Design Patterns for working with Fast Data

Ian Downard, Technical Evangelist with MapR

Portland Java User Group
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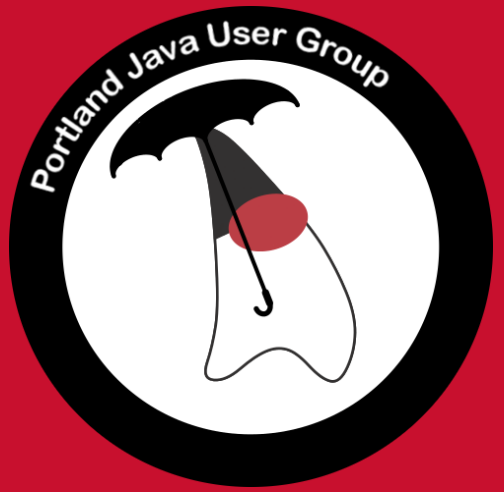

Abstract

- Apache Kafka is an open-source message broker project that provides a platform for storing and processing real-time data feeds. In this presentation Ian Downard will describe the concepts that are important to understand in order to effectively use the Kafka API. You will see how to prepare a development environment from scratch, how to write a basic publish/subscribe application, and how to run it on a variety of different cluster types, starting with a single-node cluster on Virtual Box, then on multi-node cluster using Heroku's "Kafka as a Service", and finally on an enterprise-grade multi-node cluster using MapR's Converged Data Platform.
- Ian will also discuss strategies for working with "fast data" and how to maximize the throughput of your Kafka pipeline. He'll describe which Kafka configurations and data types have the largest impact on performance and provide some useful JUnit tests, combined with statistical analysis in R, that can help quantify how various configurations effect throughput.
- The code and presentation for this talk will be available at https://github.com/iandow/design-patterns-for-fast-data

Author

- Ian Downard is a technical evangelist for MapR where he is focused on creating developer-friendly ways to use the MapR Converged Data Platform.

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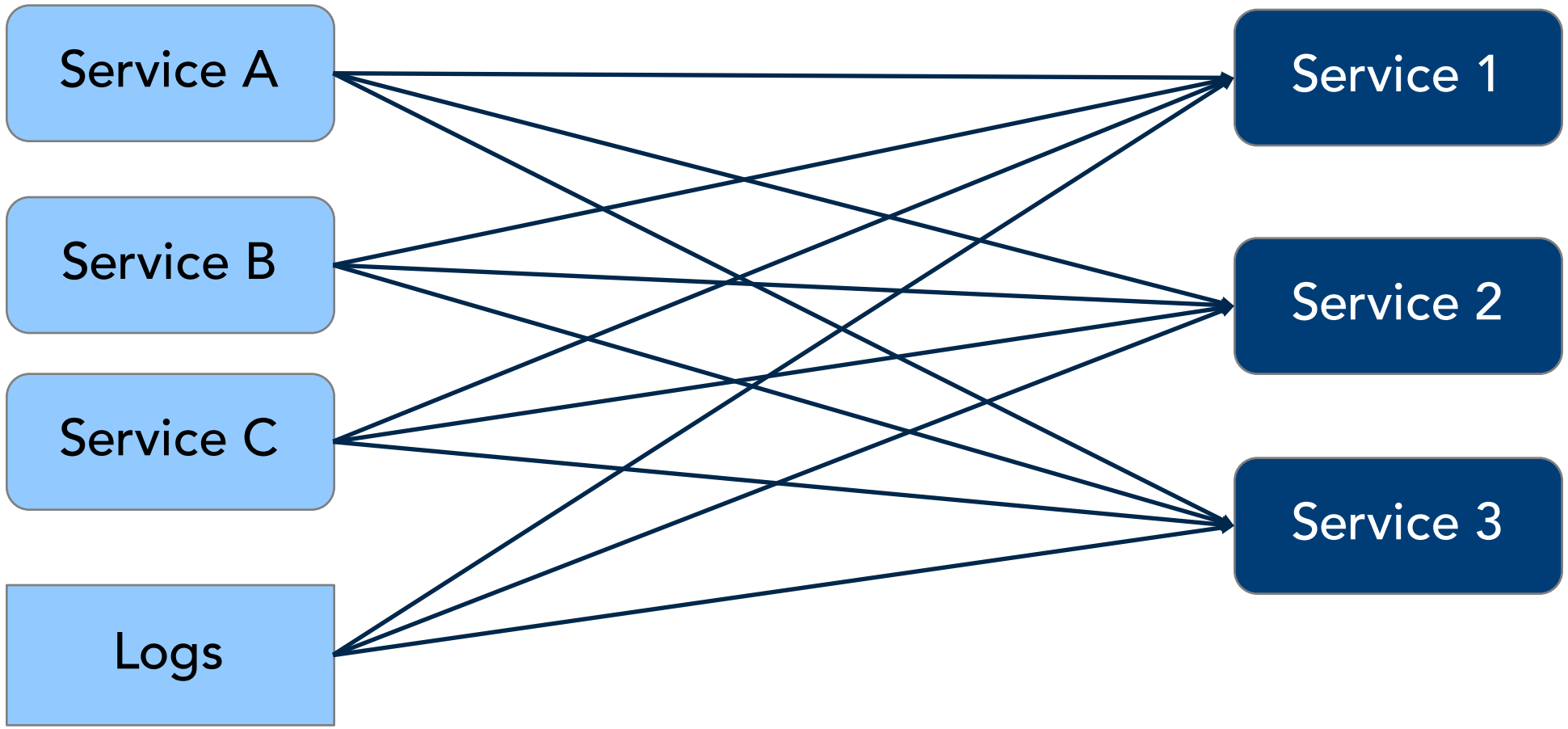
- GitHub: https://github.com/iandow
- LinkedIn: https://www.linkedin.com/in/iandownard

What is Kafka?

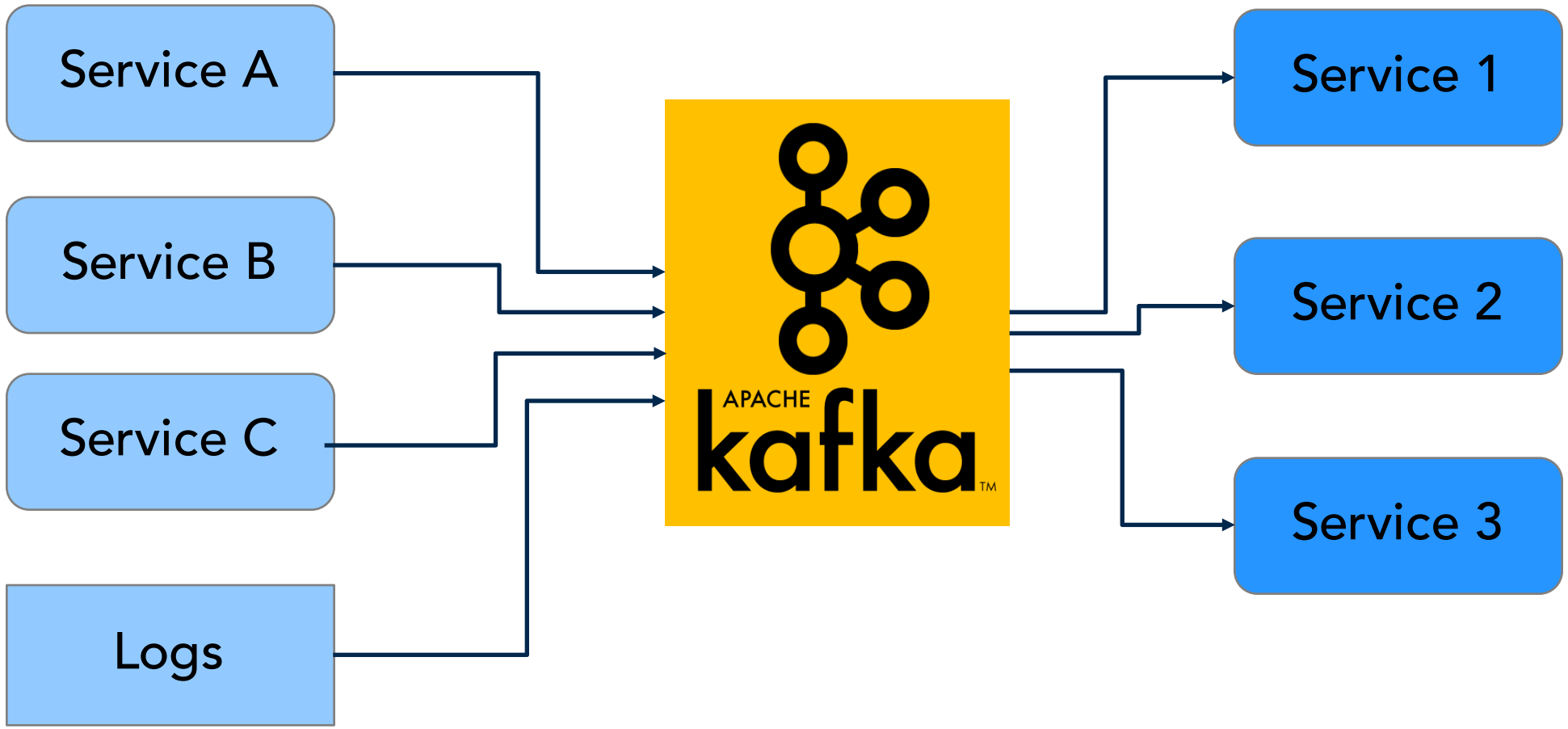
- A distributed publish-subscribe messaging system.
- Persists on disk (not “in-memory”).
- Supports true streaming (not just fast batching).
- Can be used for data storage AND data processing (not just storage)
- Oriented around small messages and dynamic data sets (i.e. “streams”).



