Using Kafka and Kudu for fast, low-latency SQL analytics on streaming data

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The problem

- Building a system that supports low-latency streaming and batch workloads simultaneously is hard
- Current solutions to this are complicated and error-prone (e.g. lambda arch)
- Too much expertise is currently required to make it work

Building a near-real time data architecture

How can we...

1. Enable data to flow into our query system quickly, reliably, and efficiently
2. Allow for stream-processing of this data if desired
3. Enable batch processing to access up-to-the-second information

...while keeping complexity at a minimum?

Problem domains that require stream + batch

Credit Card & Monetary Transactions

Identify fraudulent transactions as soon as they occur.

Healthcare

Continuously monitor patient vital stats and proactively identify at-risk patients.
Report on this data.

Retail

- Real-time in-store Offers and Recommendations.
- Email and marketing campaigns based on real-time social trends

Digital Advertising & Marketing

Optimize and personalize digital ads based on real-time information.

Consumer Internet, Mobile & E-Commerce

Optimize user engagement based on user's current behavior. Deliver recommendations relevant "in the moment"

Manufacturing

- Identify equipment failures and react instantly
- Perform proactive maintenance.
- Identify product quality defects immediately to prevent resource wastage.

Security & Surveillance

Identify threats and intrusions, both digital and physical, in real-time.

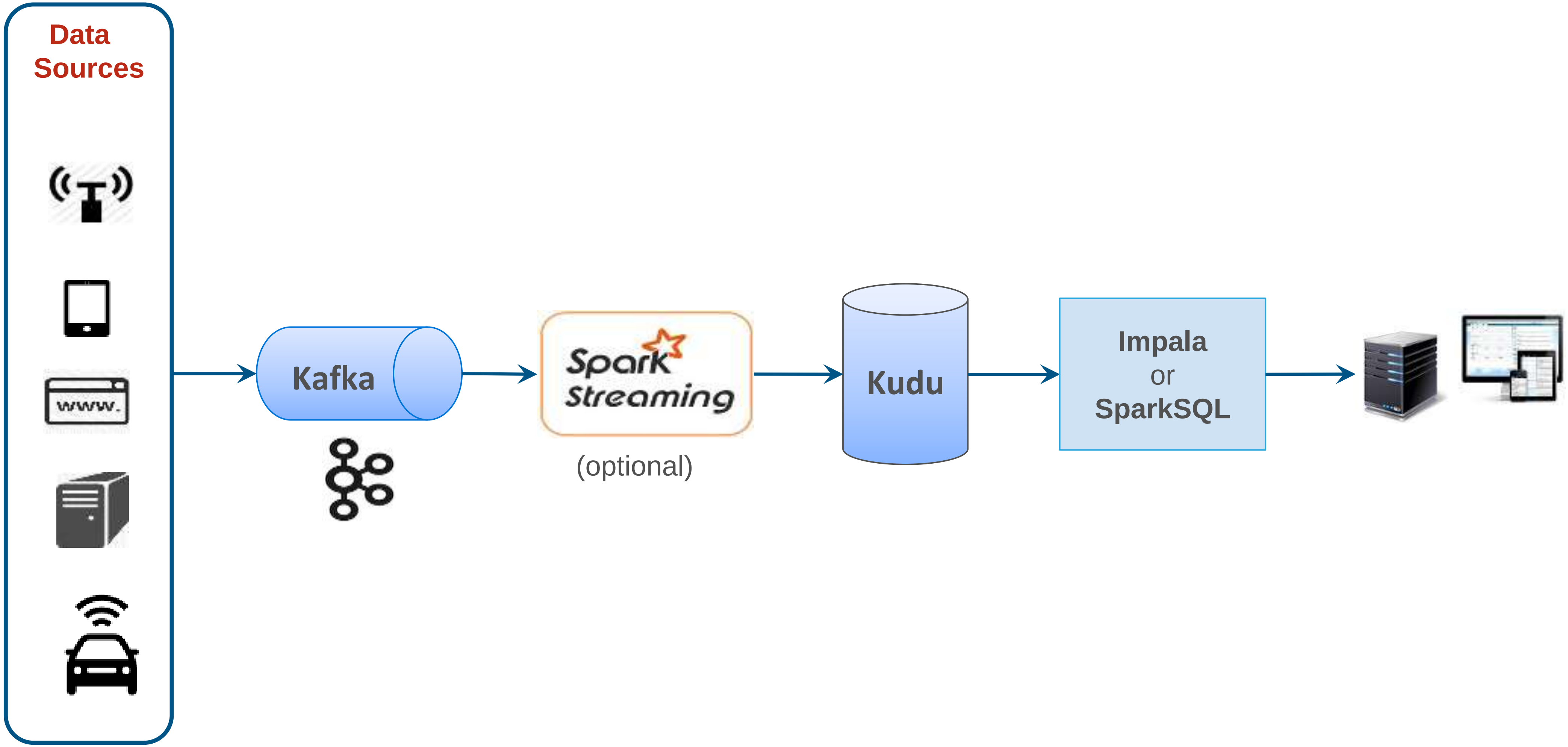
Transportation & Logistics

- Real-time traffic conditions
- Tracking fleet and cargo locations and dynamic re-routing to meet SLAs

Agenda

- A new low-latency, high throughput architecture for analytics
- Building an ingest pipeline
- Storing and querying structured data
- Design tradeoffs
- Demo
- Q&A

A modern, low-latency analytics architecture



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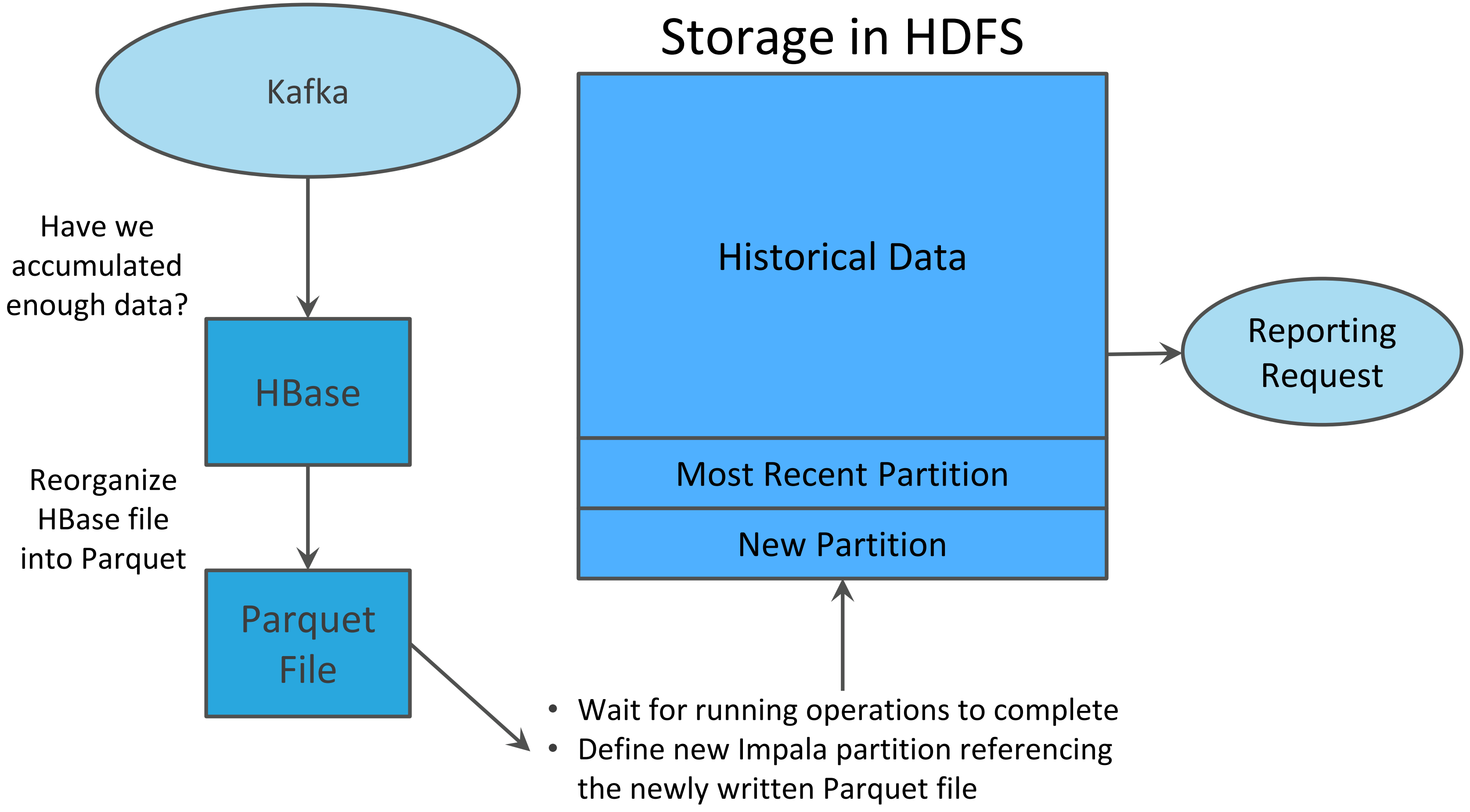
“Traditional” real-time analytics in Hadoop

