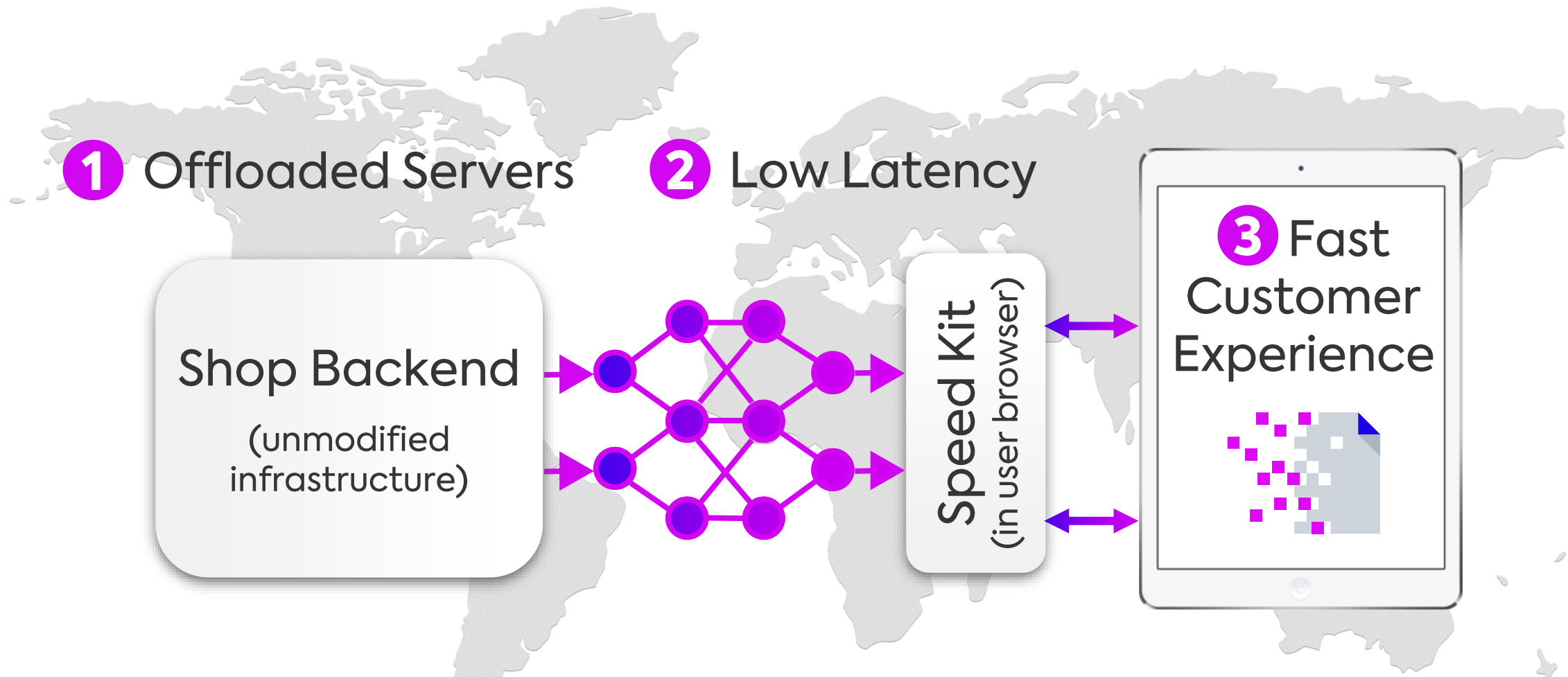# Beaconnect
Continuous Web Performance A/B Testing at Scale

Wolfram Wingerath, Benjamin Wollmer, Markus Bestehorn, Stephan Succo,
Sophie Ferrlein, Florian Bücklers, Jörn Domnik, Fabian Panse,
Erik Witt, Anil Sener, Felix Gessert, Norbert Ritter

Carl von Ossietzky Universität Oldenburg

Baqend

amazon | science

UH Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Speed Kit: Web Performance Plugin

1 Offloaded Servers   **2** Low Latency   **3** Fast Customer Experience

Shop Backend

(unmodified infrastructure)

Speed Kit
(in user browser)

Wolfram Wingerath, Felix Gessert, et al.: Speed Kit: A Polyglot & GDPR-Compliant Approach For Caching Personalized Content, ICDE (2020).