How many connections?

m Consumers

n Producers



How many connections?

n Producers

m Consumers

Kafka Strengths

- Elastic, fault tolerant, and low latency.
  - Fits well into microservice architectures.
- Low CapEx message bus for Big Data.
- Supports both real-time processing and short-term storage.
- Kafka is becoming the default for inter-service communication.

Who is streaming data?

- Retail: orders, sales, shipments, price adjustments
- Financial Services: stock prices, credit card fraud
- Web sites: clicks, impressions, searches, web click fraud
- Operating Systems: machine metrics, and logs

Some examples of streaming datasets

- Social Media
  - https://dev.twitter.com/streaming/overview
- IoT
  - Lots of examples at https://data.sparkfun.com/streams/
  - http://dweet.io is pretty cool
- Servers:
  - /var/log/syslog
  - tcpdump
- Banking
  - Yahoo Finance API: **https://github.com/cjmatta/TwitterStream**, **http://meumobi.github.io/stocks%20apis/2016/03/13/get-realtime-stock-quotes-yahoo-finance-api.html**
  - NYSE markets: http://www.nyxdata.com/Data-Products/Daily-TAQ
- Other
  - screen scrape anything

The Streaming APIs

Overview

The Streaming APIs give developers low latency access to Twitter's global stream of Tweet data. A proper implementation of a streaming client will be pushed messages indicating Tweets and other events have occurred, without any of the overhead associated with polling a REST endpoint.

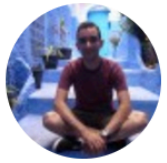
If your intention is to conduct singular searches, read user profile information, or post Tweets, consider using the REST APIs instead.

Twitter offers several streaming endpoints, each customized to certain use cases.

Public streams	Streams of the public data flowing through Twitter. Suitable for following specific users or topics, and data mining.
User streams	Single-user streams, containing roughly all of the data corresponding with a single user's view of Twitter.
Site streams	The multi-user version of user streams. Site streams are intended for servers which must connect to Twitter on behalf of many users.

adilmoujahid.com/posts/2014/07/twitter-analytics/

http://adilmoujahid.com/posts/2014/07/twitter-analytics/

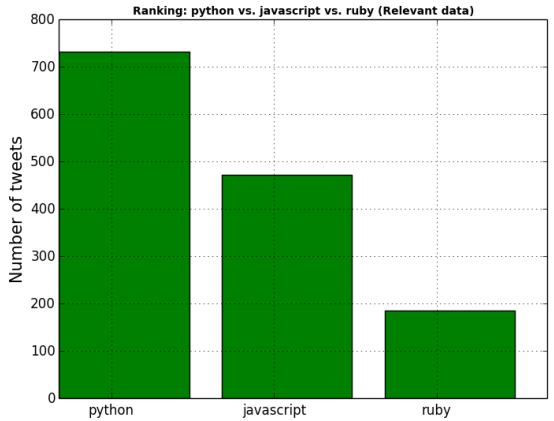


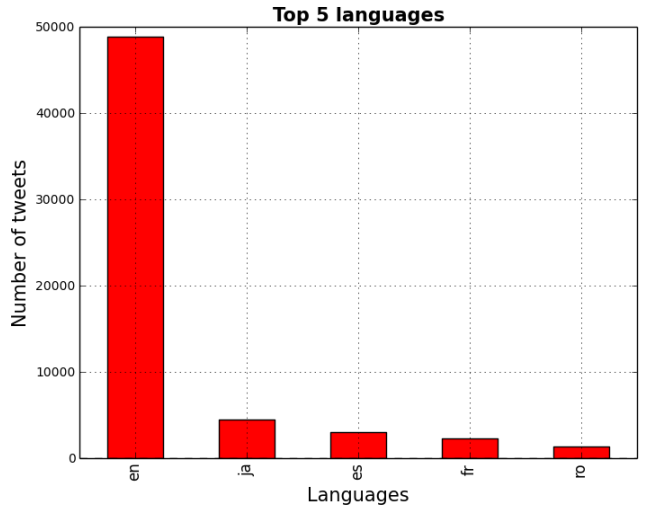
Adil Moujahid

An Introduction to Text Mining using Twitter Streaming API and Python

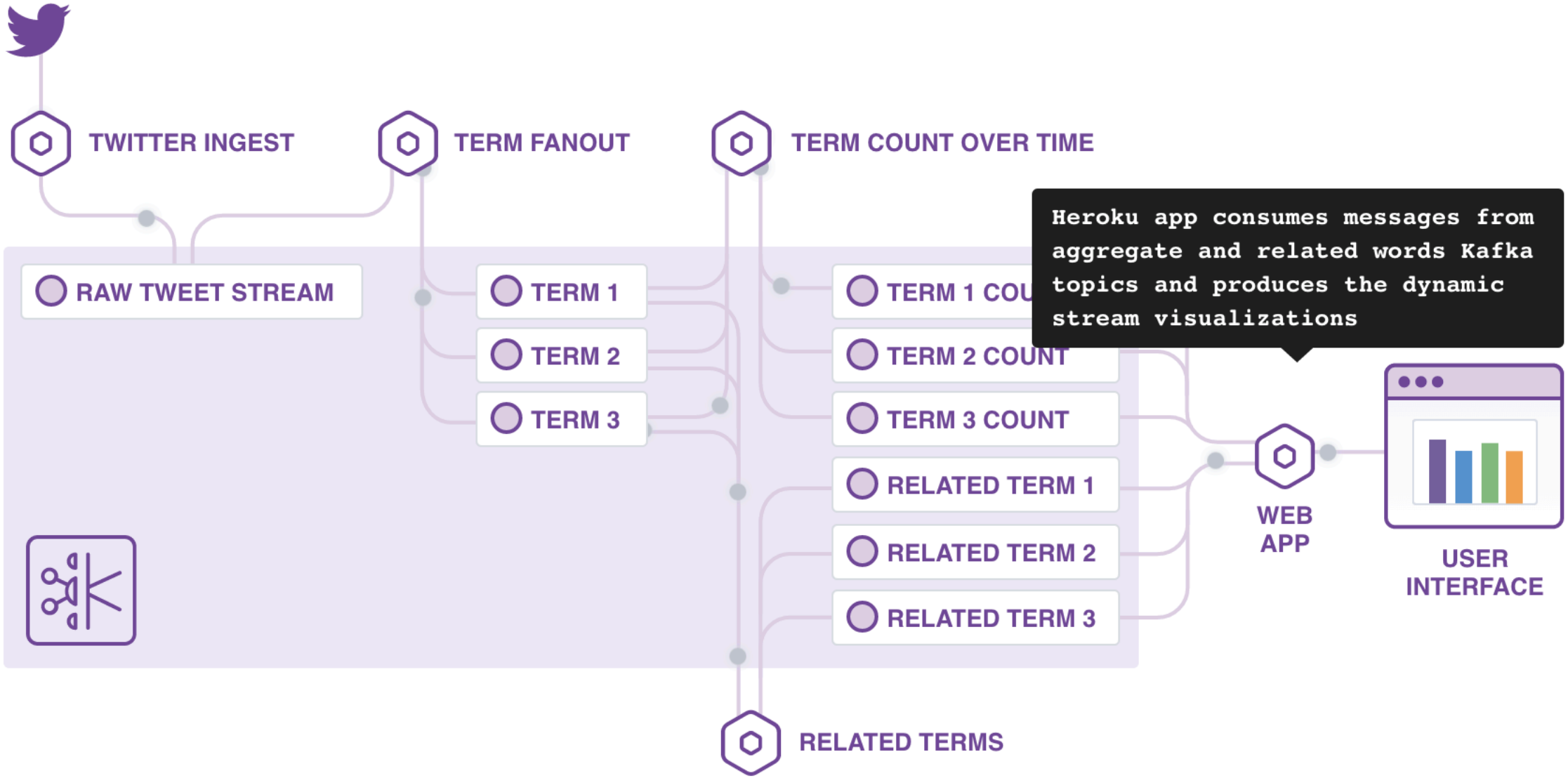
// tags python pandas text mining matplotlib twitter api

"Text mining is the application of natural language processing techniques and analytical methods to text data in order to derive relevant information."