Fraud detection in the real world means storage complexity

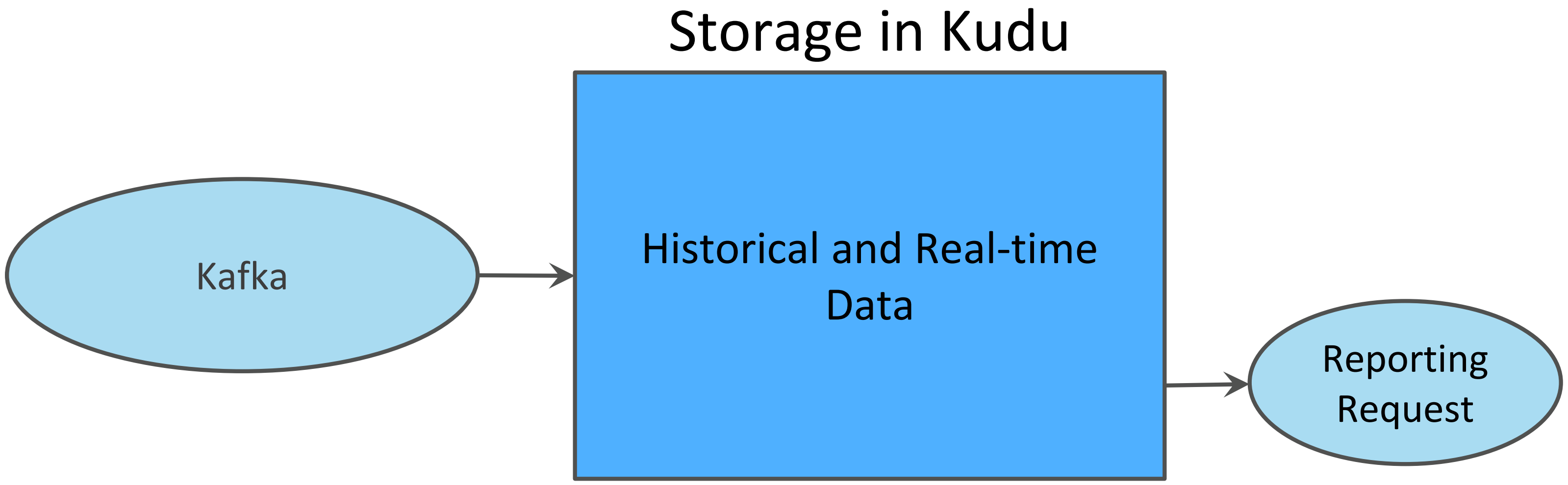


- Wait for running operations to complete
- Define new Impala partition referencing the newly written Parquet file

Considerations:

- How do I handle failure during this process?
- How often do I reorganize data streaming in into a format appropriate for reporting?
- When reporting, how do I see data that has not yet been reorganized?
- How do I ensure that important jobs aren’t interrupted by maintenance?

Real-time analytics in Hadoop with Kudu



Improvements:

- Fewer systems to operate
- No cron jobs or background processes
- Handle late arrivals or data corrections with ease
- New data available immediately for analytics or operations

Xiaomi use case

- World’s 4th largest smart-phone maker (most popular in China)
- Gather important RPC tracing events from mobile app and backend service.
- Service monitoring & troubleshooting tool.