Split Testing for Web Performance

Speed Kit Users   **vs.**   **Normal Users**
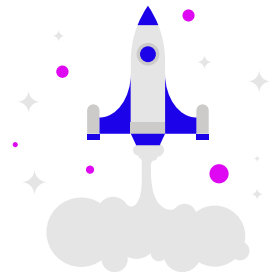
Tracking →   ← Tracking
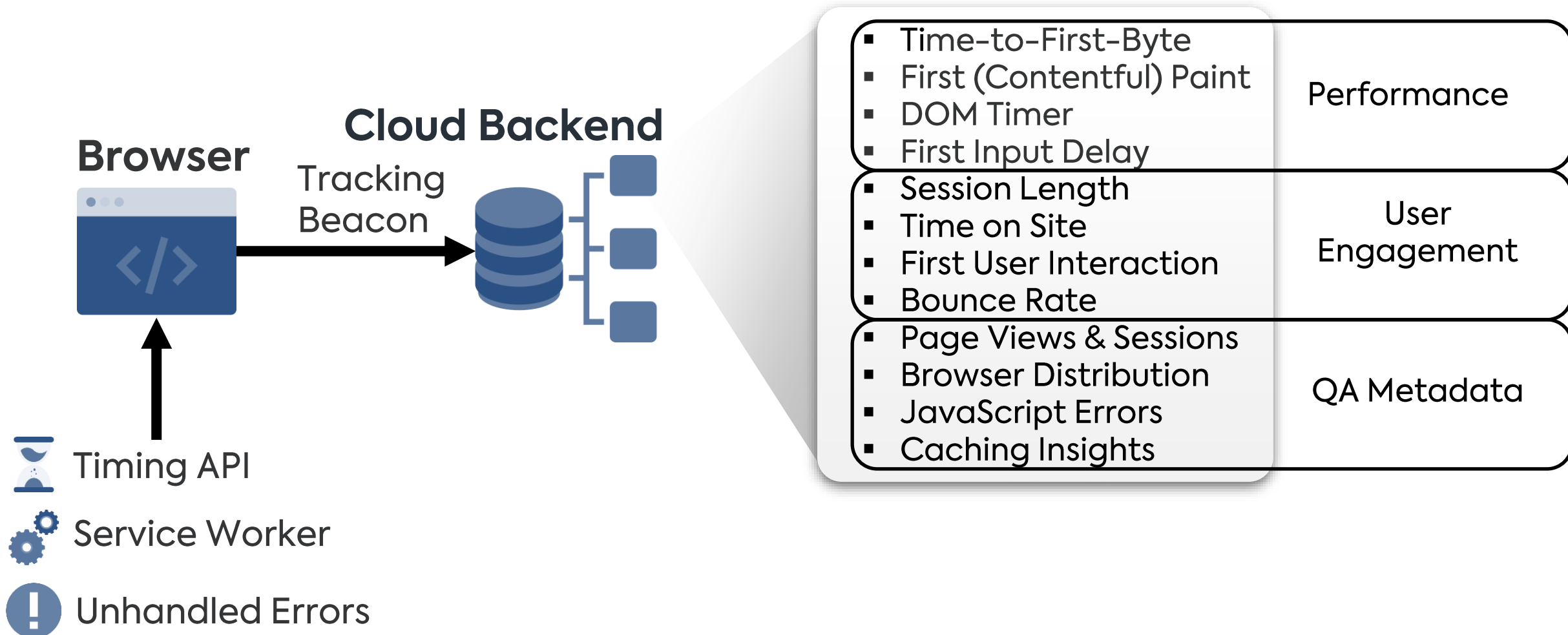
- Speed Kit <u>enabled</u>

- **Measurable uplift**:
  - **+** Performance
  - **+** User engagement
  - **+** ...

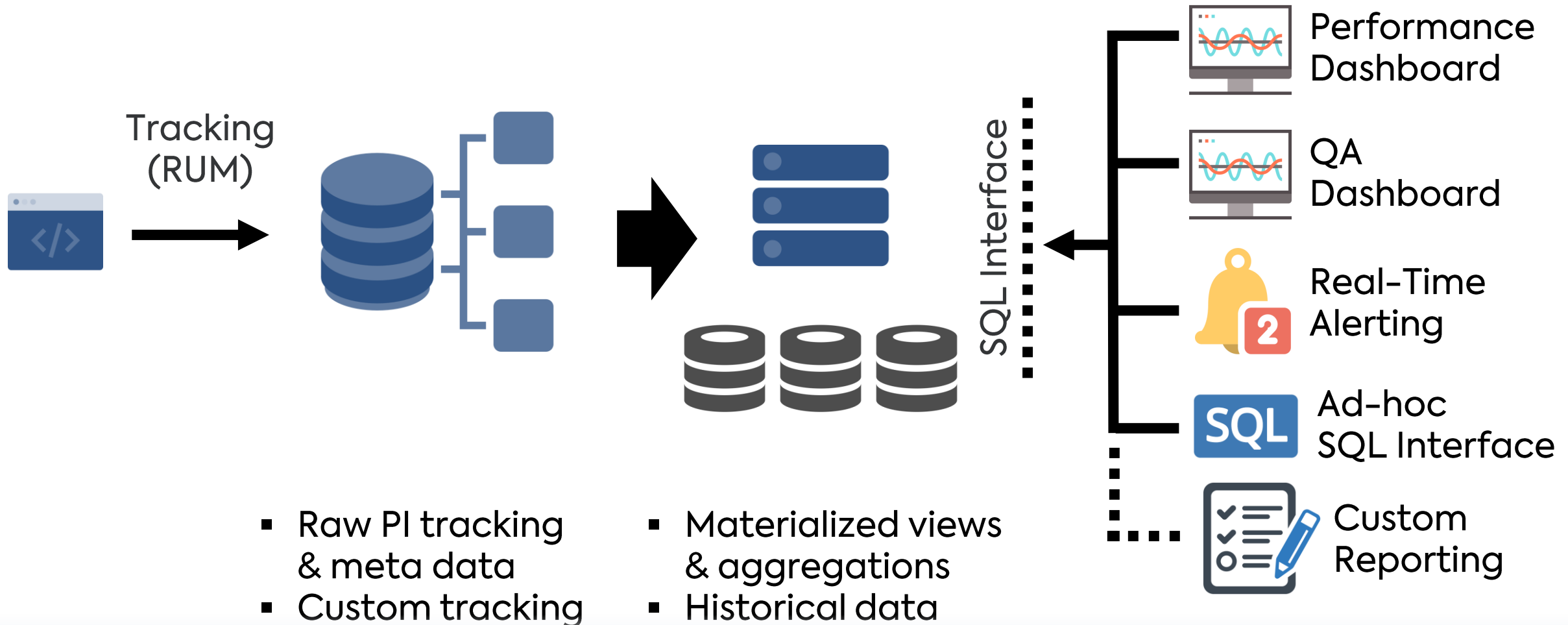- Speed Kit <u>disabled</u>
  (no acceleration)

