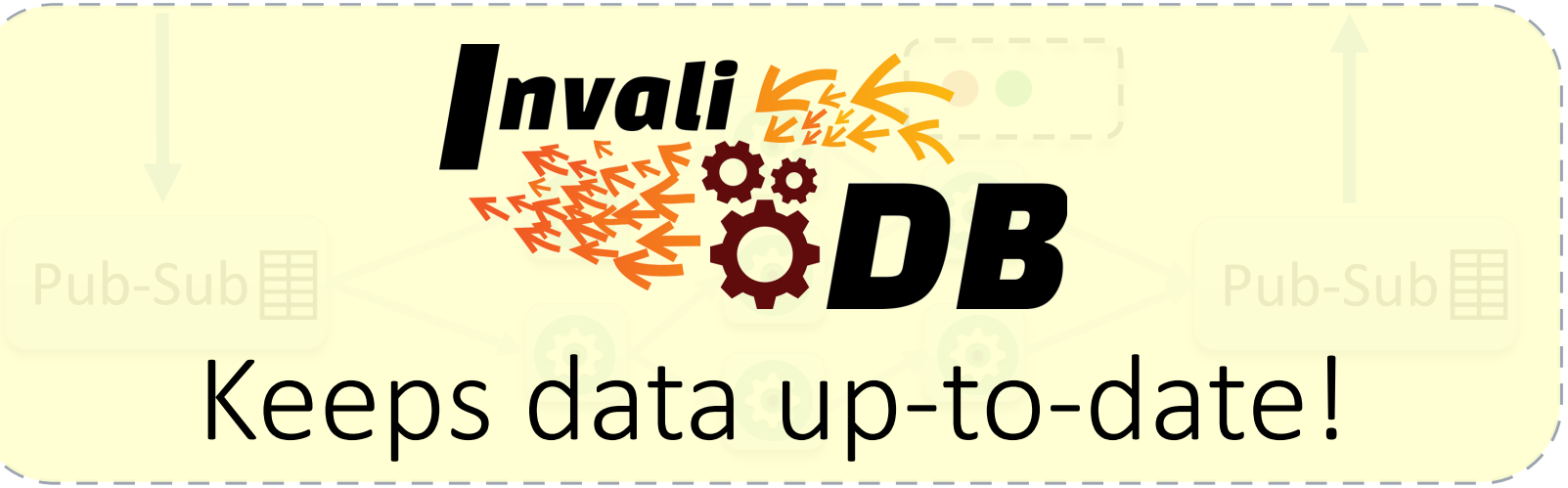
InvaliDB

Invalidating DB Queries



Baqend Real-Time Queries

Real-Time Decoupled



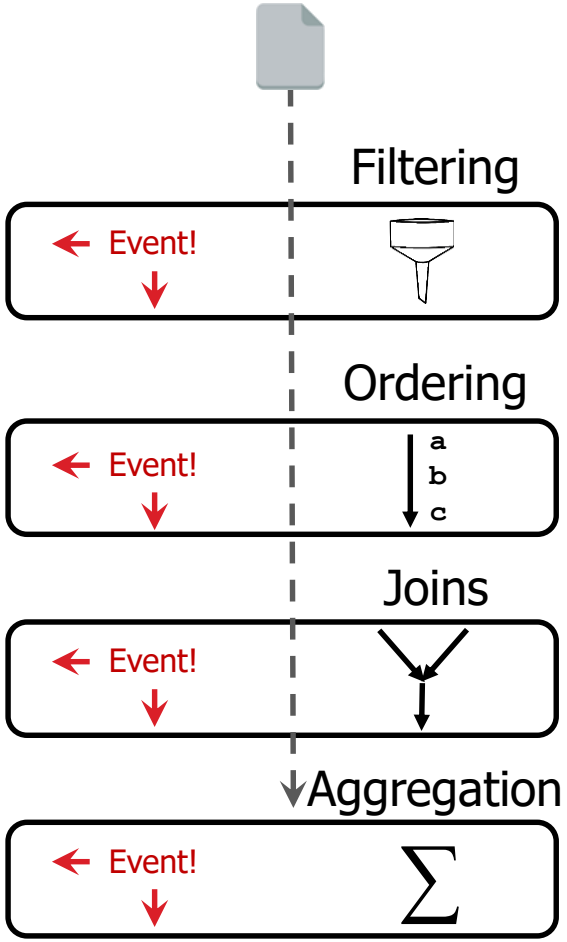
Keeps data up-to-date!