High write throughput

- >5 Billion records/day and growing

Query latest data and quick response

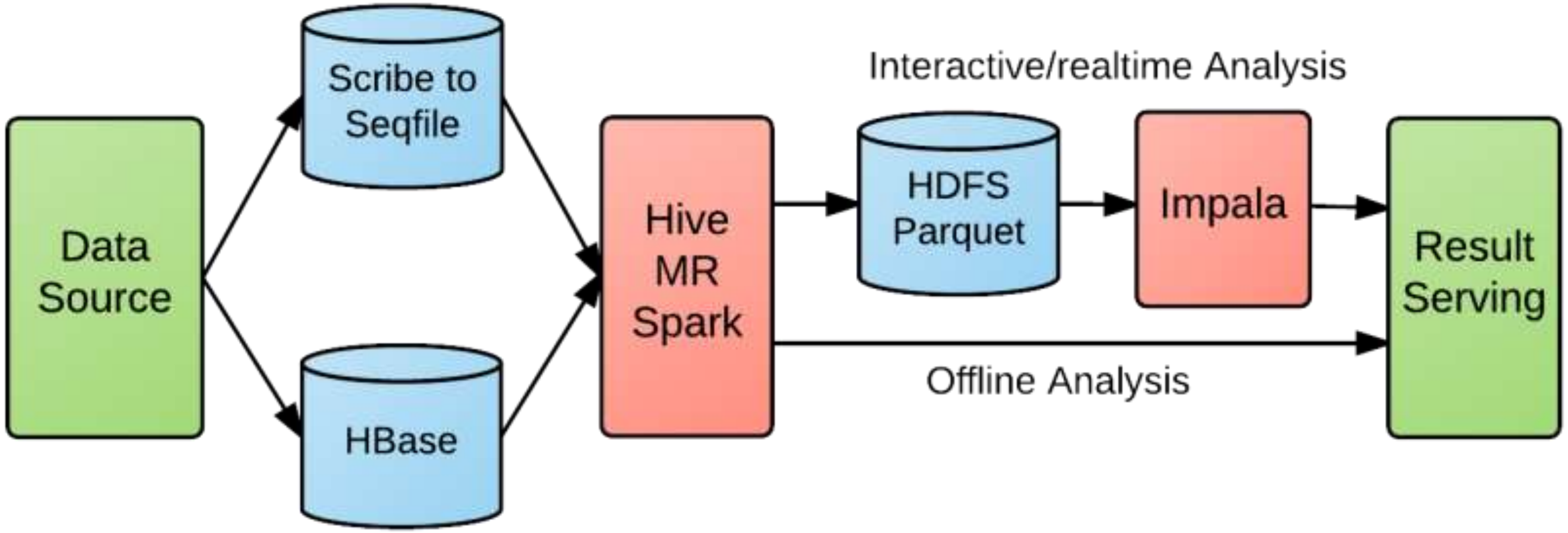
- Identify and resolve issues quickly

Can search for individual records

- Easy for troubleshooting

Xiaomi big data analytics pipeline

Before Kudu



Large ETL pipeline delays

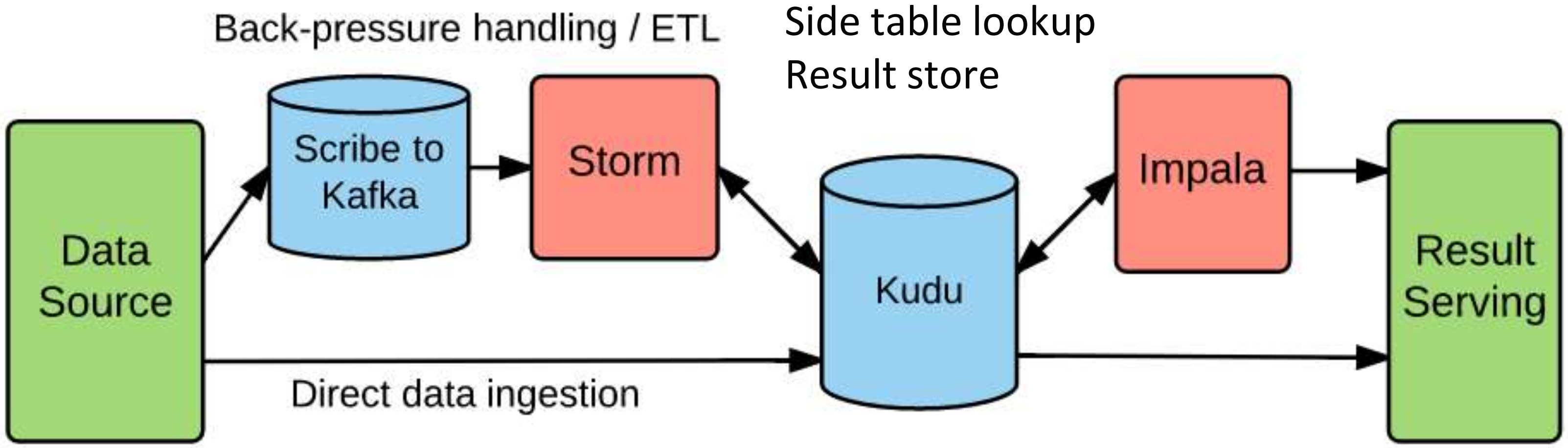
- High data visibility latency (from 1 hour up to 1 day)
- Data format conversion woes

Ordering issues

- Log arrival (storage) not exactly in correct order
- Must read 2 – 3 days of data to get all of the data points for a single day

Xiaomi big data analytics pipeline

Simplified with Kafka and Kudu



Back-pressure handling / ETL

Data Source

Scribe to Kafka

Storm

OLAP scan
Side table lookup
Result store

Kudu

Impala

Result Serving

Direct data ingestion

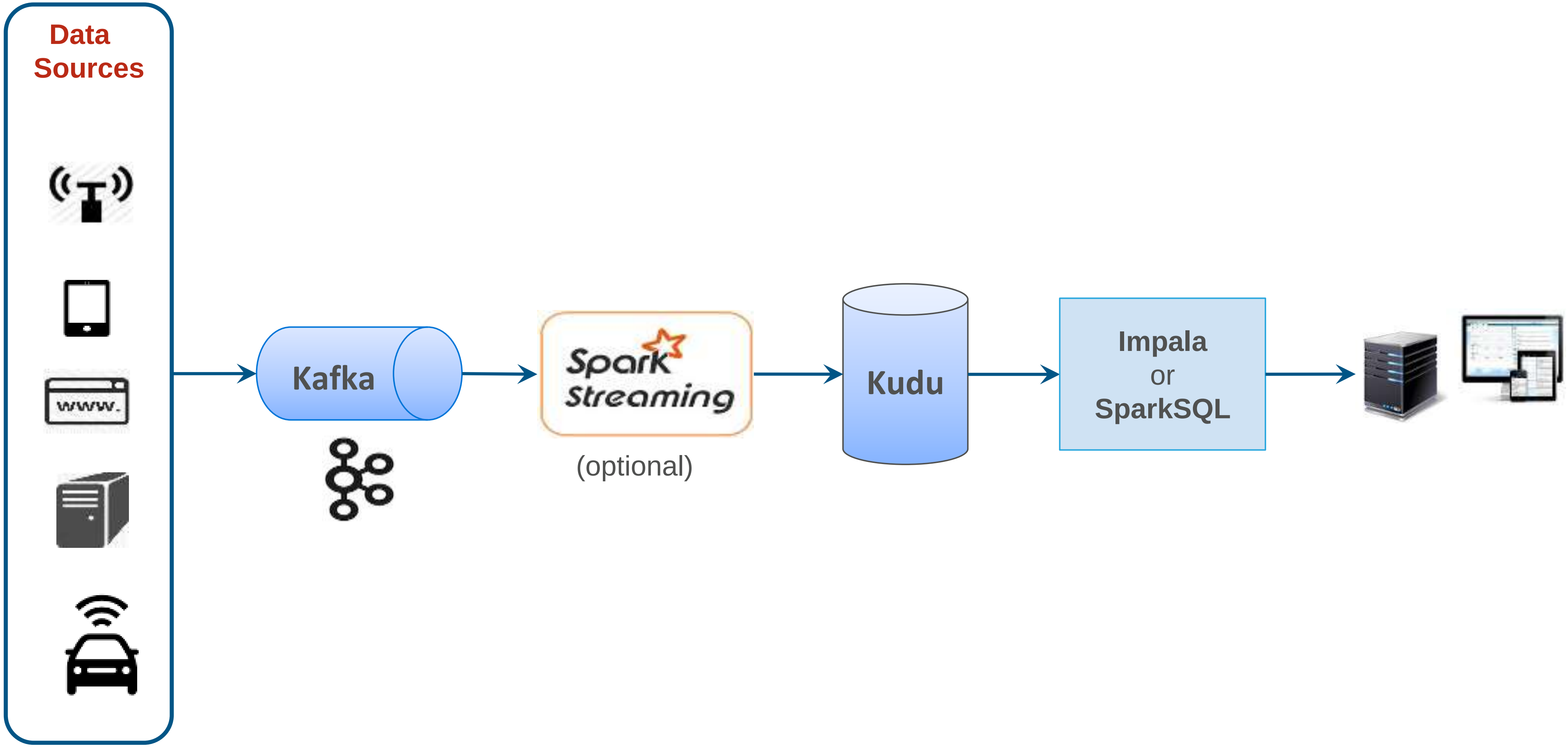
Low latency ETL pipeline

- ~10s data latency
- For apps that need to avoid direct backpressure or need ETL for record enrichment

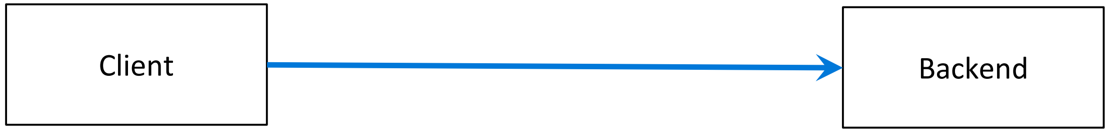
Direct zero-latency path

- For apps that can tolerate backpressure and can use the NoSQL APIs
- Apps that don’t need ETL enrichment for storage / retrieval

A modern, low-latency analytics architecture



kafka



Data Pipelines Start like this.