Real-User Monitoring (RUM)

Browser

Cloud Backend

Tracking Beacon

- Time-to-First-Byte
- First (Contentful) Paint
- DOM Timer
- First Input Delay

Performance

- Session Length
- Time on Site
- First User Interaction
- Bounce Rate

User Engagement

- Page Views & Sessions
- Browser Distribution
- JavaScript Errors
- Caching Insights

QA Metadata

Timing API

Service Worker

Unhandled Errors

Real-User Monitoring (RUM)

Collection   **Ingestion**   **Analytics**   **Reporting**

Tracking
(RUM)
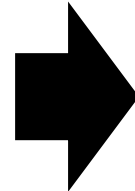
SQL Interface

Performance Dashboard

QA Dashboard

Real–Time Alerting

SQL Ad-hoc SQL Interface

Custom Reporting

- Raw PI tracking & meta data
- Custom tracking

- Materialized views & aggregations
- Historical data

Real-User Monitoring (RUM)

Collection

Ingestion

Analytics

Reporting

Tracking (RUM)

SQL Interface

Flink
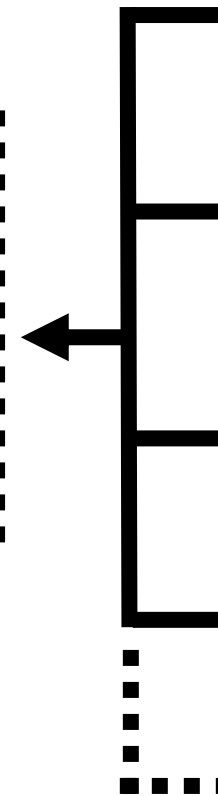
Performance Dashboard

QA Dashboard

Real–Time Alerting

Ad–hoc SQL Interface

Custom Reporting

- Raw PI tracking & meta data
- Custom tracking

- Materialized views & aggregations
- Historical data

When to Send Data Beacons?

VLDB 2022

click &
click detection

navigation &
processing

user input

navigationStart
redirectStart
redirectEnd
fetchStart
domainLookupStart
domainLookupEnd
connectStart
(secureConnectionStart)
connectEnd
requestStart
responseStart
responseEnd

| Prompt for unload | redirect | App cache | DNS | TCP | Request | Response | Processing | onLoad |

unload

loadEventEnd
loadEventStart
domComplete
domContentLoaded
domInteractive
domLoading
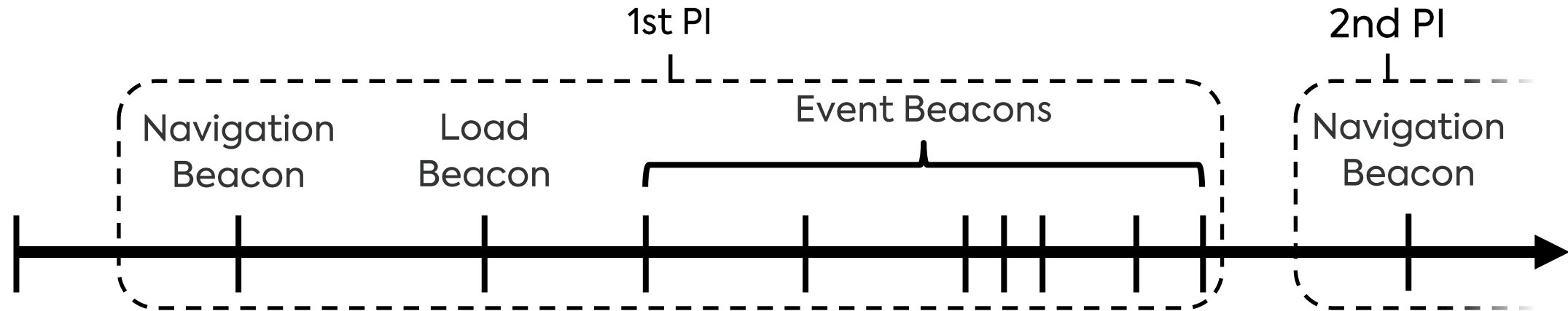unloadEnd
unloadStart

Philippe le Hegaret: Performance Timing Information:
Part 1 – Navigation Timing, W3C Blog (2012)