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

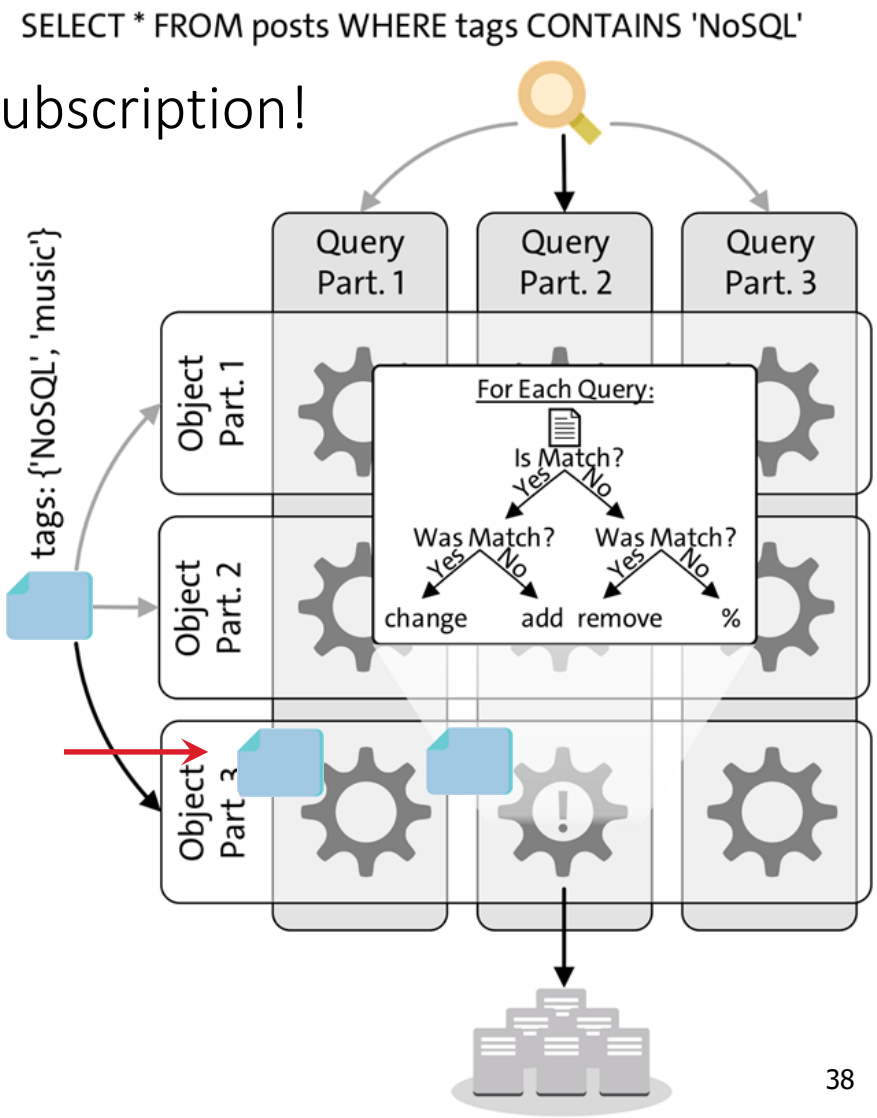
Two-dimensional partitioning:

- *by Query*
- *by Object*

→ scales with queries and writes

Implementation:

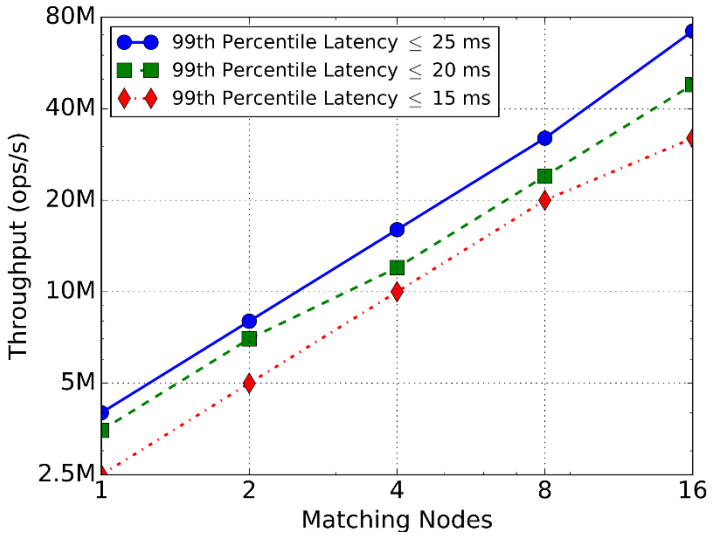
- Apache Storm
- Topology in Java
- MongoDB query language
- **Pluggable query engine**