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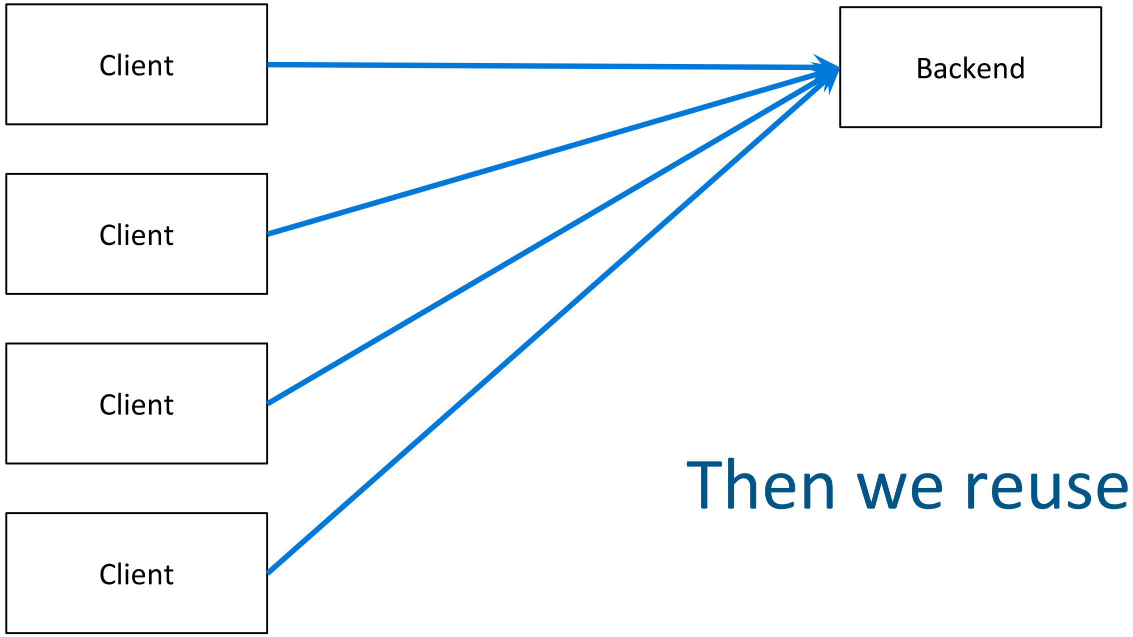
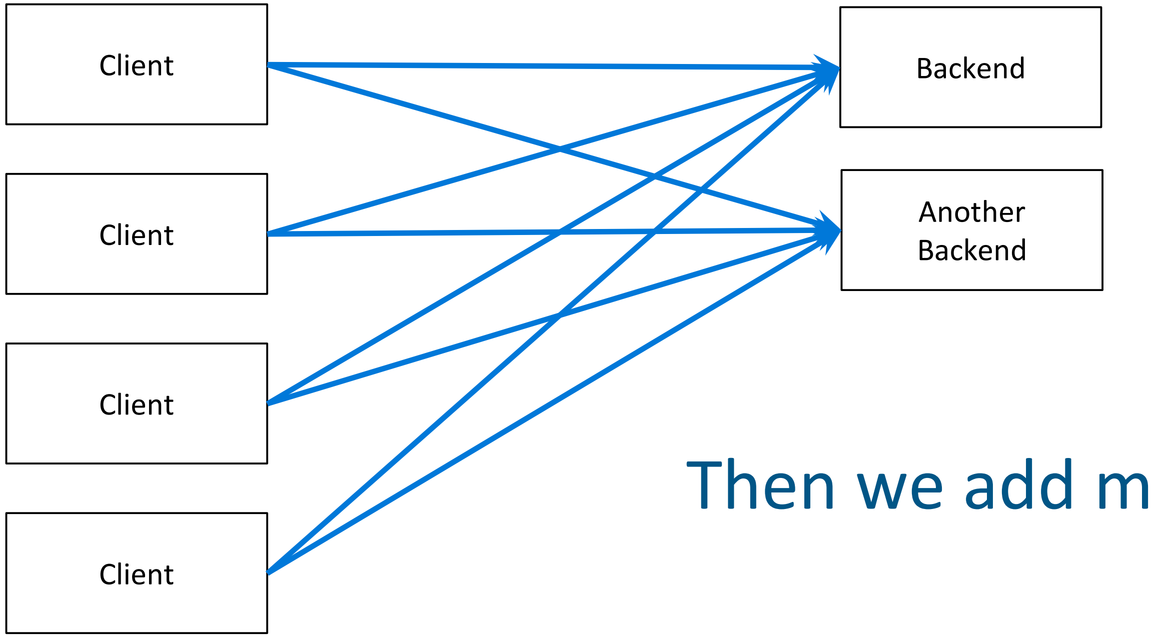
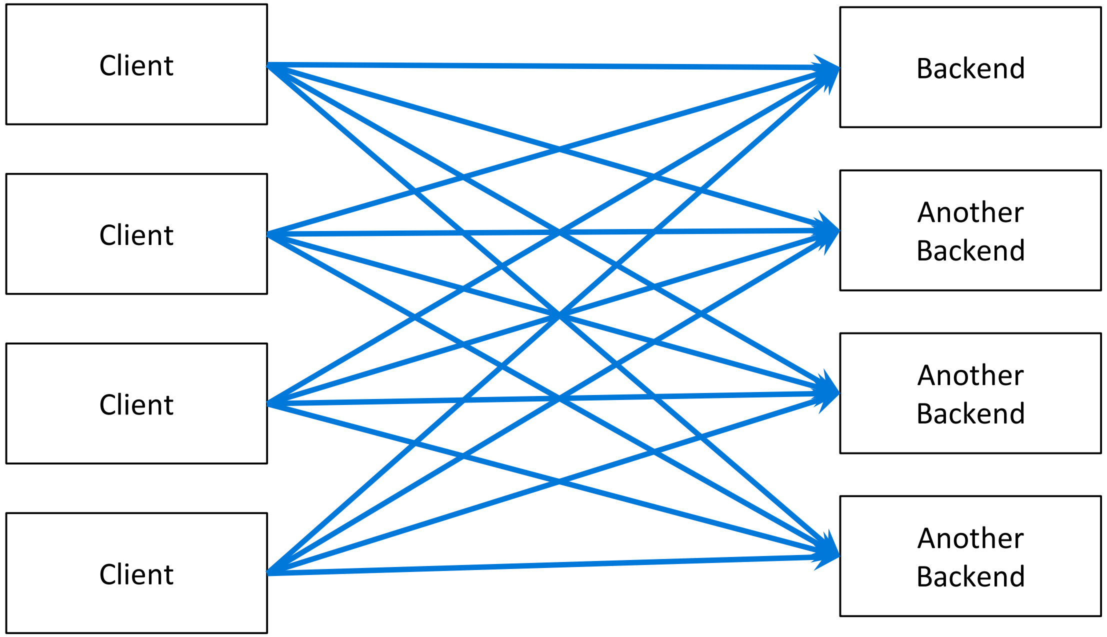