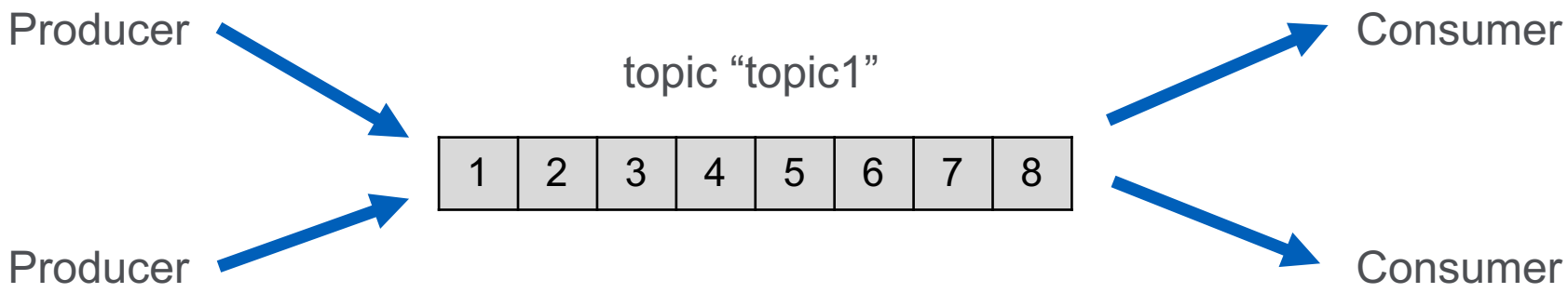




https://heroku.github.io/kafka-demo/

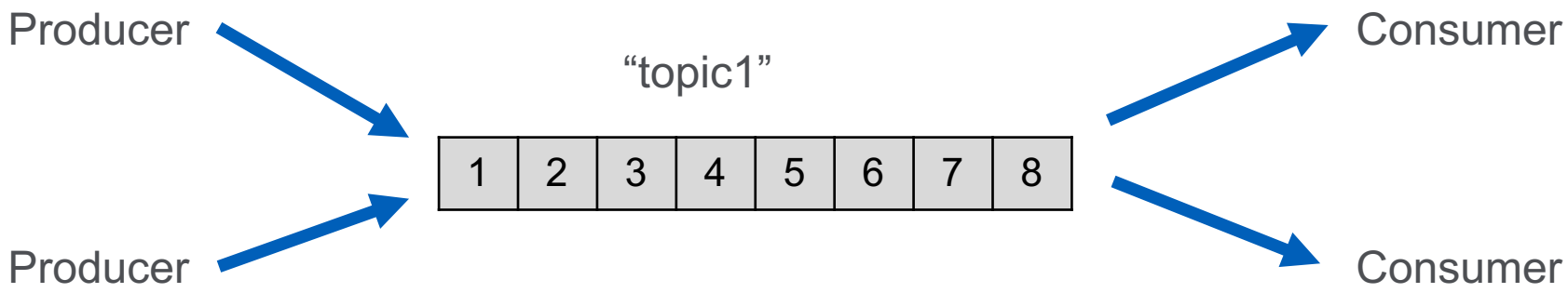


Message Log



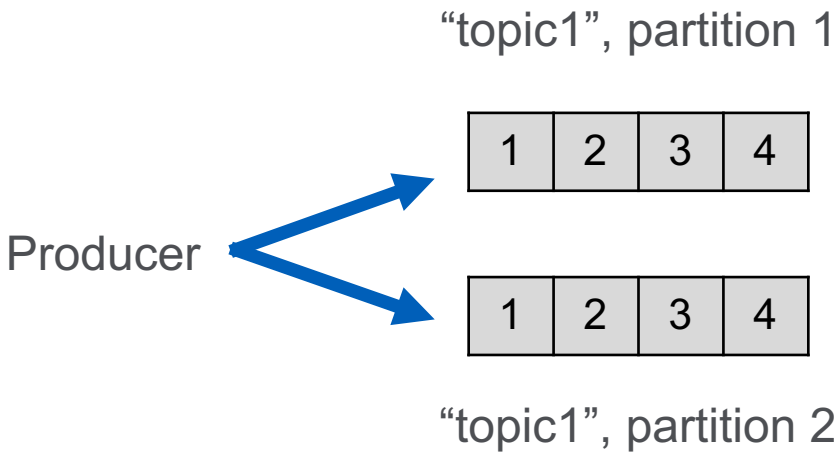
- Messages contain <Key, Value>
- delivered in order
- transferred as bytes (you specify serializer / deserializer)
- remain available for TTL
- with **at least once semantics**

Message Log



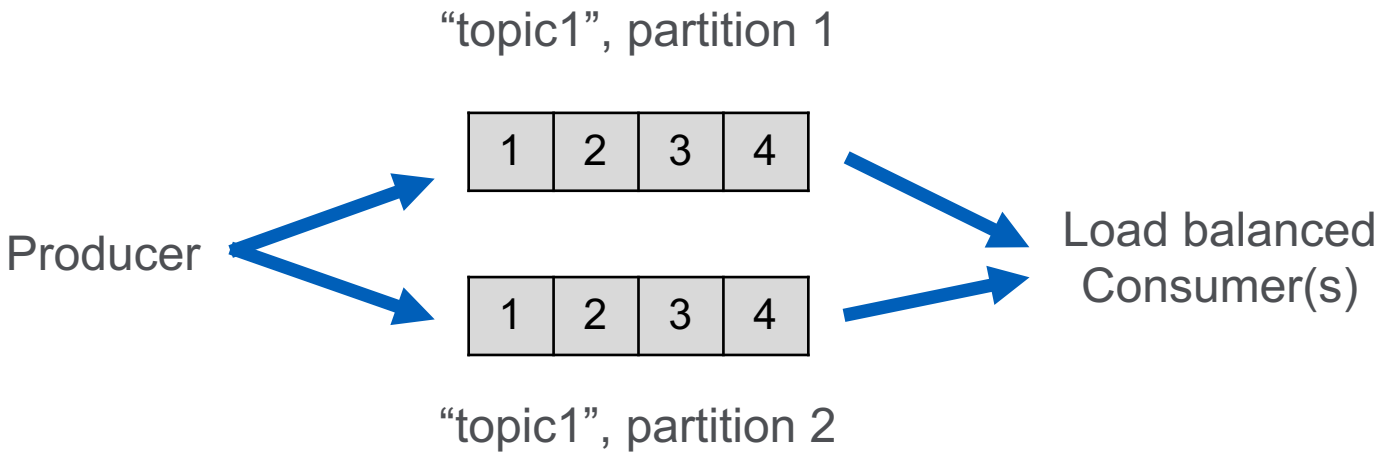
- Producers send messages one at a time
- Consumers subscribe to topics, poll for messages, and receive records many at a time

Partitioning



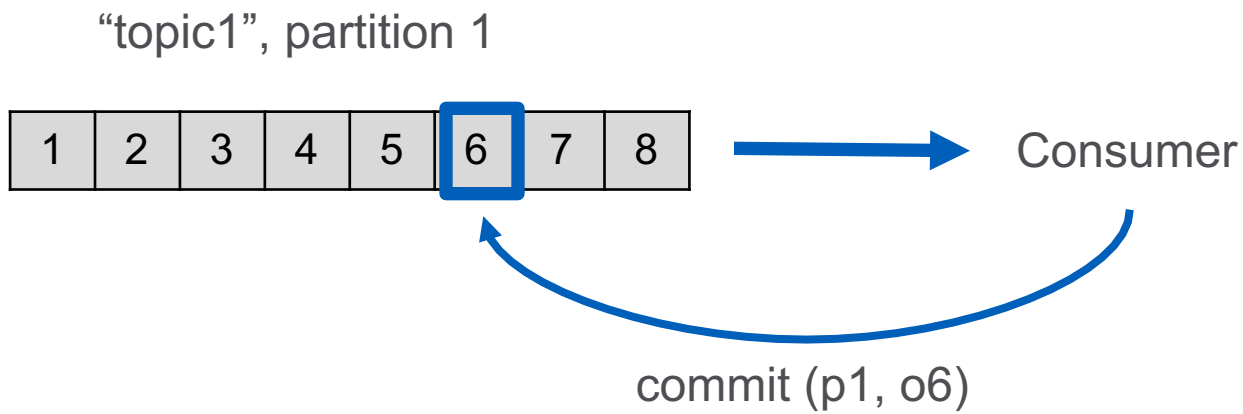
- Producer sees a topic as one logic object.
- The order of messages within a single partition is guaranteed