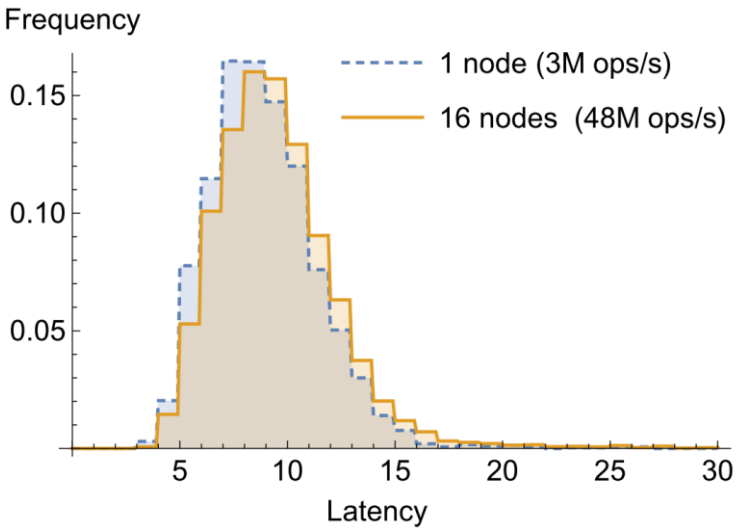
Baqend Real-Time Queries

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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https://twitter.com/bschneids11/status/859767319534469122

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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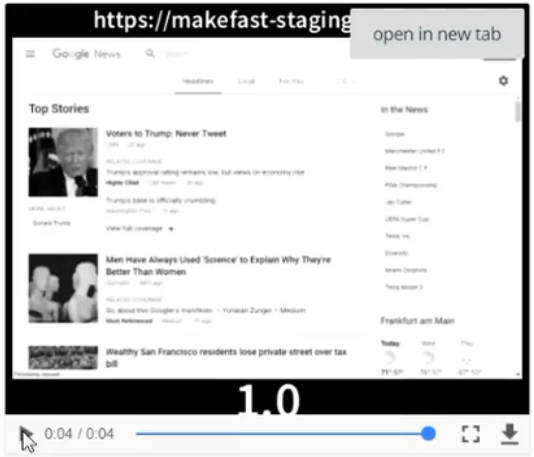
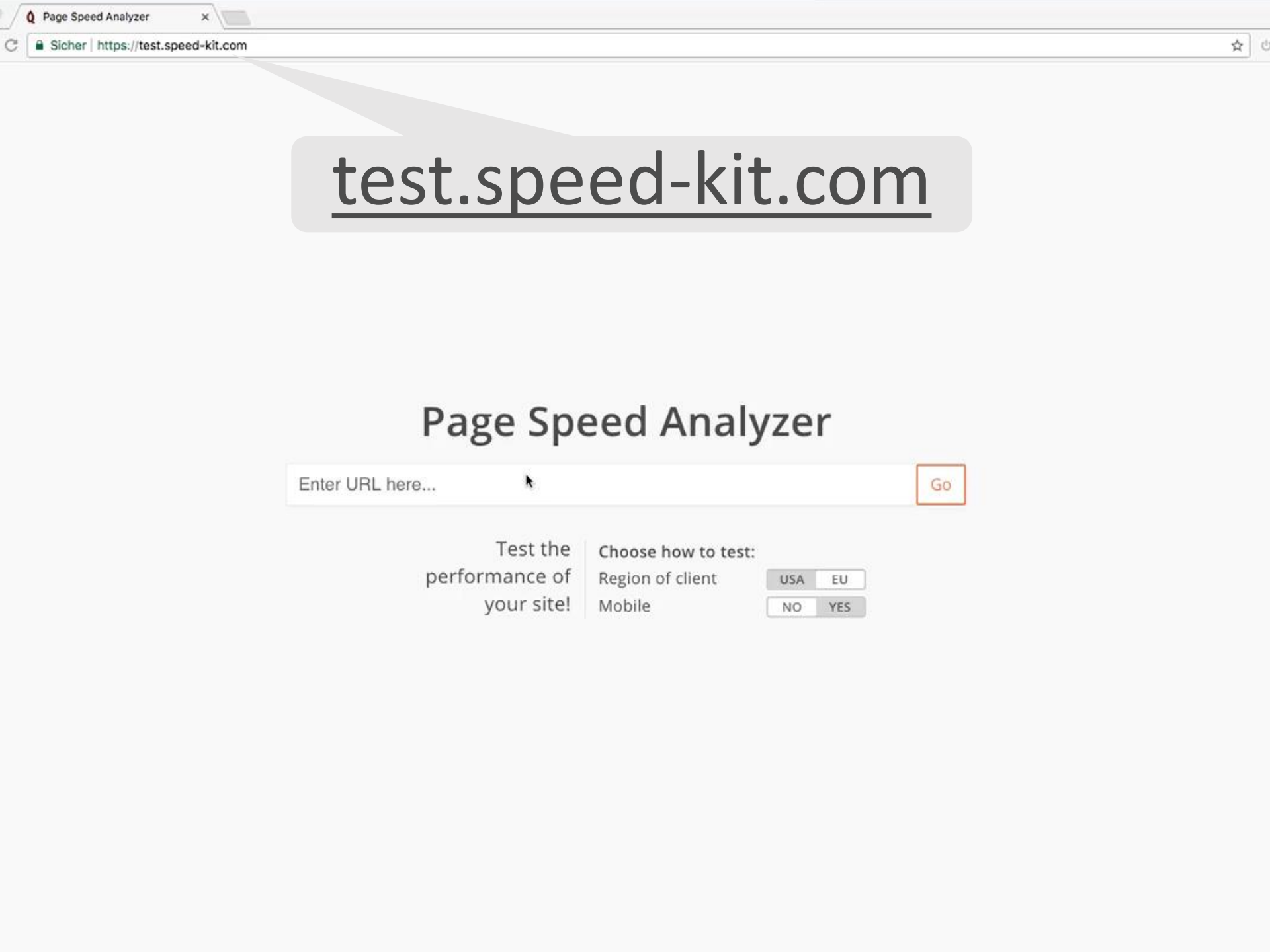
Accelerating Legacy Websites