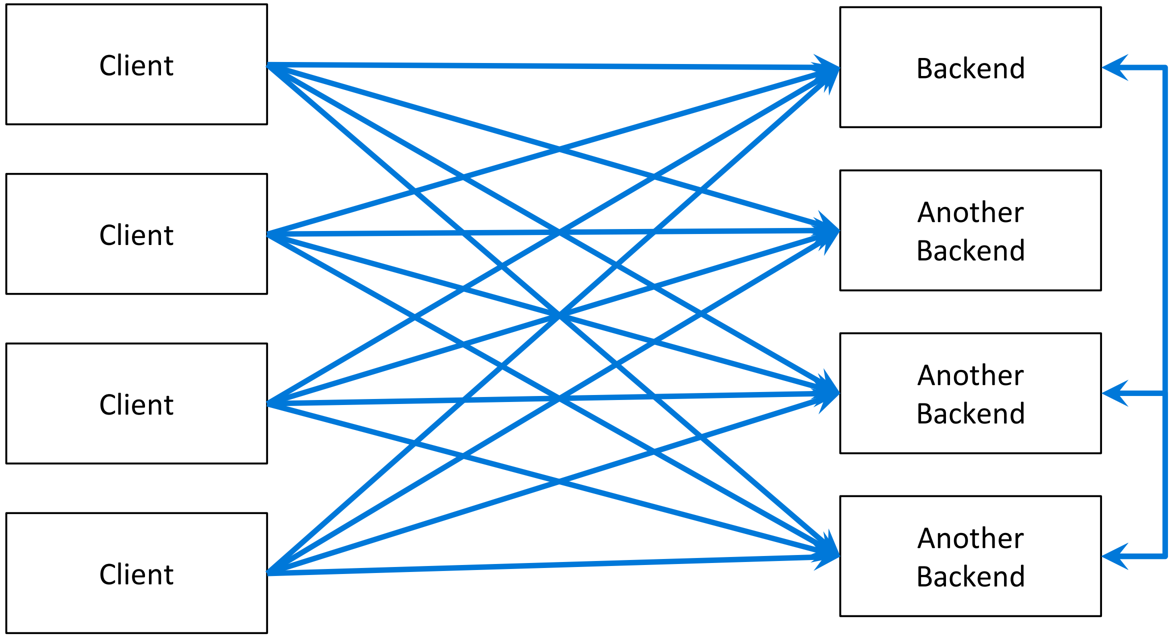
Then we reuse them



Then we add multiple backends



Then it starts to look like this



With maybe some of this

Adding applications should be easier

We need:

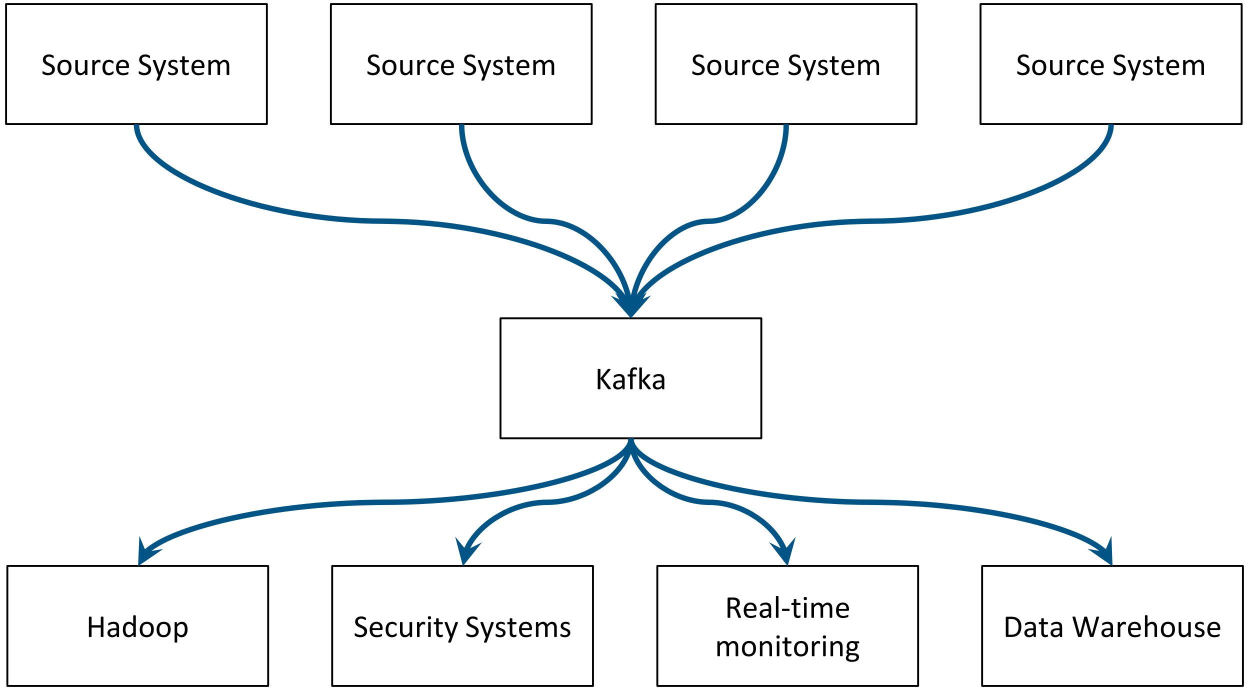
- Shared infrastructure for sending records
- Infrastructure must scale
- Set of agreed-upon record schemas

Why Kafka

Producers

Broker

Consumers



Kafka decouples data pipelines

About Kafka

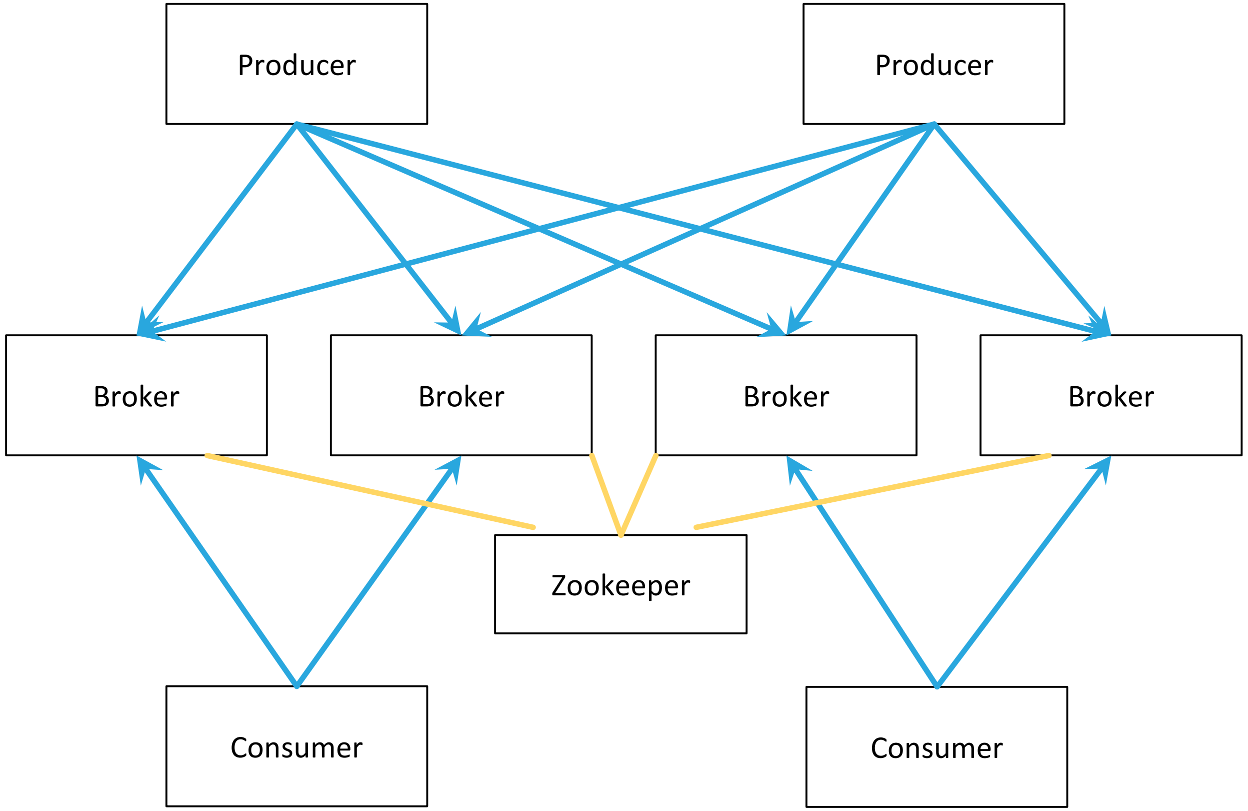
- Publish/Subscribe Messaging System From LinkedIn
- High throughput (100’s of k messages/sec)
- Low latency (sub-second to low seconds)
- Fault-tolerant (Replicated and Distributed)
- Supports Agnostic Messaging
- Standardizes format and delivery
- Huge community