Partitioning



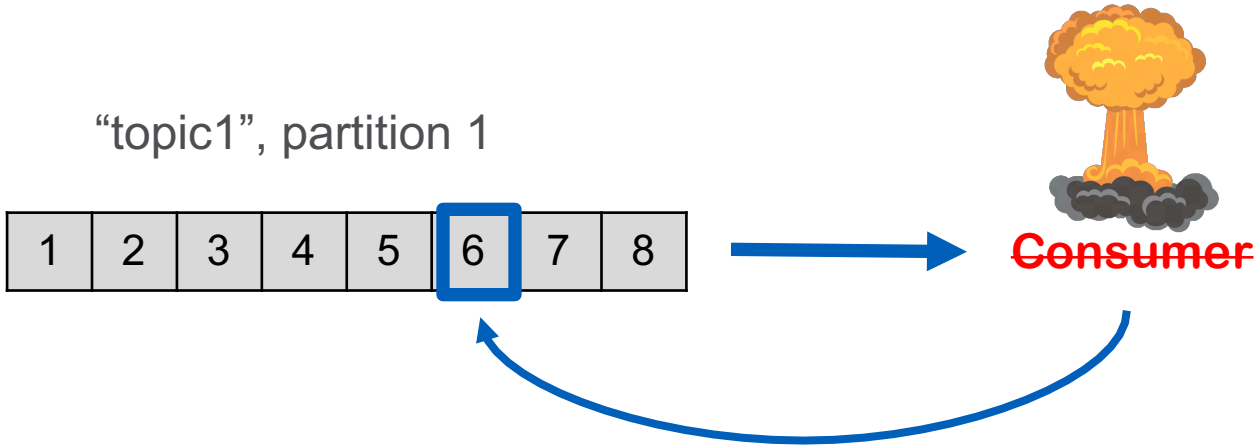
- A single partition can only be read by one consumer.
- Partitioning facilitates concurrent consumers.
- New consumers are automatically assigned a partition.

Commit



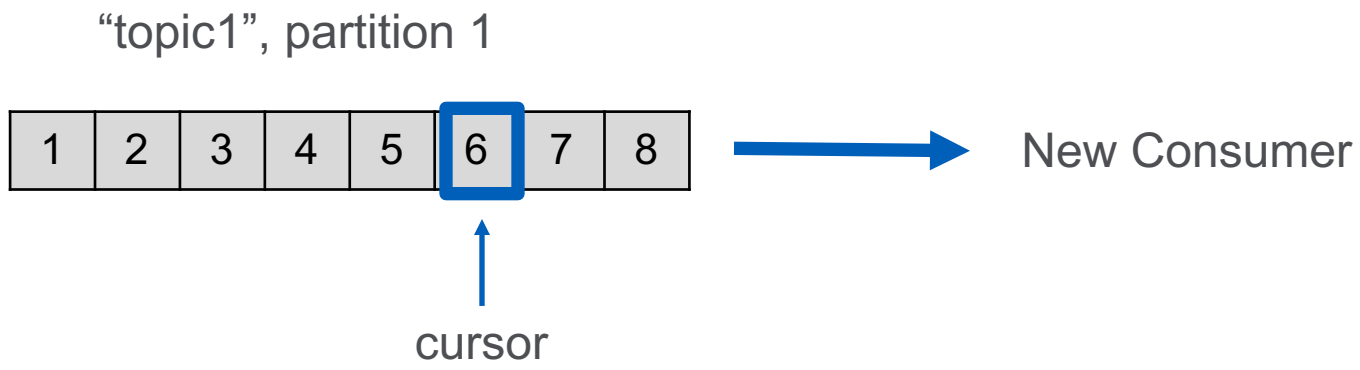
- Calling commit marks where a consumer has finished processing.

Commit



- Thanks to commit, when a consumer crashes, we let it.

Commit



- When another consumer takes its place, it continues where the old consumer left off.

Kafka depends on Zookeeper

- **Leader election** – each partition has a leader
- **Cluster membership** – broker up/down status
- **Topic Configurations** – topic names, partitions, replicas, TTLs…

DEMO: Kafka CLI

- Create, alter, pub/sub, and delete topic.
- See where topics are saved.

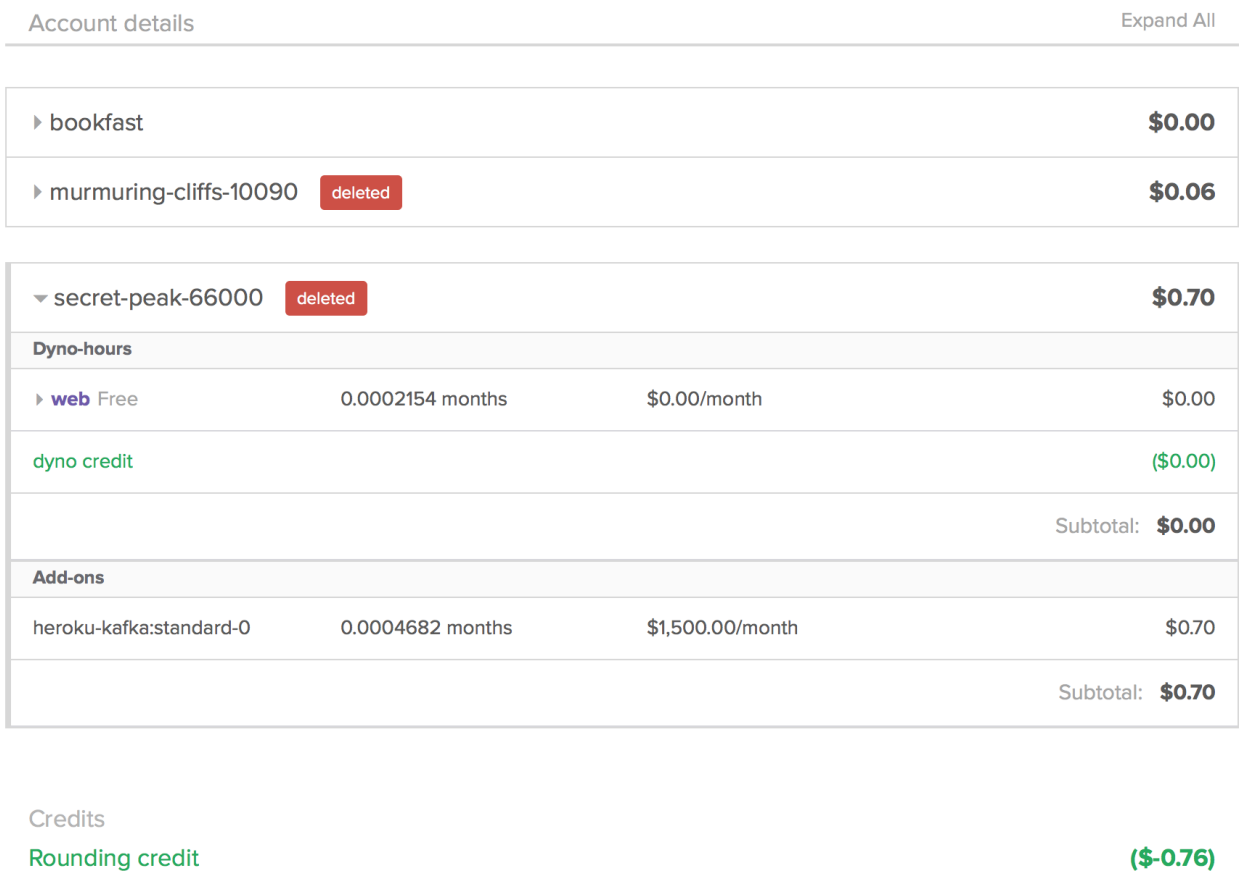
DEMO: Java API

- Basic producer/consumer example

DEMO: Heroku Kafka-as-a-Service

- Demo app:
  - https://github.com/iandow/heroku-kafka-demo-java

- Docs and Pricing:
  - https://devcenter.heroku.com/articles/kafka-on-heroku
  - $1,500/month !!!
  - Oh, but rounding credits.