Types of Data Beacons
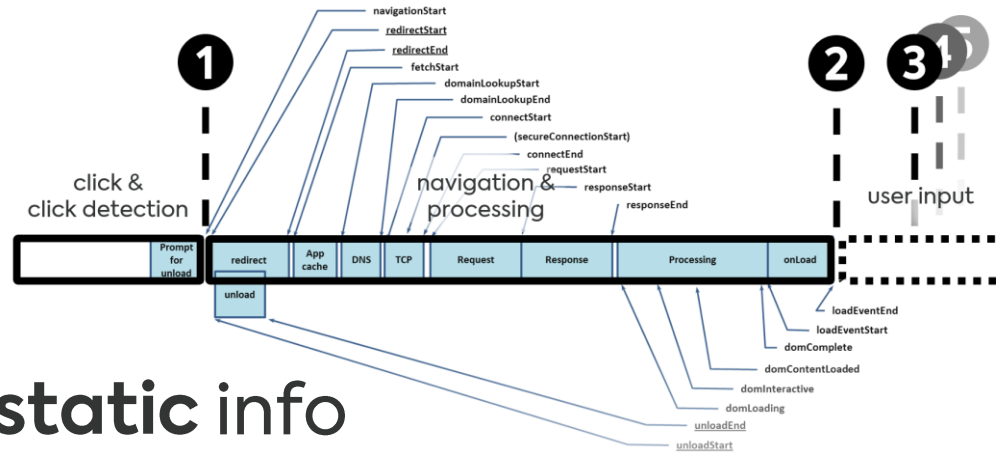
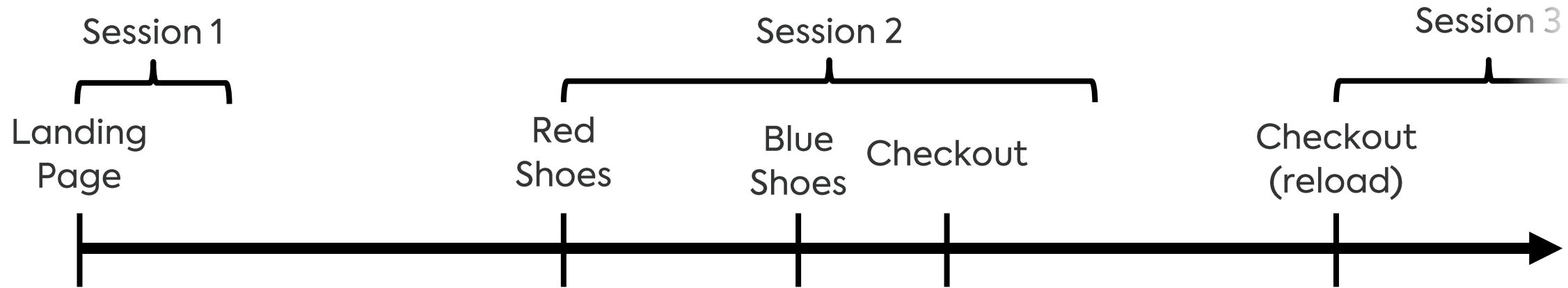1. 1 for **static** info
    (URL, user agent, session ID, …)

2. 1 for **timings**
    (TTFB, load time, FCP, …)

3. 0–n for **events**
    (first input, add–to–cart, …)

Aggregating Page Impressions

- **Beacon Join → PI**: How do we handle events that come late?

  - Simply wait 5 minutes?

  - Wait for next PI or session timeout?

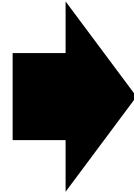 - ...?

- How to resolve **user agents**?
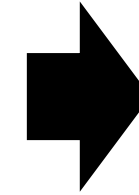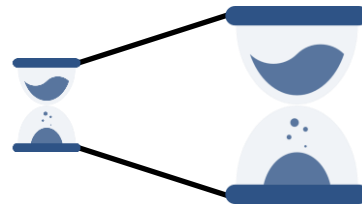
Aggregating Session Data