Architecture

Producers

Kafka Cluster

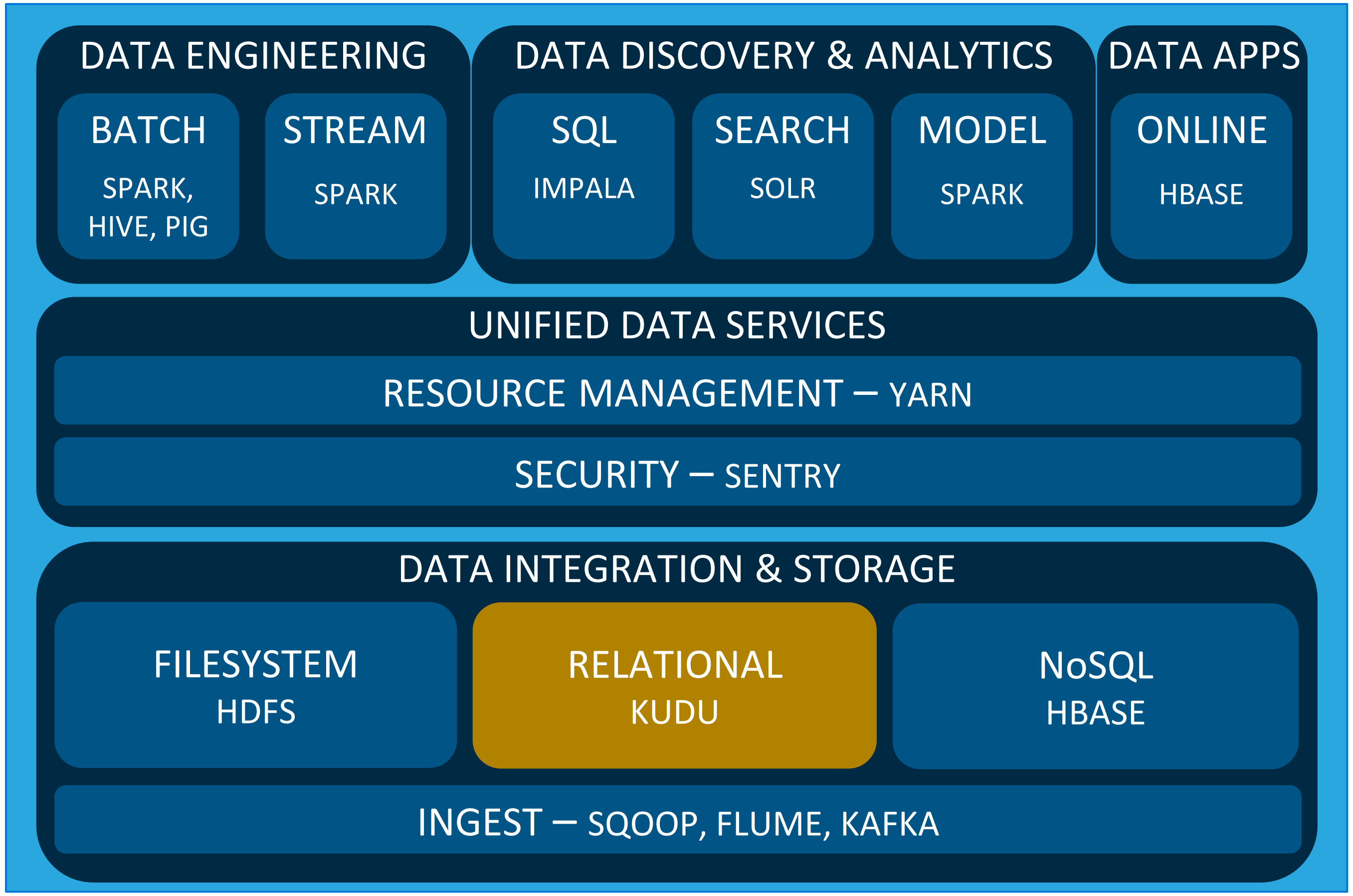
Consumers



KUDU

Kudu is a high-performance distributed storage engine

Storage for fast (low latency) analytics on fast (high throughput) data



- Simplifies the architecture for building analytic applications on changing data
- Optimized for fast analytic performance
- Natively integrated with the Hadoop ecosystem of components

Kudu: Scalable and fast tabular storage

Scalable

- Tested up to 275 nodes (~3PB cluster)
- Designed to scale to 1000s of nodes and tens of PBs

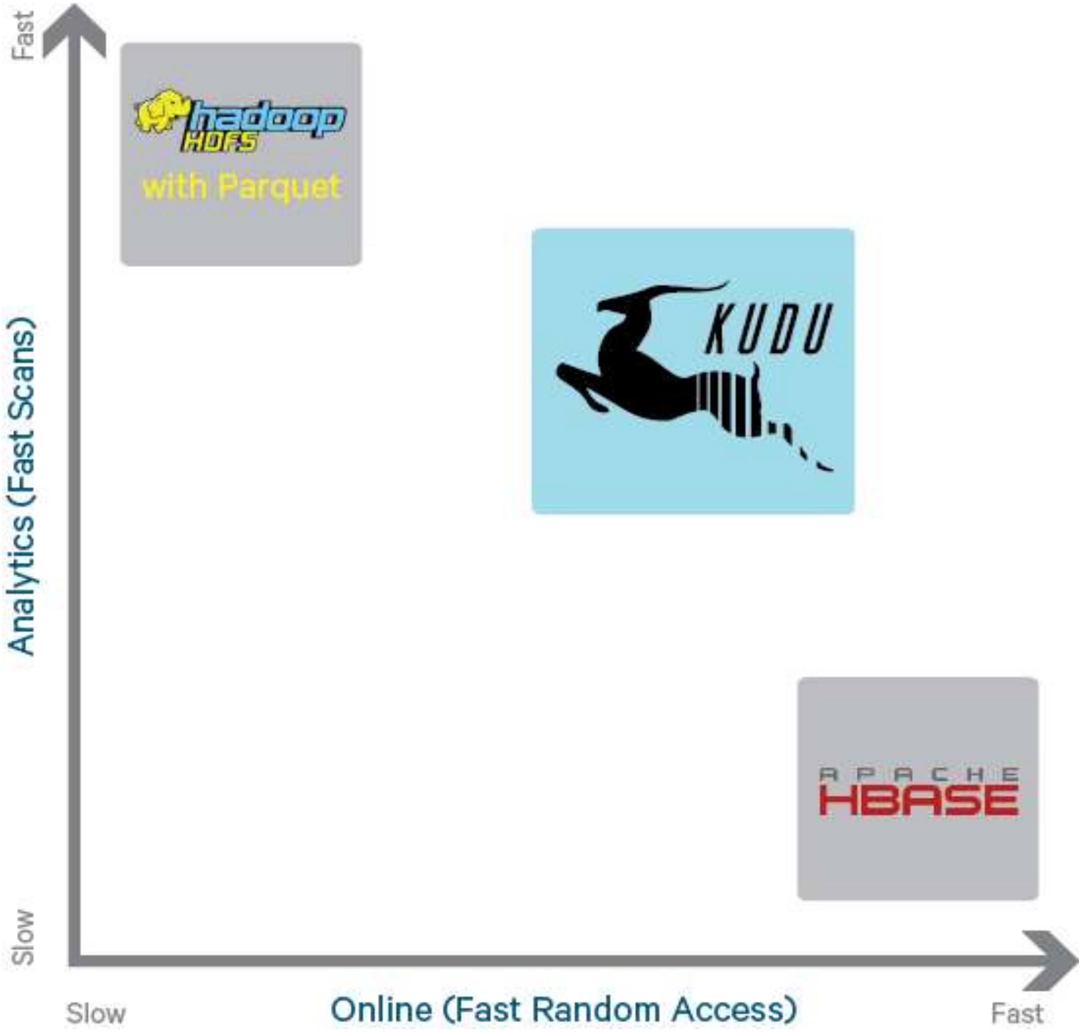
Fast

- Millions of read/write operations per second across cluster
- Multiple GB/second read throughput per node