DEMO: Kafka in a web app

- How to send a message
  - How to ensure delivery guarantee
  - How to handle failure
    - Demonstrate it:
      - Change 20 second timeout in DemoResources.java
      - Observe the java.util.concurrent.Timeout in the user specified callback
      - Also observe that the message may ultimately get there, (if its in transit)
    - To get rid of Dropwizard metrics, change timeout in DemoApplication.java
      - reporter.start(1, TimeUnit.*MINUTES*);

Consumer Groups, Cursors, and Partitions

ProducerRecord vs ConsumerRecord

- Producers send messages one at a time as ProducerRecord
- Consumers subscribe to topics and poll for messages and receive them many-at-a-time as ConsumerRecords

Consumer Groups, Cursors, and Partitions

- Consumer Groups – groups of consumers working together
- Cursors – track positions of consumers
- Partitions – subdivide a topic for scale
- Replication Factor – replicate partitions across nodes for fault tolerance

Partition Balancing

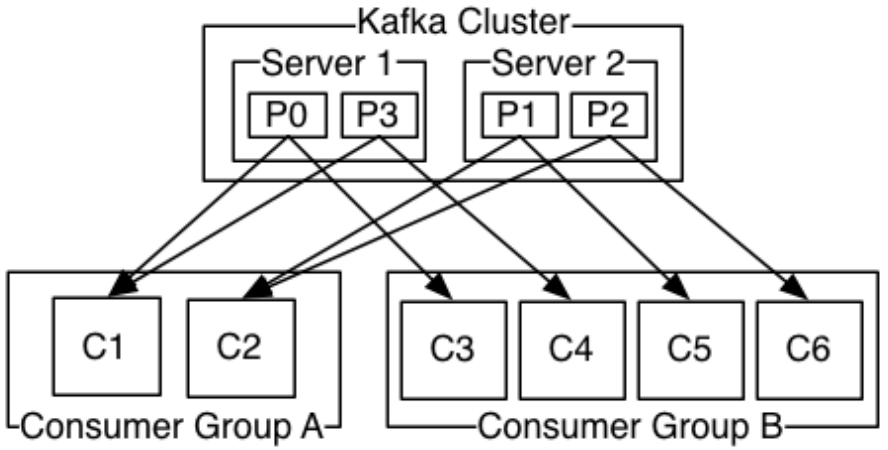
- Available partitions are balanced among consumers for a given group
  - Single partition can be read by only one consumer
  - A single consumer can read multiple partitions
  - Examples:
    - 3 partitions, 2 consumers: 2 & 1
    - 5 partitions, 1 consumer: 5
    - 3 partitions, 4 consumers: 1, 1, 1, 0 (4th consumer gets no messages)

- When new consumers join or new partitions added, rebalance occurs
  - Some consumers will gain or lose partitions and there may be a slight pause in message delivery while this happens
  - Can cause duplicates if consumers don't properly commit cursors

Consumer Groups

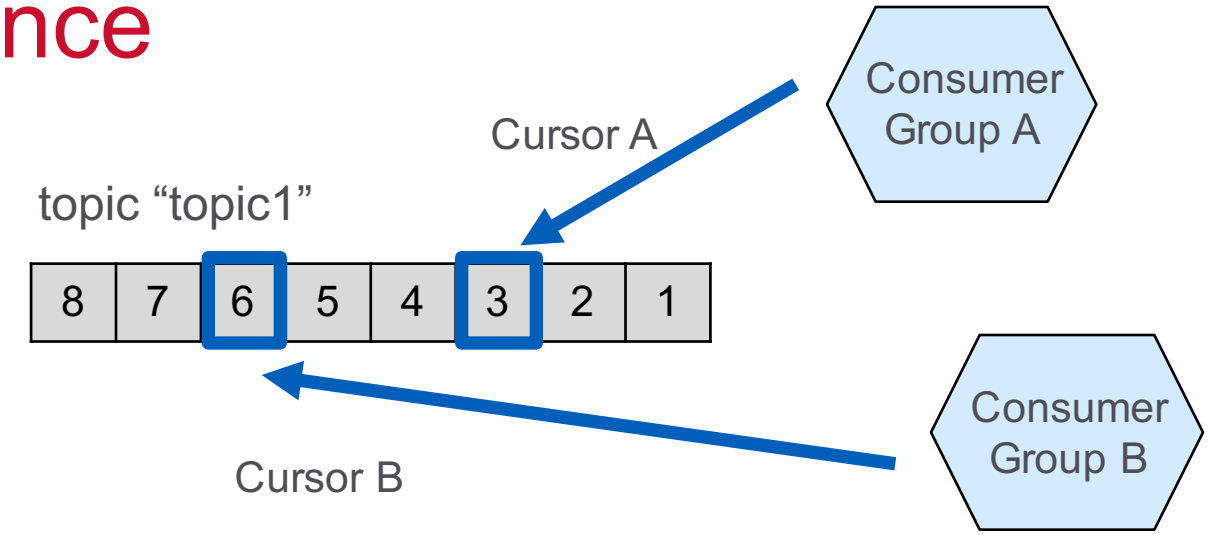
- Only one consumer IN A GROUP can consume one topic/partition simultaneously

- Consumers in different groups will see the same messages if they read the same topic/partition



http://kafka.apache.org/documentation.html

Cursor Persistence



- Ensure consumers pick up from where they left off after a stop
- Tracks last known commit point for message reads
- By default, auto commit after 5s (`auto.commit.interval.ms`)
  - If slow consumer code, auto commit() might go out before processed
  - You can explicitly commit with `consumer.commit()`
- If you need to concurrent consumers, would you use consumer groups or topic partitions?

At Least Once semantics

- Messages may be seen multiple times
  - Producer side
    - Retransmit on network
    - Producer might fail and resend previously sent messages on restart
  - Consumer side
    - Client might crash after get but before cursor.commit()

- Applications must be **idempotent** message processors

Batching Behavior

- Producer.send() places messages in client-side memory buffer

- That buffer is not flushed until one of three criteria met:
  - Timeout (linger.ms)
  - Max memory (buffer.memory)
  - Producer.flush() called

Serialization

- Each Kafka message is a byte array.
- You must convert <K,V> to/from bytes with a serializer
- Two provided out of the box
  - ByteArraySerializer/ByteArrayDeserializer
  - StringSerializer/StringDeserializer
- You can write your own serializer.

Key Concept - Serialization

- If you're streaming data that is a byte array, use the byte array serializer.
- If you're streaming data that is a String, use the String serializer.
- If you're streaming data that is a POJO, use ???

How to stream a POJO

1. Make it serializable
   - Otherwise you'll get a java.io.NotSerializableException later when we write the object to a byte array
2. Write the object to a byte array
3. Send that byte array
   - Why can't we just send the Person object?
4. In the consumer, poll the topic, then convert record.value() to your POJO.

```
//Prepare bytes to send:
ByteArrayOutputStream bos = new ByteArrayOutputStream();
ObjectOutput out = null;
out = new ObjectOutputStream(bos);
out.writeObject(person1);
out.flush();
byte[] value = bos.toByteArray();
```

```
//Create object from bytes:
ByteArrayInputStream bis = new ByteArrayInputStream(record.value());
ObjectInput in = null;
try {
    in = new ObjectInputStream(bis);
    Object obj = in.readObject();
    System.out.println("Consumed object " + obj);
    Person p2 = (Person)obj;
    System.out.println("Consumed person " + p2.getName());
```

Problems with streaming POJOs

- What if your raw data is dirty, and casting fails because you streamed a record with missing POJO fields?
- The overhead of encoding/decoding a POJO to/from bytes is redundant, especially if this is done at multiple stages in the Kafka pipeline.
- It's better to postpone parsing/casting downstream.

How would you stream this?

```
080449201DAA T 000001957000001030000N0000000000000004CT100010071007
080449201DAA T 000001310000010700000N0000000000000005CT10031007
080449201DAA T 000000666000000896000N0000000000000006CT10041005
080449201DAA T 000001802000001051000N0000000000000007CT100310051009
080449201DAA T 000001322000000897000N0000000000000008CT100410051005
080449201DAA T 000000935000000894000N0000000000000009CT10031007
080449201DAA T 000000751000001054000N0000000000000010CT100410081006
080449201DAA T 000000313000000887000N0000000000000011CT1004100810081007
080449201DAA T 000000218000001051000N0000000000000012CT100410091005
080449201DAA T 000001913000001045000N0000000000000013CT10041006
080449201DAA T 000001245000001051000N0000000000000014CT1001100610071008
```

Schema excerpt

FIELD	OFFSET	SIZE	FORMAT	DESCRIPTION
Time	0	9	Date	Time of quote with milliseconds (HHMMSSXXX) This is the time the quote was published by the SIP (CTA or UTP)
Exchange	9	1	Text	The Exchange that issued the quote: ■ A – NYSE MKT Stock Exchange ■ B – NASDAQ OMX BX Stock Exchange ■ Z – BATS Exchange
Symbol	10	16	Text	Security symbol (six-character root, ten-character suffix)
Bid Price	26	11	Number	Bid price, seven characters for the whole number, four characters for decimals
Bid Size	37	7	Number	Bid size in units of trade, seven characters
Ask Price	44	11	Number	Ask price, seven characters for the whole number, four characters for decimals
Ask Size	55	7	Number	Ask size in units of trade, seven characters

Option A?