- **Bounces & Session End**: find out when and where people leave

- **Session timeout** after 30 minutes of _inactivity_

Batch Processing & Latency
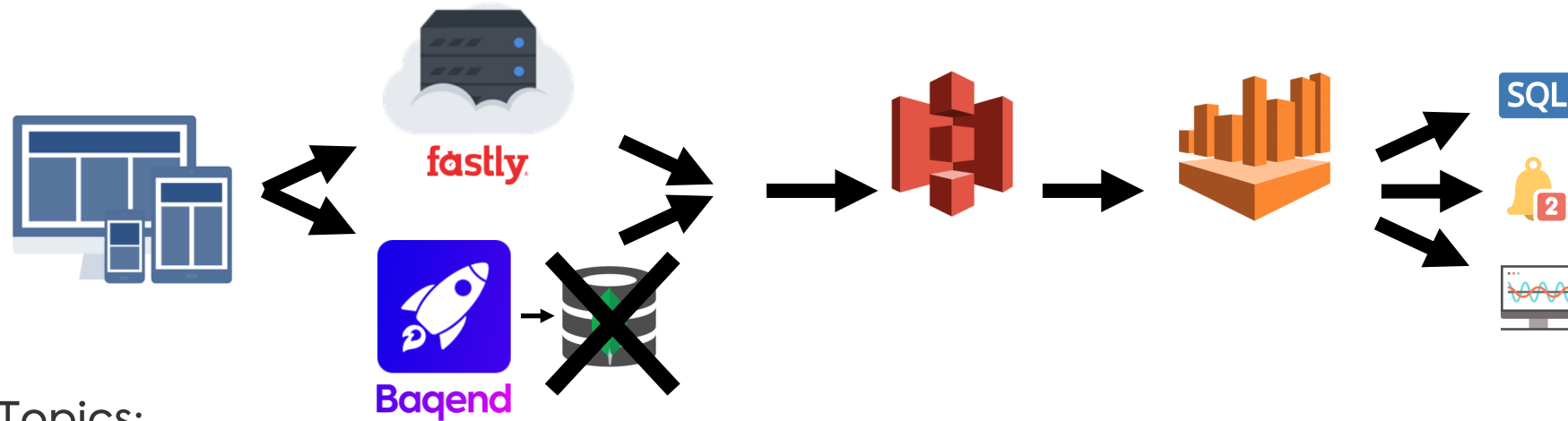
Alerting

Trend Analysis

Processing Time

- Simple metrics
  / little context
  - Counters
  - Extreme values
  - Specific errors

- Complex aggregations
  / huge time windows
  - Average session length
  - Performance by month
  - Seasonal effects

Key Topics:

✓ Continuous Aggregation

✓ Real-Time Reporting & Analytics

✓ Extreme Scalability

F. Gessert, W. Wingerath. Batching Was Yesterday: Real-Time Tracking & Analysis For 100+ Million Visitors, Flink Forward (2021)

Beaconnect: Continuous Processing

Reengineered Aggregation Pipeline

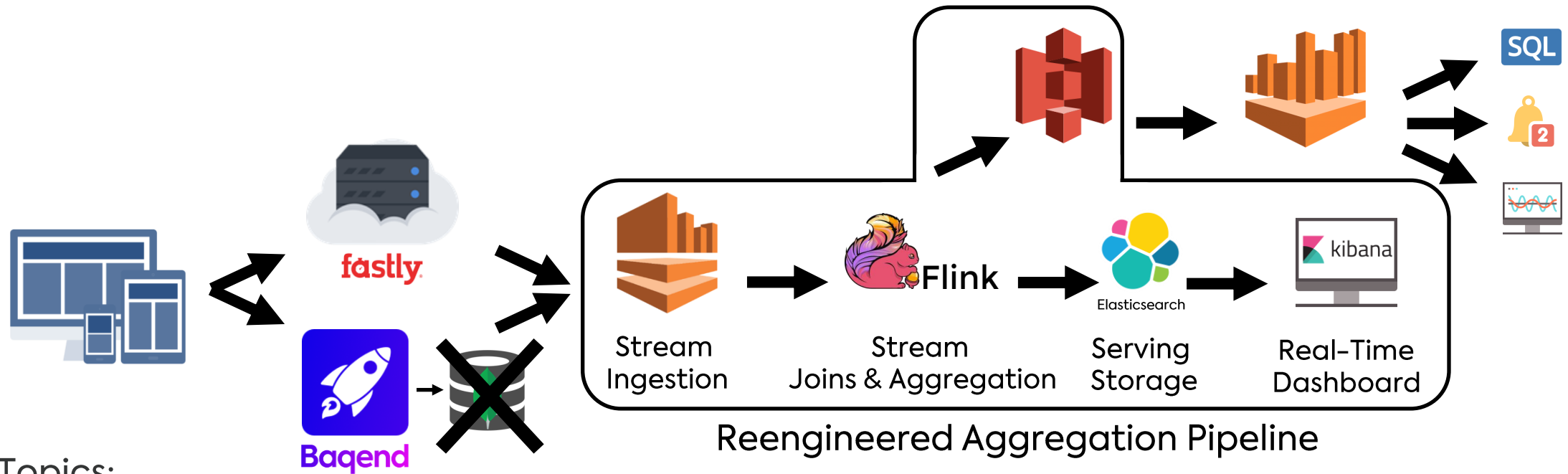Stream Ingestion → Stream Joins & Aggregation → Serving Storage → Real-Time Dashboard

Key Topics:

✓ Continuous Aggregation

✓ Real-Time Reporting & Analytics

✓ Extreme Scalability

F. Gessert, W. Wingerath. Batching Was Yesterday: Real-Time Tracking & Analysis For 100+ Million Visitors, Flink Forward (2021)
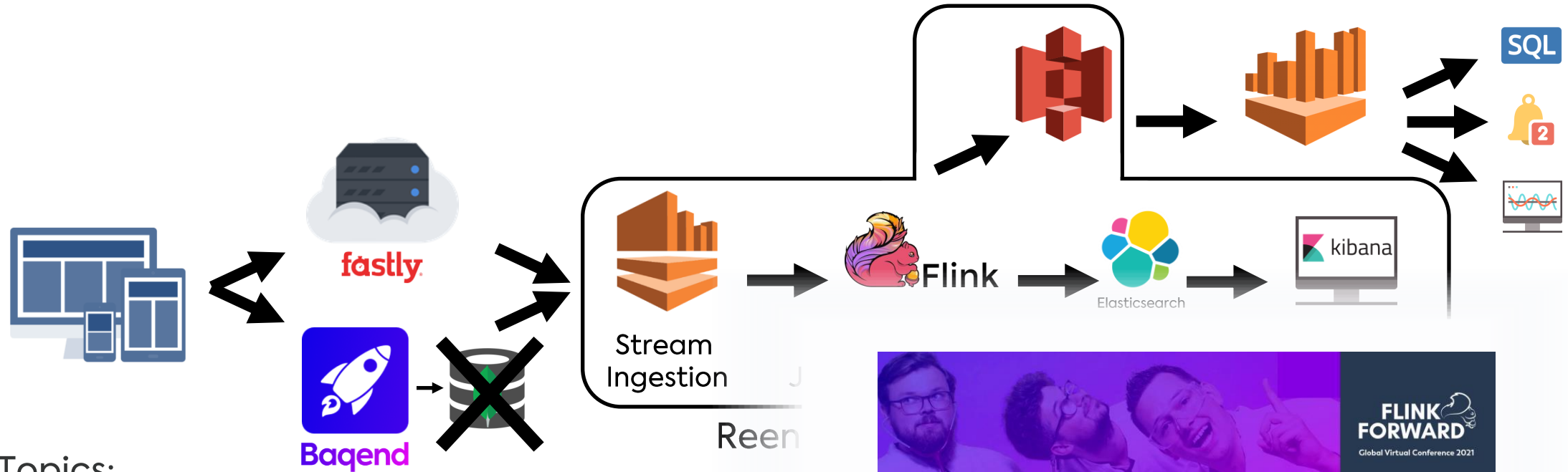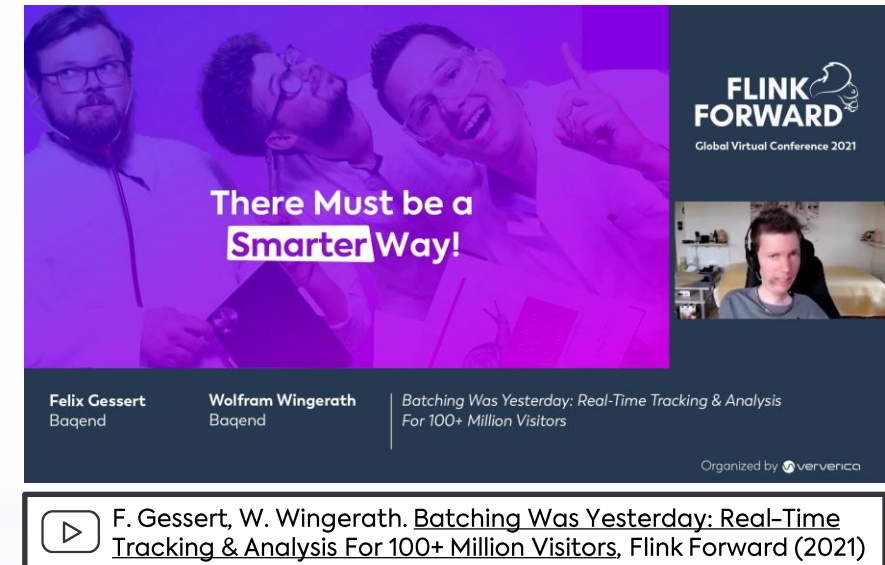
Beaconnect: Continuous Processing

Stream
Ingestion

Flink

Elasticsearch

kibana

SQL

Reen

Key Topics:

✓ Continuous Aggregation

✓ Real–Time Reporting & Analytics

✓ Extreme Scalability

There Must be a **Smarter** Way!