Testing Future Performance

Domains	Requests	Response Size
13	145	2.37 MB

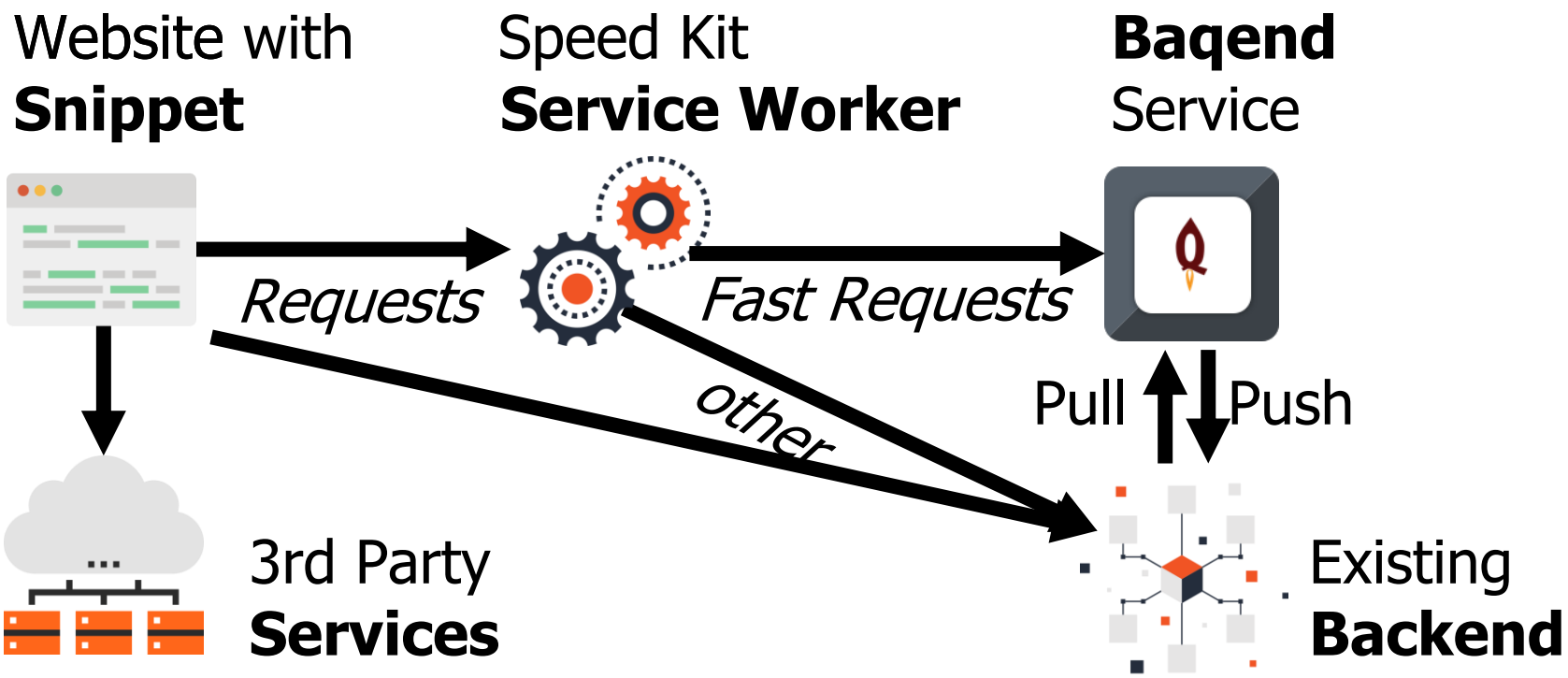
Your Website		Your Website with Speed Kit
	2.10x Faster	
1016ms	Speed Index	484ms
216ms	3.22x Faster Time To First Byte	67ms
1201ms	2.97x Faster DOMContentLoaded	404ms
2153ms	1.42x Faster FullyLoaded	1511ms
1.7s	1.75x Faster Last Visual Change	1s