Tabular

- Store tables like a normal database
- Individual record-level access to 100+ billion row tables

Kudu design goals



- High throughput for big scans
  Goal: Within 2x of Parquet

- Low-latency for short accesses
  Goal: 1ms read/write on SSD

- Database-like semantics
  Initially, single-row atomicity

- Relational data model
  - SQL queries should be natural and easy
  - Include NoSQL-style scan, insert, and update APIs

Kudu storage system interfaces

- A Kudu table has a SQL-like schema
  - And a finite number of columns (unlike HBase/Cassandra)
  - Types: BOOL, INT8, INT16, INT32, INT64, FLOAT, DOUBLE, STRING, BINARY, TIMESTAMP
  - Some subset of columns makes up a possibly-composite primary key
  - Fast ALTER TABLE
- Java, C++, and Python NoSQL-style APIs
  - Insert(), Update(), Delete(), Scan()
- Integrations with Kafka, MapReduce, Spark, Flume, and Impala
  - Apache Drill work-in-progress

Kudu use cases

Kudu is best for use cases requiring:

- Simultaneous combination of sequential and random reads and writes
- Minimal to zero data latencies

Time series

- Examples: Streaming market data, fraud detection / prevention, risk monitoring
- Workload: Insert, updates, scans, lookups

Machine data analytics

- Example: Network threat detection
- Workload: Inserts, scans, lookups

Online reporting / data warehousing

- Example: Operational data store (ODS)
- Workload: Inserts, updates, scans, lookups

Tables and tablets

- Each table is horizontally partitioned into tablets
  - *Range* or *hash* partitioning
    - `PRIMARY KEY (host, metric, timestamp) DISTRIBUTE BY HASH(timestamp) INTO 100 BUCKETS`
    - Translation: `bucketNumber = hashCode(row[‘timestamp’]) % 100`
- Each tablet has N replicas (3 or 5), kept consistent with Raft consensus
- Tablet servers host tablets on local disk drives

Metadata

- Replicated master
  - Acts as a tablet directory
  - Acts as a catalog (which tables exist, etc)
  - Acts as a load balancer (tracks TS liveness, re-replicates under-replicated tablets)
- Caches all *metadata* in RAM for high performance
- Client configured with master addresses
  - Asks master for tablet locations as needed and caches them

Impala integration

- `CREATE TABLE … DISTRIBUTE BY HASH(col1) INTO 16 BUCKETS AS SELECT … FROM …`
- `INSERT/UPDATE/DELETE`

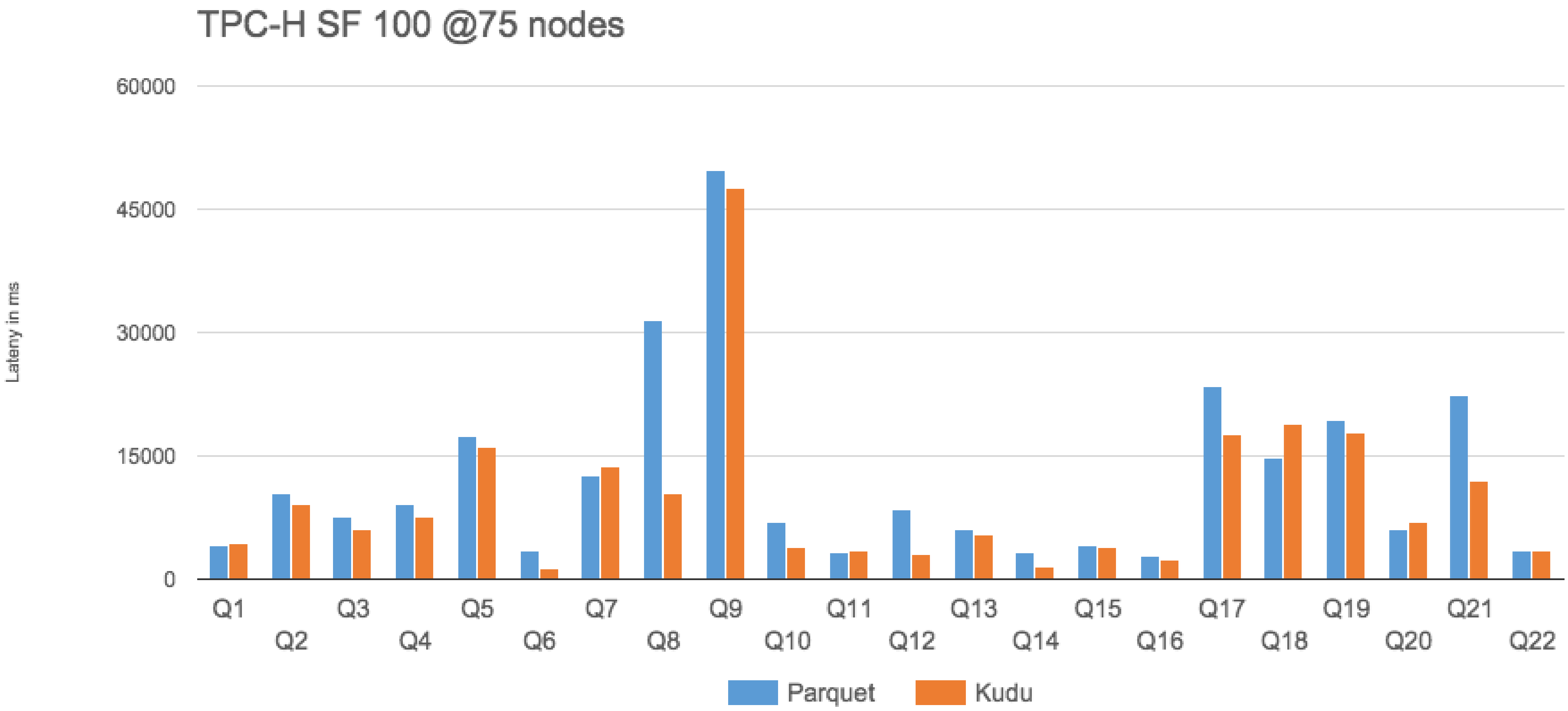
- Optimizations like predicate pushdown, scan parallelism, plans for more on the way

Spark DataSource integration

```
sqlContext.load("org.kududb.spark",
     Map("kudu.table" -> “foo”,
         "kudu.master" -> “master.example.com”))
   .registerTempTable(“mytable”)
df = sqlContext.sql(
   “select col_a, col_b from mytable “ +
   “where col_c = 123”)
```

TPC-H (analytics benchmark)