Felix Gessert
Baqend

Wolfram Wingerath
Baqend

Batching Was Yesterday: Real-Time Tracking & Analysis For 100+ Million Visitors

Organized by Ververica

▶ F. Gessert, W. Wingerath. <u>Batching Was Yesterday: Real–Time Tracking & Analysis For 100+ Million Visitors</u>, Flink Forward (2021)
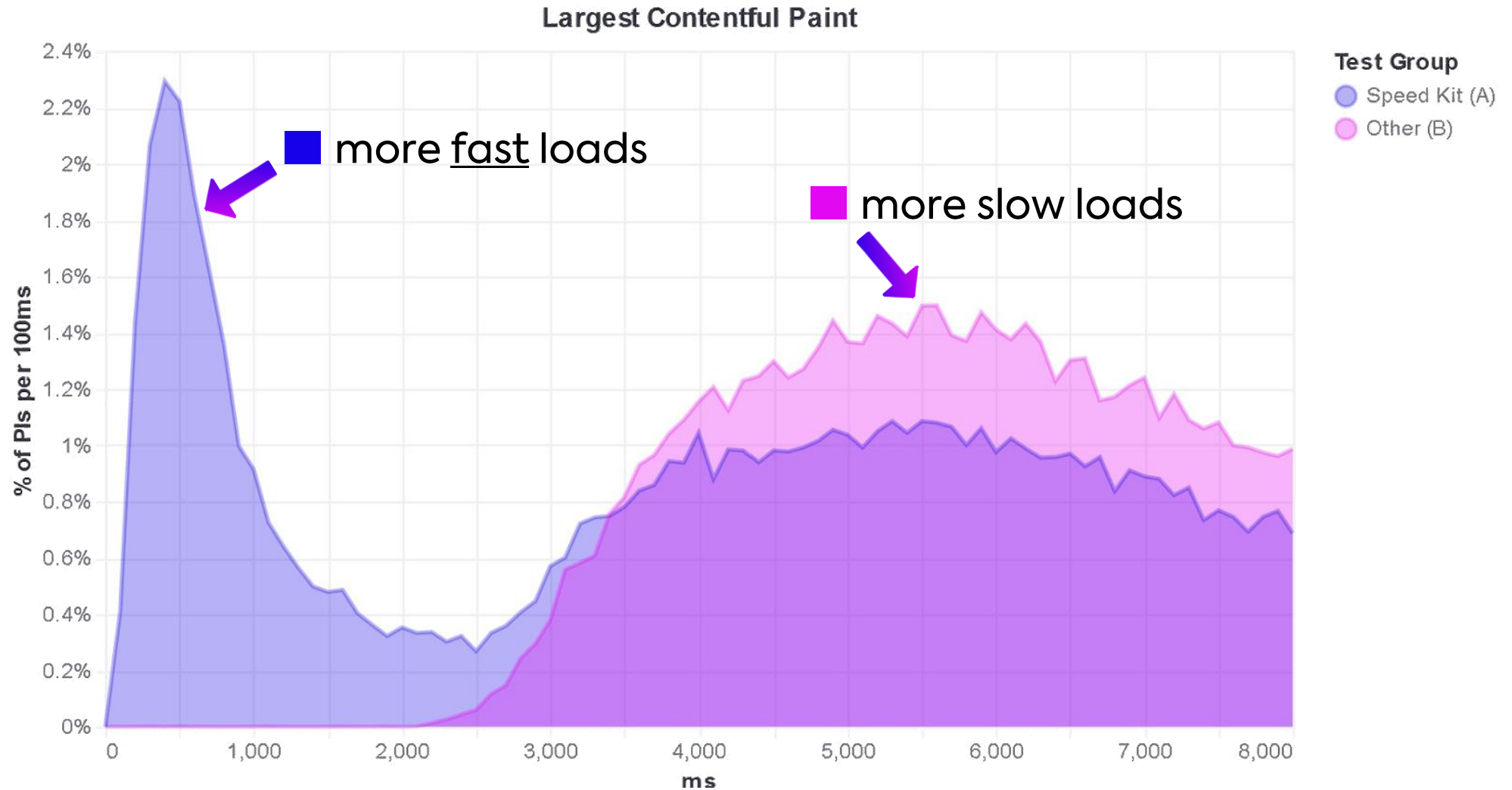
Real-Time Dashboarding Example

VLDB 2022

Largest Contentful Paint

more <u>fast</u> loads

more slow loads

Test Group
- Speed Kit (A)
- Other (B)
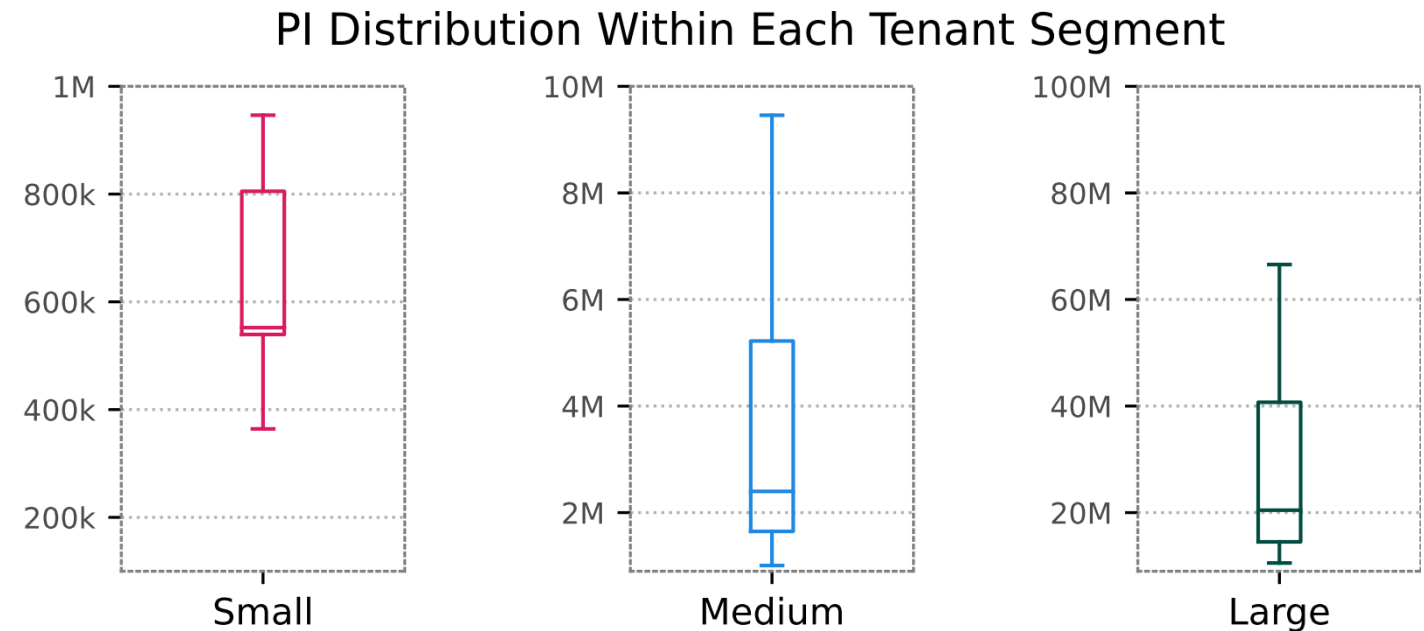
Traffic* Across 3 Orders of Magnitude