Print Report


Page Speed Analyzer
Sicher | https://test.speed-kit.com
test.speed-kit.com
Page Speed Analyzer
Enter URL here...
Go
Test the performance of your site!
Choose how to test:
Region of client
USA
EU
Mobile
NO
YES

Speed Kit

Baqend Caching for Legacy Websites



Speed Kit

How to Use It

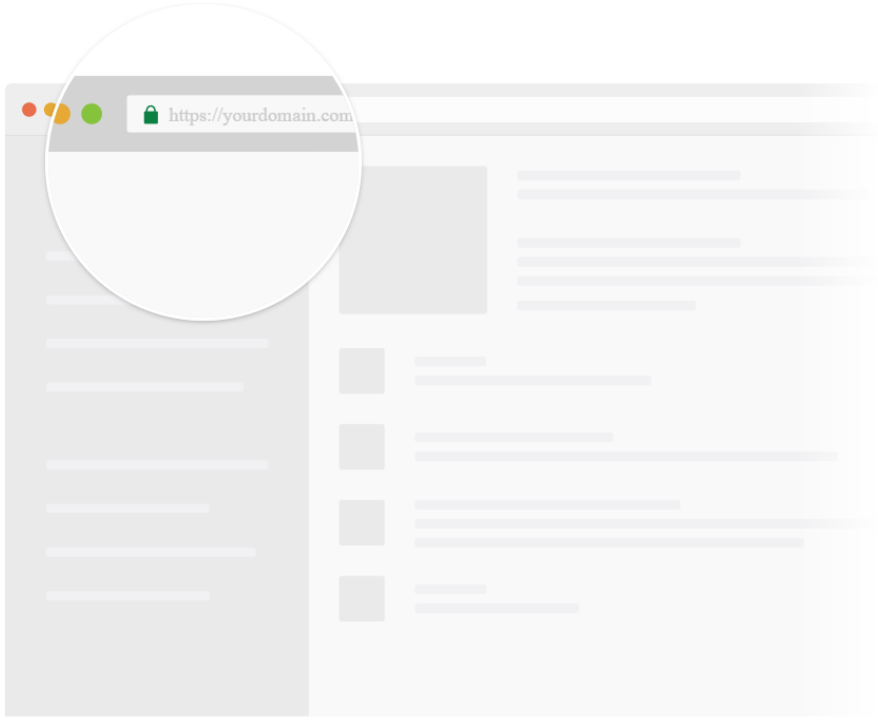
Adding Speed Kit to a Site

Speed Kit

How to Use It

1. Configure Domain

Set which URLs Baqend should accelerate.



Speed Kit

How to Use It

2. Include Code Snippet

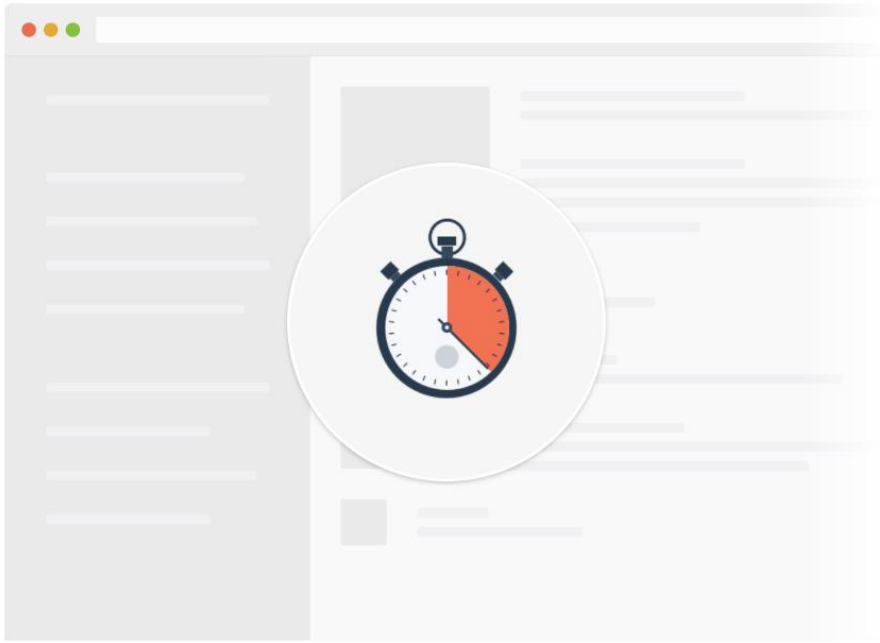
Add the Speed Kit Service Worker to the website.