- Parse each record into a JSON object,
- Publish json_object.toString()
- Stream with with String serializer

```
JSONObject trade_info = new JSONObject();
trade_info.put("date", record.substring(0, 9));
trade_info.put("exchange", record.substring(9, 10));
trade_info.put("symbol root", record.substring(10, 16).trim());
trade_info.put("symbol suffix", record.substring(16, 26).trim());
trade_info.put("saleCondition", record.substring(26, 30).trim());
trade_info.put("tradeVolume", record.substring(30, 39));

producer.send(
        new ProducerRecord<String, String>(key, trade_info.toString())
);
```

Option B?

- Create a POJO (“Tick”) with attributes for each field
- Parse each record and create a Tick object
- Stream Tick objects using a **custom serializer**

```
public class Tick implements Serializable {
    private String date;
    private String exchange;
    private String symbol_root;
    private String symbol_suffix;
    private String saleCondition;
    private String tradeVolume;

    public String getDate() {
        return date;
    }

    public void setDate(String date) {
        this.date = date;
    }

    public String getExchange() {
        return exchange;
    }

    public void setExchange(String exchange) {
        this.exchange = exchange;
    }
```

Option C?

- Create a POJO “Tick” with a single byte[] attribute, and getters that return fields by directly indexing the byte[]
- Annotate getters with @JsonProperty

```
public class Tick implements Serializable {
    private byte[] data;

    public Tick(byte[] data) { this.data = data; }

    public Tick(String data) { this.data = data.getBytes(Charsets.ISO_8859_1); }

    @JsonProperty("date")
    public String getDate() { return new String(data, 0, 9); }

    @JsonProperty("exchange")
    public String getExchange() { return new String(data, 9, 1); }

    @JsonProperty("symbol-root")
    public String getSymbolRoot() { return trim(10, 6); }

    @JsonProperty("symbol-suffix")
    public String getSymbolSuffix() { return trim(16, 10); }

    @JsonProperty("sale-condition")
    public String getSaleCondition() { return trim(26, 4); }

    @JsonProperty("trade-volume")
    public double getTradeVolume() { return digitsAsInt(30, 9); }
```

A

```
JSONObject trade_info = new JSONObject();
trade_info.put("date", record.substring(0, 9));
trade_info.put("exchange", record.substring(9, 10));
trade_info.put("symbol root", record.substring(10, 16).trim());
trade_info.put("symbol suffix", record.substring(16, 26).trim());
trade_info.put("saleCondition", record.substring(26, 30).trim());
trade_info.put("tradeVolume", record.substring(30, 39));

producer.send(
        new ProducerRecord<String, String>(key, trade_info.toString())
);
```

B

```
public class Tick implements Serializable {
    private String date;
    private String exchange;
    private String symbol_root;
    private String symbol_suffix;
    private String saleCondition;
    private String tradeVolume;

    public String getDate() {
        return date;
    }

    public void setDate(String date) {
        this.date = date;
    }

    public String getExchange() {
        return exchange;
    }

    public void setExchange(String exchange) {
        this.exchange = exchange;
    }
```

C

```
public class Tick implements Serializable {
    private byte[] data;

    public Tick(byte[] data) { this.data = data; }

    public Tick(String data) { this.data = data.getBytes(Charsets.ISO_8859_1); }

    @JsonProperty("date")
    public String getDate() { return new String(data, 0, 9); }

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    public String getExchange() { return new String(data, 9, 1); }

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    public String getSymbolRoot() { return trim(10, 6); }

    @JsonProperty("symbol-suffix")
    public String getSymbolSuffix() { return trim(16, 10); }

    @JsonProperty("sale-condition")
    public String getSaleCondition() { return trim(26, 4); }

    @JsonProperty("trade-volume")
    public double getTradeVolume() { return digitsAsInt(30, 9); }
```

Major Performance Factors

- Replication turned on?
- Streaming large messages?
- Producers sending synchronously or async.?
- Send buffer flushed until one of three criteria met:
  - Timeout (linger.ms)
  - Max memory (buffer.memory)
  - Producer.flush() called
- **Topics / Producer affinity**

Major Performance Factors

- What affects producer latency?
  - Using send futures? (i.e. synchronous sends)
  - acks=all,1,or 0 (ack after leader logs / after all replicas log / or not at all)
  - ”Nagle’s algorithm” and the `linger.ms` config
- What affects producer throughput?
  - Producer batch.size
  - Concurrent producer.send()
  - Number of topics
  - Message size
- What affects consumer throughput?
  - Partitions

Major Performance Factors

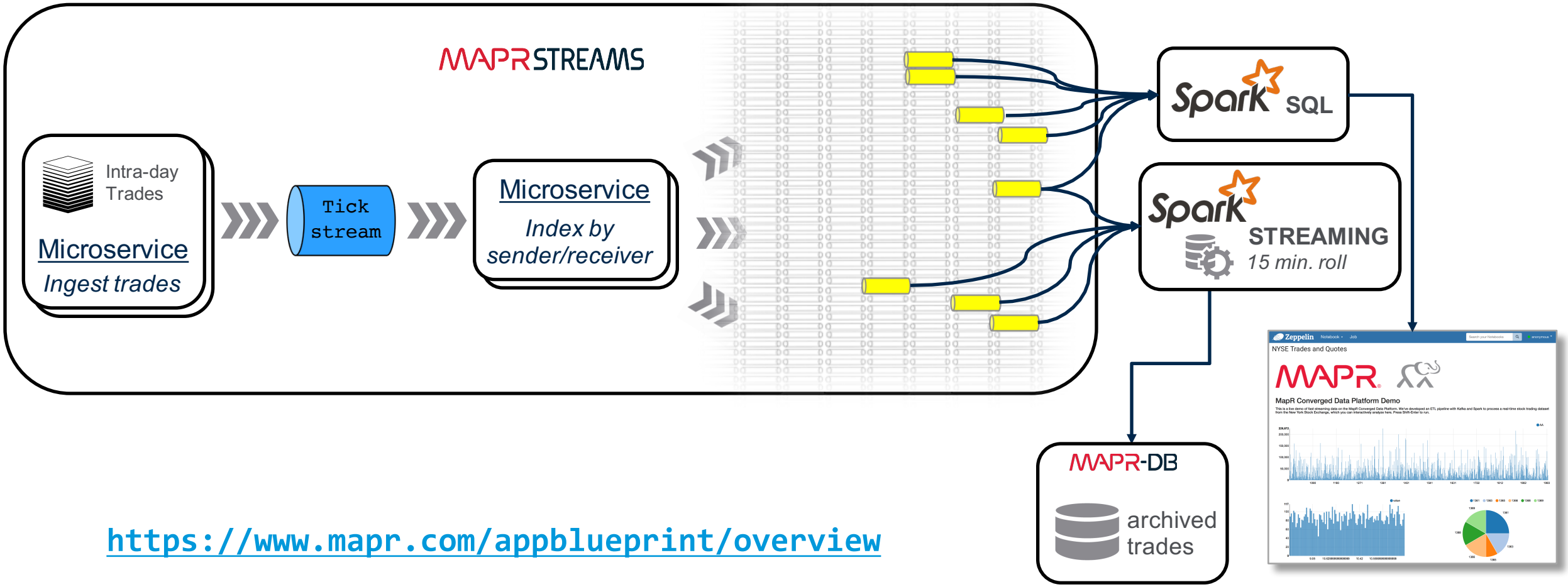
- What affects Kafka server stability?
  - Garbage Collection: Long GCs from sending large messages can break the kafka/zookeeper connection.
  - Topics can easily consume disk space
  - May need to increase file handles
    - Topic data and index files are in log.dir (e.g. /tmp/kafka-logs)
    - Kafka keeps an open file for each topic.
      - Reference: http://www.michael-noll.com/blog/2013/03/13/running-a-multi-broker-apache-kafka-cluster-on-a-single-node/

Read vs Processing Parallelism

- Consumer read parallelism
  - Concurrent reads can be achieved via topic partitioning and consumer groups
  - If your consumer logic is CPU-bound, use partitions or consumer groups

- Downstream Processing Parallelism
  - If you need more processing threads than read threads, then **“fan-out”** the data to more topics.

What I mean by, “Fan-out”:



https://www.mapr.com/appblueprint/overview

Performance Anti-Pattern

- Problem: I want to count all the messages read in each consumer thread.

- Anti-pattern: I'll just increment a counter in a synchronized block.

Performance Anti-Pattern

- I want to count all the messages read in each consumer thread.

- Fine, I'll just increment a counter in a synchronized block.

  - Lesson learned: **synchronization really hurts throughput.**
  - Solution: I decreased the cost of metric collection to near zero by giving each thread its own metrics structure, and every second or so, updating a shared metric structure with locks.

Performance Anti-Pattern

- I want to be sure never to read a duplicate message.