Overall Monthly Traffic

- >100M users

- >200M sessions

- >650M PIs

- >3B data beacons

PI Distribution Within Each Tenant Segment

*Monthly Page Impressions (PIs)

3-Level Aggregation

Partial Page Impressions (PPIs)
Enhanced Data Beacons

Time	Browser	Device	Test Group	First Contentful Paint (FCP)
11:05:04.578	Firefox	Mobile	Speed Kit	127ms
11:06:48.139	Chrome	Mobile	Original	958ms

1–Min. Time Windows
Immediate Aggregates (Storage)

	Browser	Device	Test Group	First Contentful Paint (FCP)
11:05	Firefox	Mobile	Speed Kit	{200ms: 1, 500ms: 2}
	Firefox	Mobile	Original	{600ms: 2, 800ms: 5}
	Safari	Desktop	Original	{1100ms: 1}
11:06	Firefox	Mobile	Speed Kit	{200ms: 3}
	Chrome	Mobile	Speed Kit	{400ms: 2}
	Opera	Tablet	Original	{700ms: 1, 1300ms: 2}
	Safari	Desktop	Original	{600ms: 4, 900ms}

Arbitrary Time Windows
Real–Time Reporting (Dashboard Queries)

	Browser	Device	Test Group	First Contentful Paint (FCP)
11:05 – 11:06	Firefox	Mobile	Speed Kit	{200ms: 4, 500ms: 2}

Dashboarding Query Efficiency
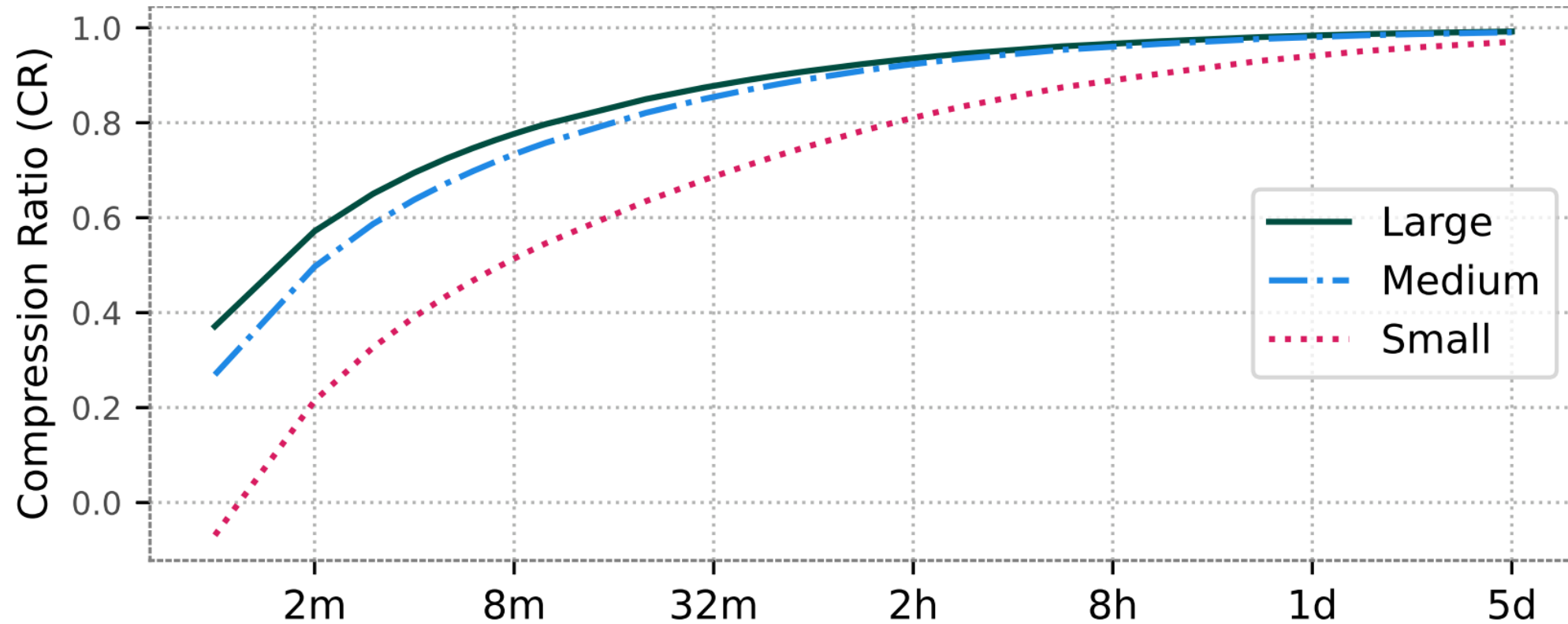
$$\text{Compaction Ratio: } CR = 1 - \frac{|\text{intermediate aggregates}|}{|PIs|}$$

Ongoing Research

- **Prefetching** & Click Prediction

- **Connection-Aware**

  - Compression & Push

  - Image Optimization

- **Vision-based**

  - Image Optimization

  - Regression Testing (QA)

  - Speed Metrics (SI/FMP)

- **Anomaly detection** on Real-User Data

- Content-based **Staleness Minimization**

- Workload-based **TTL Estimation**

- Config **Optimization**

- Dynamic Block **Inference**

- Dual & Adaptive **Bloom Filter**

Thanks!

Questions?

Material available at: **baqend.com/publications**

Contact: research@baqend.com

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🚀 **Baqend**

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