Speed Kit

How to Use It

3. Requests Accelerated

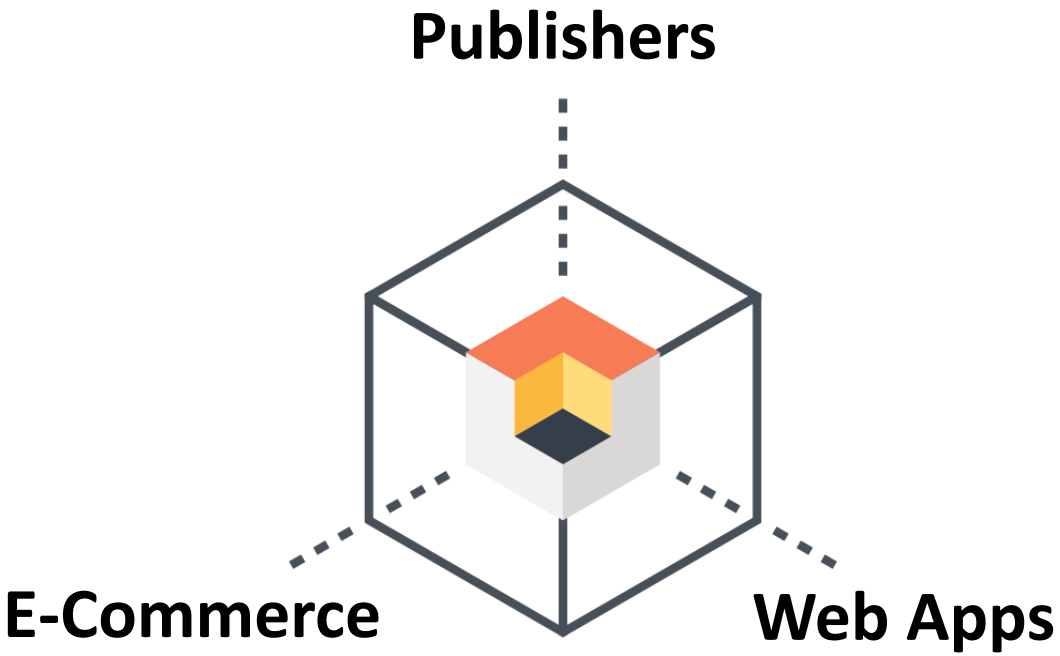
Speed Kit routes the requests through Baqend‘s CDN.



Speed Kit

Works Across Tech Stacks

Does it work for you? Try it:
https://test.speed-kit.com/



Speed Kit
Works For **Publishers**

Does it work for you? Try it:
https://test.speed-kit.com/

kicker.de

Domains	Requests	Response Size
42	243	4.4 MB

Your Website		Your Website with Speed Kit
	4.11x Faster 3332ms Speed Index 810ms	
	10.13x Faster 638ms Time To First Byte 63ms	
	4.91x Faster 5163ms DOMContentLoaded 1051ms	
	3.67x Faster 13850ms FullyLoaded 3770ms	
	3.98x Faster 3.5s Last Visual Change 0.9s	

Print Report

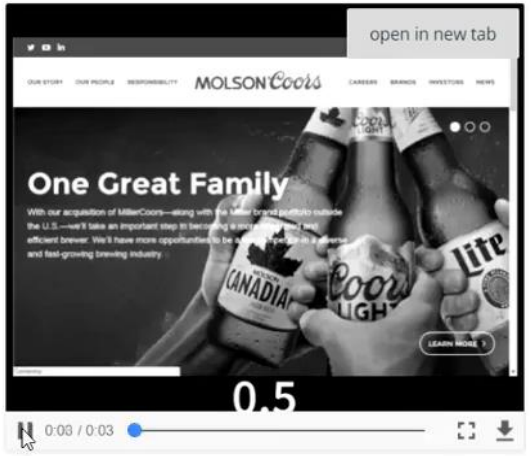
Speed Kit

Works For **Landing Pages**

Does it work for you? Try it:
https://test.speed-kit.com/

molsoncoors.com

Domains	Requests	Response Size
5	23	5.55 MB

Your Website		Your Website with Speed Kit
	3.14x Faster 1493ms Speed Index 476ms	
	149.00x Faster 298ms Time To First Byte 2ms	
	3.31x Faster 820ms DOMContentLoaded 248ms	
	3.61x Faster 1753ms FullyLoaded 486ms	
	3.27x Faster 1.6s Last Visual Change 0.5s	

Print Report

Unexpected result?