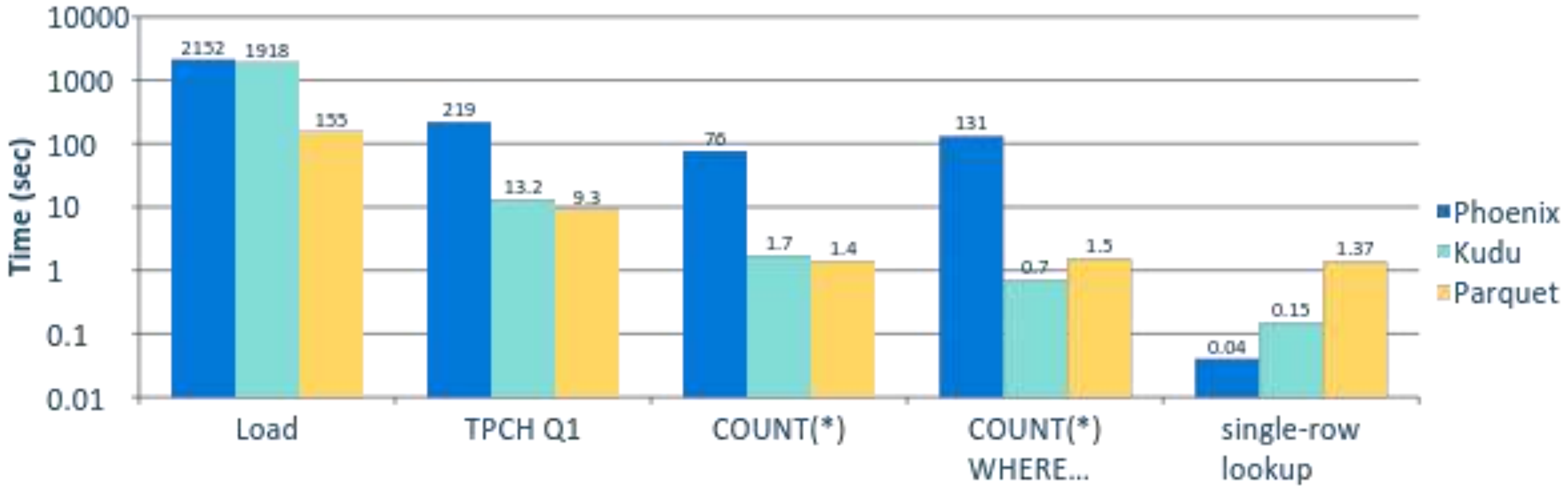
- 75 server cluster
  - 12 (spinning) disks each, enough RAM to fit dataset
  - TPC-H Scale Factor 100 (100GB)
- Example query:
  - `SELECT n_name, sum(l_extendedprice * (1 - l_discount)) as revenue FROM customer, orders, lineitem, supplier, nation, region WHERE c_custkey = o_custkey AND l_orderkey = o_orderkey AND l_suppkey = s_suppkey AND c_nationkey = s_nationkey AND s_nationkey = n_nationkey AND n_regionkey = r_regionkey AND r_name = 'ASIA' AND o_orderdate >= date '1994-01-01' AND o_orderdate < '1995-01-01’ GROUP BY n_name ORDER BY revenue desc;`



- Kudu outperforms Parquet by 31% (geometric mean) for RAM-resident data

Versus other NoSQL storage

- **Apache Phoenix: OLTP SQL engine built on HBase**
- 10 node cluster (9 worker, 1 master)
- TPC-H LINEITEM table only (6B rows)



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Getting Data from Kafka into Kudu

- Custom client, i.e., Kafka consumer that writes to Kudu

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- Kafka-Flume source/channel + Kudu-Flume sink

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- Kafka connect

Kafka + Kudu: A low latency data visibility path

- Upstream application pushes data to Kafka
- Kafka then acts as a buffer in order to handle backpressure from Kudu
- The Kafka Connect plugin pushes data to Kudu as it becomes available
- As soon as the data is ingested into Kudu, it becomes available

Tradeoffs

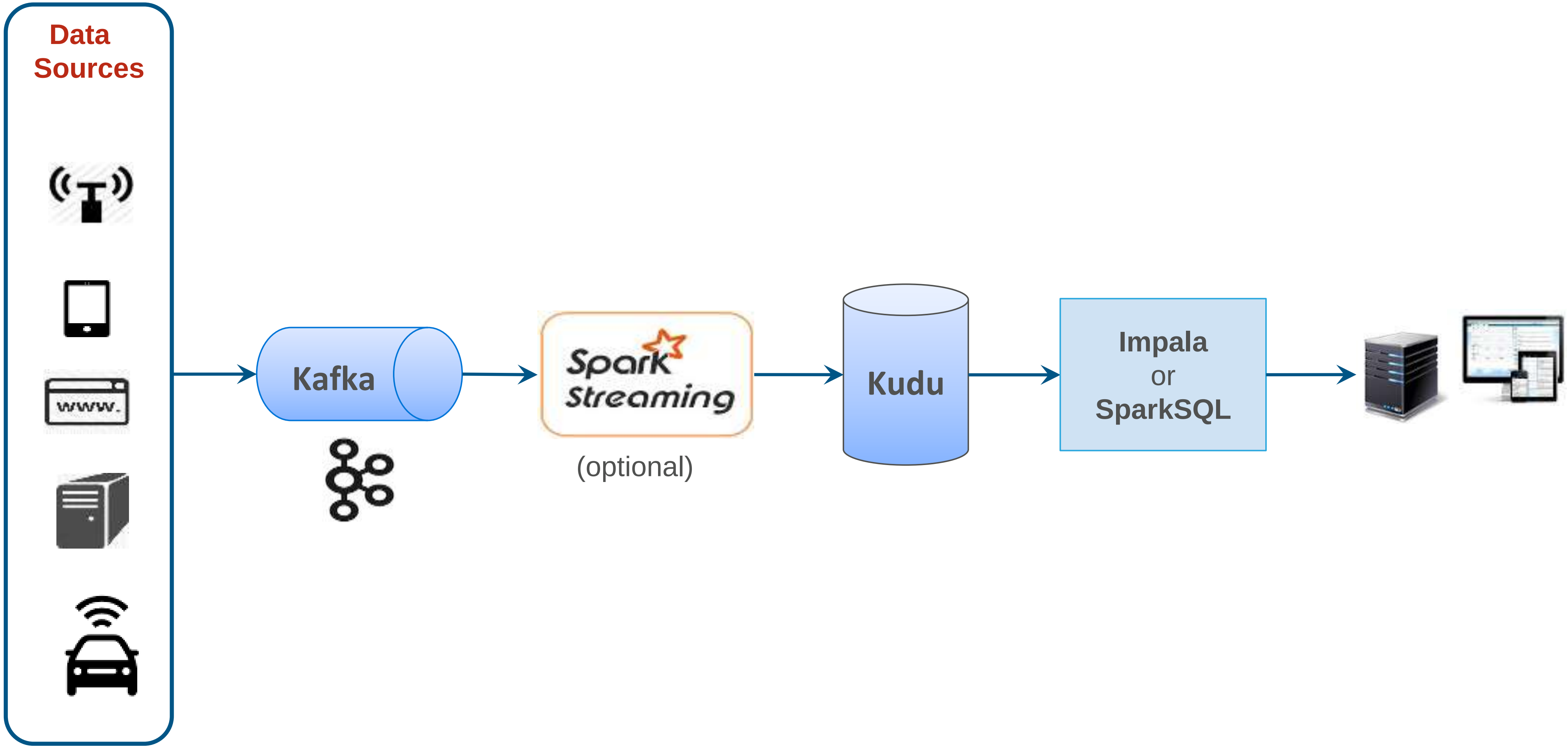
What if I need a zero-latency path?

- Possible to write to Kudu directly using the NoSQL API
- However, the app will need to tolerate queueing and backpressure itself

What if I want to store unstructured data or large binary blobs?

- Consider using Kafka + HBase instead of Kudu
    - But you won’t get the same SQL query performance

Demo



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About the Kudu project

- Apache Software Foundation incubating project
- Latest version 0.8.0 (beta) released in April
- Plans are for a 1.0 version to be released in August
- Web site: getkudu.io (also kudu.incubator.apache.org soon)
- Slack chat room for devs and users (auto-invite): getkudu-slack.herokuapp.com
- Twitter handle: @ApacheKudu
- Code: github.com/apache/incubator-kudu

Want to hear more about Kudu and Spark?

- Come to the Vancouver Spark meetup tonight here at the Hyatt at 6pm
- More info: www.meetup.com/Vancouver-Spark/

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Thank you

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Questions?

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