- Fine, I'll just commit the read point for every message I consume.

Performance Anti-Pattern

- I want to be sure never to read a duplicate message.

- Fine, I'll just commit the read point for every message I consume.
  - Lesson learned, you're still not guaranteed not to get a duplicate message. Kafka consumers must be idempotent.
  - Solution: Postpone deduplication downstream. (i.e. Give up till' later.)

Performance Anti-Pattern

- I want to stream JSON strings to simplify DB persistence and columnar selections in Spark.

- Fine, I'll just convert every message to a JSON object at the first step of my pipeline and use a JSON serializer.

Performance Anti-Pattern

- I want to stream JSON strings to simplify DB persistence and columnar selections in Spark.

- Fine, I'll just convert every message to a JSON object at the first step of my pipeline and use a JSON serializer.

  - Lesson learned**: parsing is expensive!** Handling parsing errors is expensive. Custom serializers are not as easy I as thought.
  - This anti-pattern is illustrated here: https://github.com/mapr-demos/finserv-ticks-demo/commit/35a0ddaad411bf7cec34919a4817482df2bf6462
  - Solution: Stream a data structure containing a byte[] to hold raw data, and annotate it with com.fasterxml.jackson.annotation.JsonProperty.
  - Example: https://github.com/mapr-demos/finserv-ticks-demo/blob/35a0ddaad411bf7cec34919a4817482df2bf6462/src/main/java/com/mapr/demo/finserv/Tick2.java

Good Practices

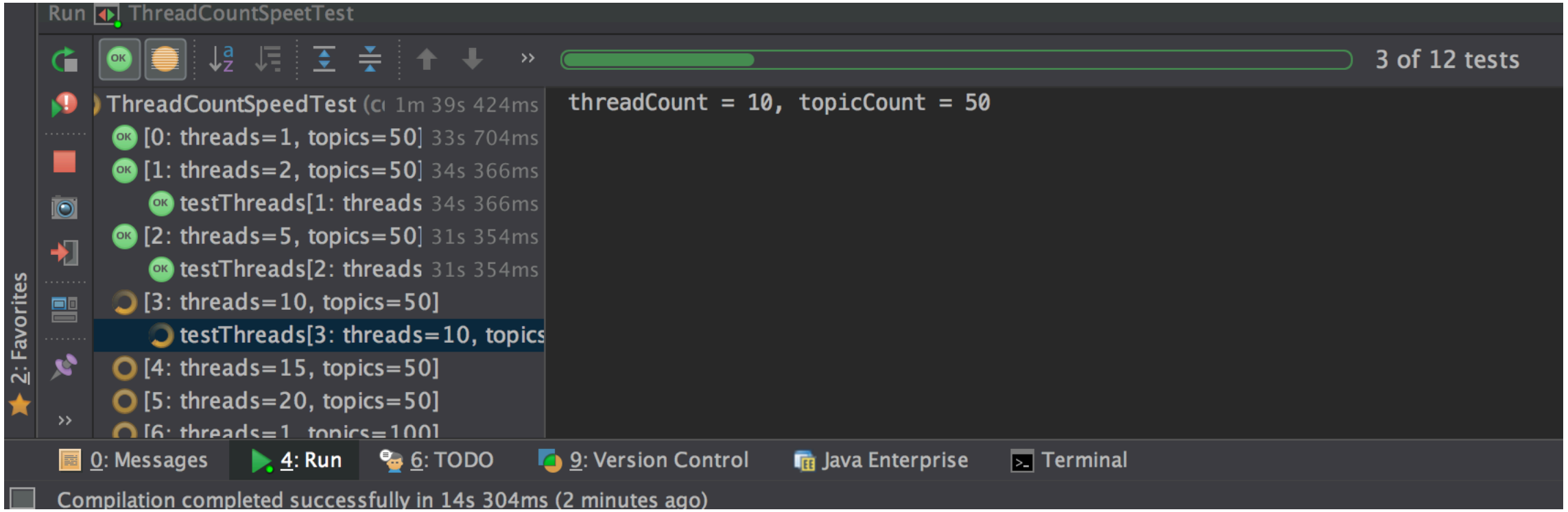
- Design your data structures to prefer arrays of objects, and primitive types, instead of the standard Java or Scala collection classes (e.g. HashMap).
- Maintain affinity between topic and producer thread.
  - Kafka will batch multiple sends together. If a send hits only one topic, it will benefit from writes to sequential memory locations.
  - Reference code: https://github.com/mapr-demos/finserv-application-blueprint/blob/master/src/test/java/com/mapr/demo/finserv/ThreadCountSpeedIT.java
- Consider using numeric IDs or enumeration objects instead of strings for keys.

Three Performance Takeaways

1. Process as little as possible in the pipeline.
   - Transfer byte arrays. It's faster than serializers based on strings, POJOs, or custom serialization.
2. Use JSON annotation. It makes persistence easier in the final stages. It also makes data analysis easier because it gives you an easy schema.
3. Categorize raw data into multiple topics (aka "fan-out"). It makes real-time analysis easier.
4. Use parameterized tests in Junit to tune Kafka.

DEMO: Tuning Kafka with Junit

https://github.com/iandow/kafka_junit_tests



How to create Junit parameterized tests

1. Annotate test class with @RunWith(Parameterized.class).

2. Create a public static method annotated with @Parameters that returns a Collection of Objects (as Array) as test data set.

3. Create a public constructor that takes in one "row" of test data.

Benchmarks

- Lazy benchmark, by Jay Kreps at LinkedIn (2014):
  - https://engineering.linkedin.com/kafka/benchmarking-apache-kafka-2-million-writes-second-three-cheap-machines

- Answers questions like these:
  - Will Kafka slow down if I never consumer messages?
  - Should I stream small messages or large messages (in order to maximize Throughput)?
  - Should I stream small messages or large messages?

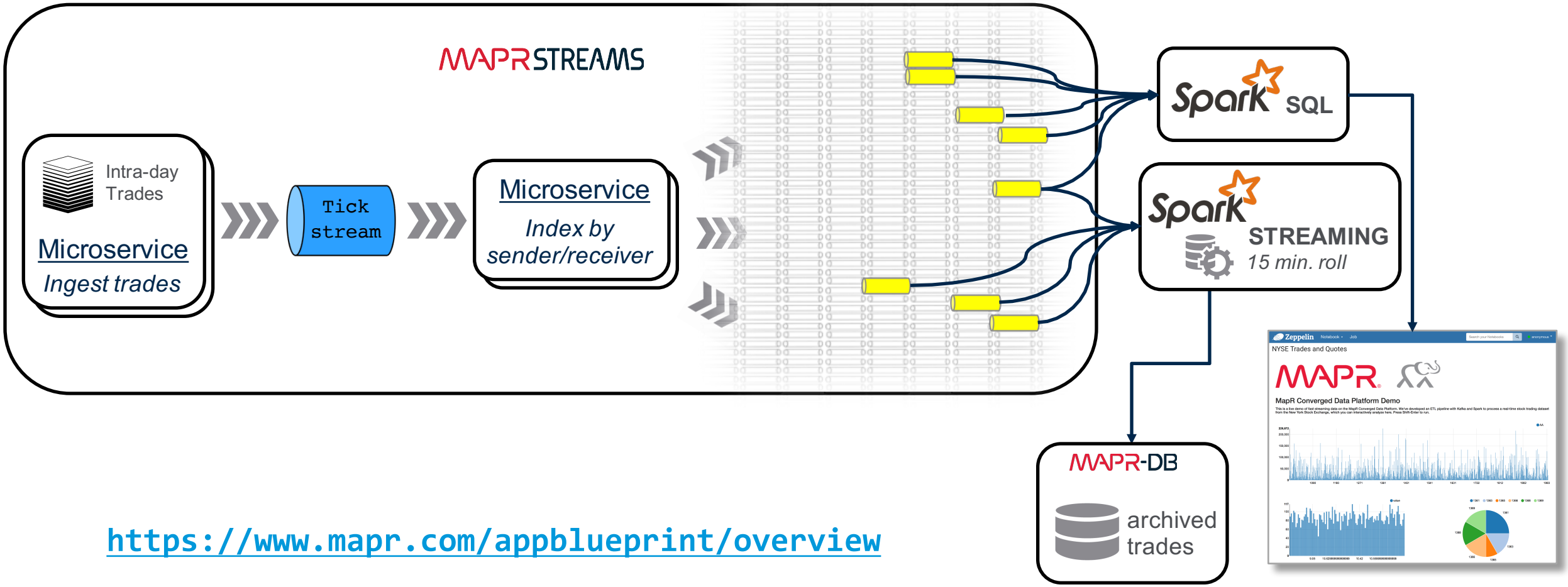
MapR Streams → (more scalable Kafka)