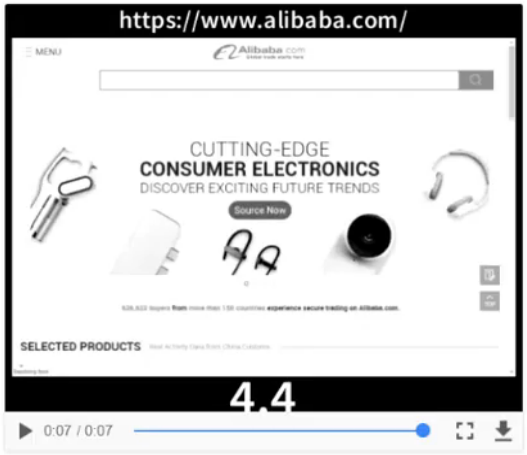
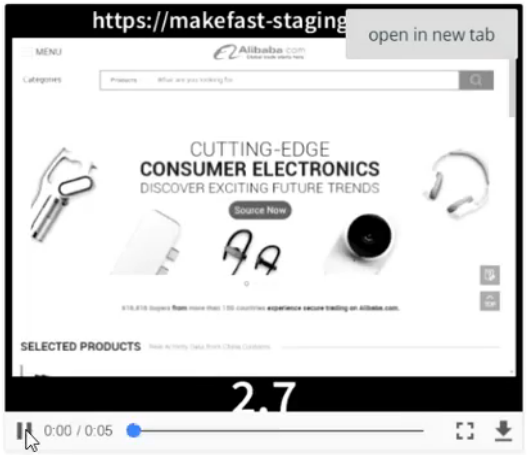
Speed Kit

Works For **E-Commerce**

Does it work for you? Try it:
https://test.speed-kit.com/

alibaba.com

Domains	Requests	Response Size
24	89	2.51 MB

Your Website		Your Website with Speed Kit
	2.82x Faster	
1701ms	Speed Index	603ms
769ms	7.77x Faster Time To First Byte	99ms
1169ms	6.22x Faster DOMContentLoaded	188ms
5362ms	1.69x Faster FullyLoaded	3177ms
4.4s	1.60x Faster Last Visual Change	2.7s

Print Report

Baqend

Try It Out!

Does it work for you? Try it:
https://test.speed-kit.com/

Platform

- Platform for building (Progressive) **Web Apps**
- **15x** Performance Edge
- Faster **Development**

Speed Kit

- Turns Existing Sites into **PWAs**
- **50-300% Faster** Loads
- **Offline** Mode

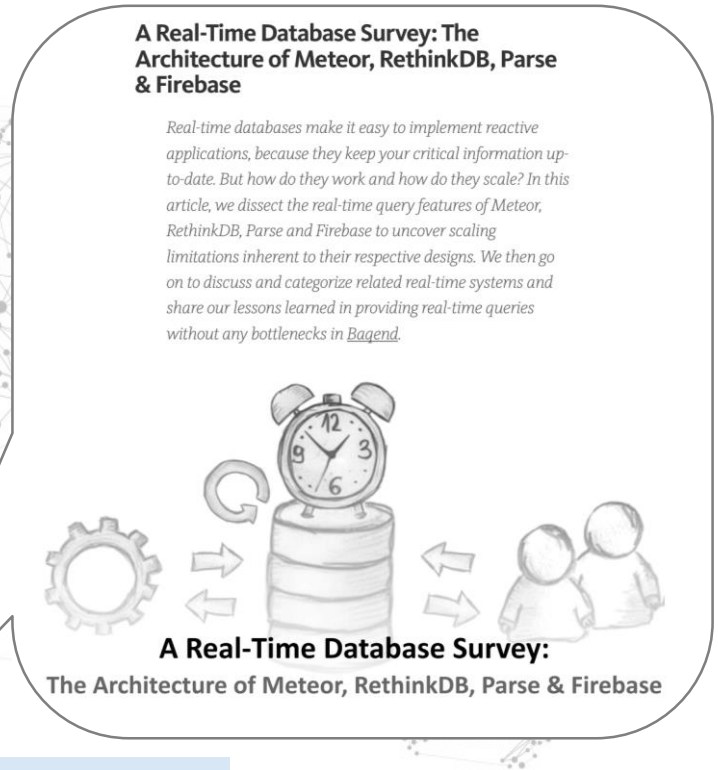
Wrap-up

- **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:

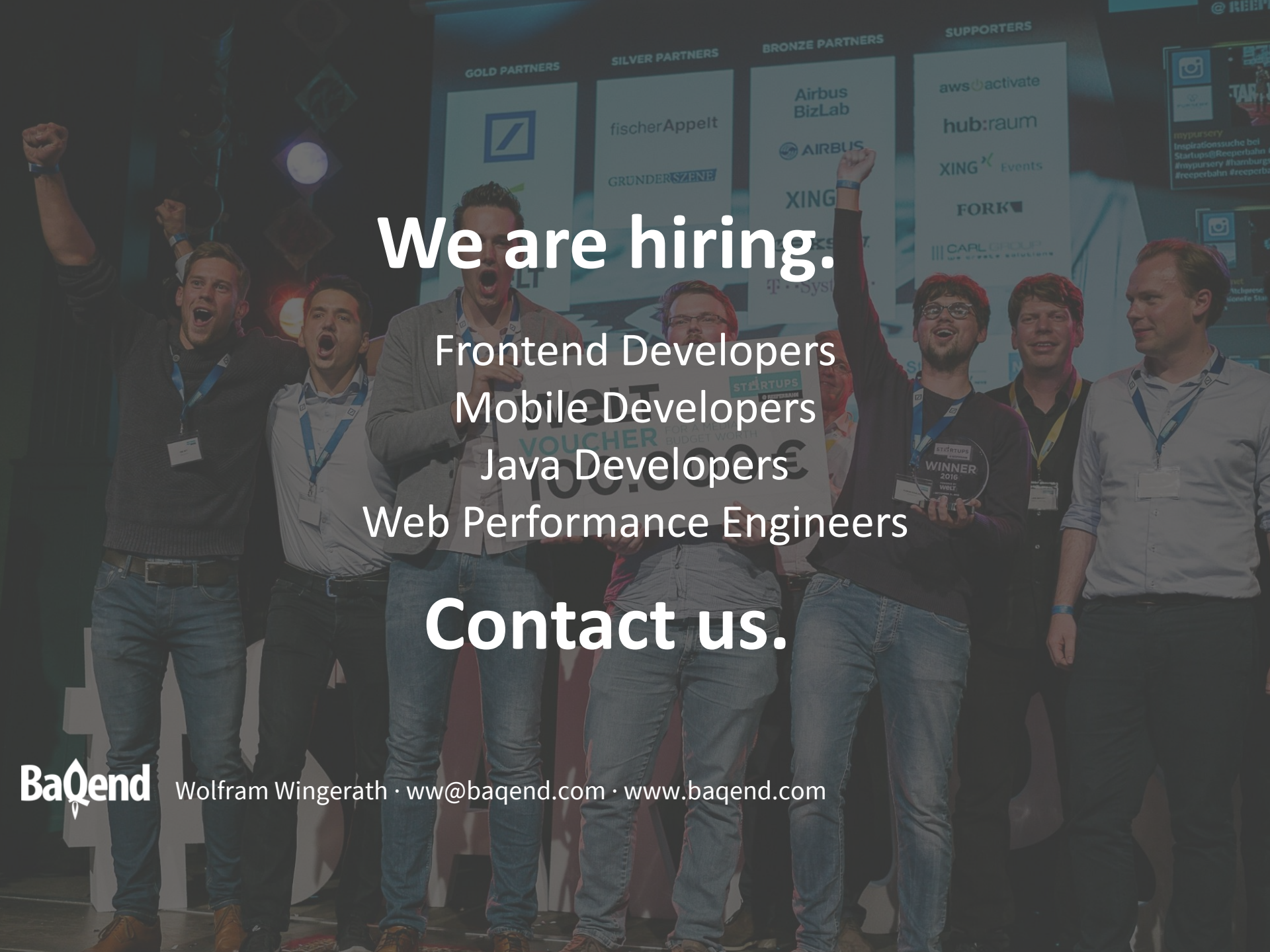
- *Quaestor: Query Web Caching for Database-as-a-Service Providers*
  VLDB ‘17
- *NoSQL Database Systems: A Survey and Decision Guidance*
  SummerSOC ‘16
- *Real-time stream processing for Big Data*
  it - Information Technology 58 (2016)
- *The Case For Change Notifications in Pull-Based Databases*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