- MapR Streams load balances topics more effectively
  - Kafka assumes all partitions are equal in terms of size and throughput
- MapR Streams stores stream data in a distributed file system (MapR-FS), allowing topics to save much more data and replicate much faster.
  - Kafka partitions are pinned to a single node, meaning they can't outgrow the storage capacity of that node.
- MapR Streams can span across clusters in multi-datacenters
  - Kafka, "More Clusters, More Problems"

https://www.mapr.com/blog/scaling-kafka-common-challenges-solved

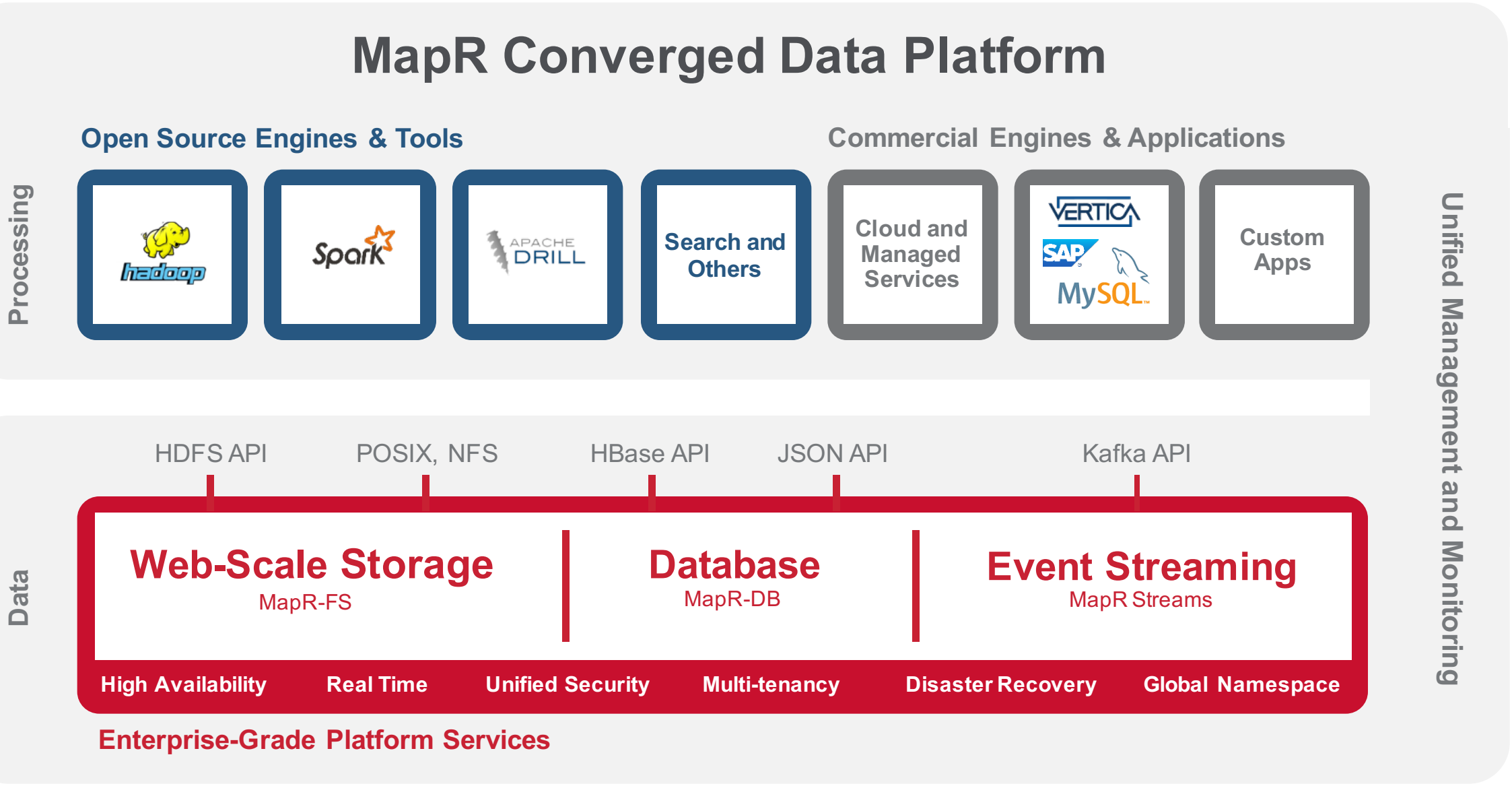
Blueprint of a Converged Application

for real-time tick streaming



https://www.mapr.com/appblueprint/overview

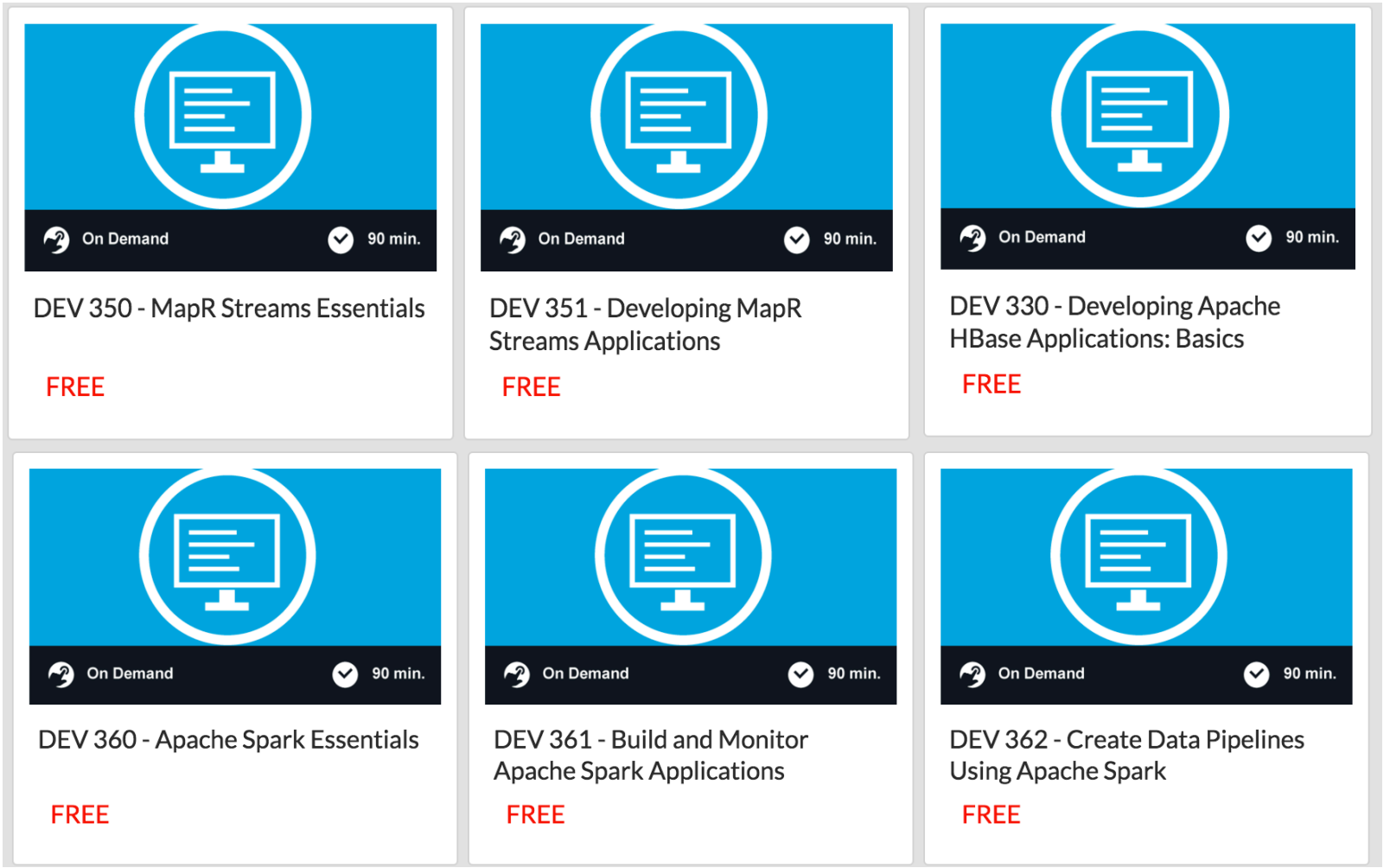
MapR Converged Data Platform



Next Steps:

- Read about Kafka and Spark Streaming
  - https://www.mapr.com/blog/real-time-streaming-data-pipelines-apache-apis-kafka-spark-streaming-and-hbase
- Read the *Streaming Architecture* ebook
  - https://www.mapr.com/streaming-architecture-using-apache-kafka-mapr-streams
- Check out this presentation and demo code
  - https://github.com/iandow/design-patterns-for-fast-data

Free training → http://learn.mapr.com



Q&A

Engage with us!

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@iandownard

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