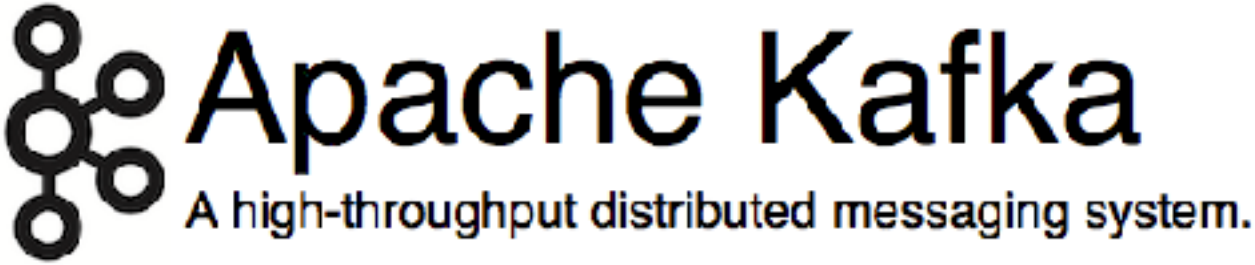
# APACHE KAFKA

# Kafka?




- http://kafka.apache.org/
- Originated at LinkedIn, open sourced in early 2011
- Implemented in Scala, some Java
- 9 core committers, plus ~ 20 contributors

# Kafka?

- LinkedIn's motivation for Kafka was:
  - "A unified platform for handling all the real-time data feeds a large company might have."
- Must haves
  - High throughput to support high volume event feeds.
  - Support real-time processing of these feeds to create new, derived feeds.
  - Support large data backlogs to handle periodic ingestion from offline systems.
  - Support low-latency delivery to handle more traditional messaging use cases.
  - Guarantee fault-tolerance in the presence of machine failures.

# Kafka @ LinkedIn, 2014

- Multiple data centers, multiple clusters
  - Mirroring between clusters / data centers
- What type of data is being transported through Kafka?
  - Metrics: operational telemetry data
  - Tracking: everything a LinkedIn.com user does
  - Queuing: between LinkedIn apps, e.g. for sending emails
  - To transport data from LinkedIn's apps to Hadoop, and back

# Kafka @ LinkedIn, 2014

- In total ~ 200 billion events/day via Kafka
  - Tens of thousands of data producers, thousands of consumers
  - 7 million events/sec (write), 35 million events/sec (read) <<< may include replicated events
  - But: LinkedIn is not even the largest Kafka user anymore as of 2014

# Kafka @ LinkedIn, 2014

"For reference, here are the stats on one of LinkedIn's busiest clusters (at peak):

15 brokers
15,500 partitions (replication factor 2)
400,000 msg/s inbound
70 MB/s inbound
400 MB/s outbound"

# Kafka adoption and use cases

- LinkedIn: activity streams, operational metrics, data bus
  - 400 nodes, 18k topics, 220B msg/day (peak 3.2M msg/s), May 2014
- Netflix: real-time monitoring and event processing
- Twitter: as part of their Storm real-time data pipelines
- Spotify: log delivery (from 4h down to 10s), Hadoop
- Loggly: log collection and processing
- Mozilla: telemetry data
- Airbnb, Cisco, Gnip, InfoChimps, Ooyala, Square, Uber, …

# How fast is Kafka?

- “Up to 2 million writes/sec on 3 cheap machines”
  - Using 3 producers on 3 different machines, 3x async replication
    - Only 1 producer/machine because NIC already saturated
- Sustained throughput as stored data grows
  - Slightly different test config than 2M writes/sec above.
- Test setup
  - Kafka trunk as of April 2013, but 0.8.1+ should be similar.
  - 3 machines: 6-core Intel Xeon 2.5 GHz, 32GB RAM, 6x 7200rpm SATA, 1GigE

# Why is Kafka so fast?

- Fast writes:
  - While Kafka persists all data to disk, essentially all writes go to the page cache of OS, i.e. RAM.
  - Cf. hardware specs and OS tuning (we cover this later)
- Fast reads:
  - Very efficient to transfer data from page cache to a network socket
  - Linux: sendfile() system call
- Combination of the two = fast Kafka!
  - Example (Operations): On a Kafka cluster where the consumers are mostly caught up you will see no read activity on the disks as they will be serving data entirely from cache.

# Why is Kafka so fast?

- Example: Loggly.com, who run Kafka & Co. on Amazon AWS
  - “99.99999% of the time our data is coming from disk cache and RAM; only very rarely do we hit the disk.”
  - “One of our consumer groups (8 threads) which maps a log to a customer can process about 200,000 events per second draining from 192 partitions spread across 3 brokers.”
    - Brokers run on m2.xlarge Amazon EC2 instances backed by provisioned IOPS

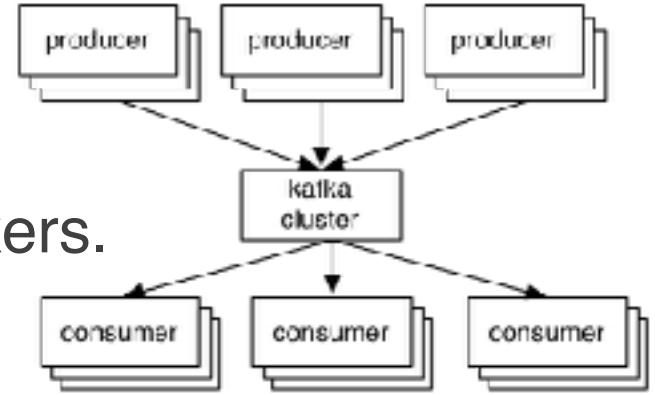
# Kafka + X for processing the data?

- Kafka + Storm often used in combination, e.g. Twitter
- Kafka + custom
  - “Normal” Java multi-threaded setups
  - Akka actors with Scala or Java, e.g. Ooyala
- Recent additions:
  - Samza (since Aug ’13) – also by LinkedIn
  - Spark Streaming, part of Spark (since Feb ’13)
- Kafka + Camus for Kafka->Hadoop ingestion

# PART 2: KAFKA CORE CONCEPTS

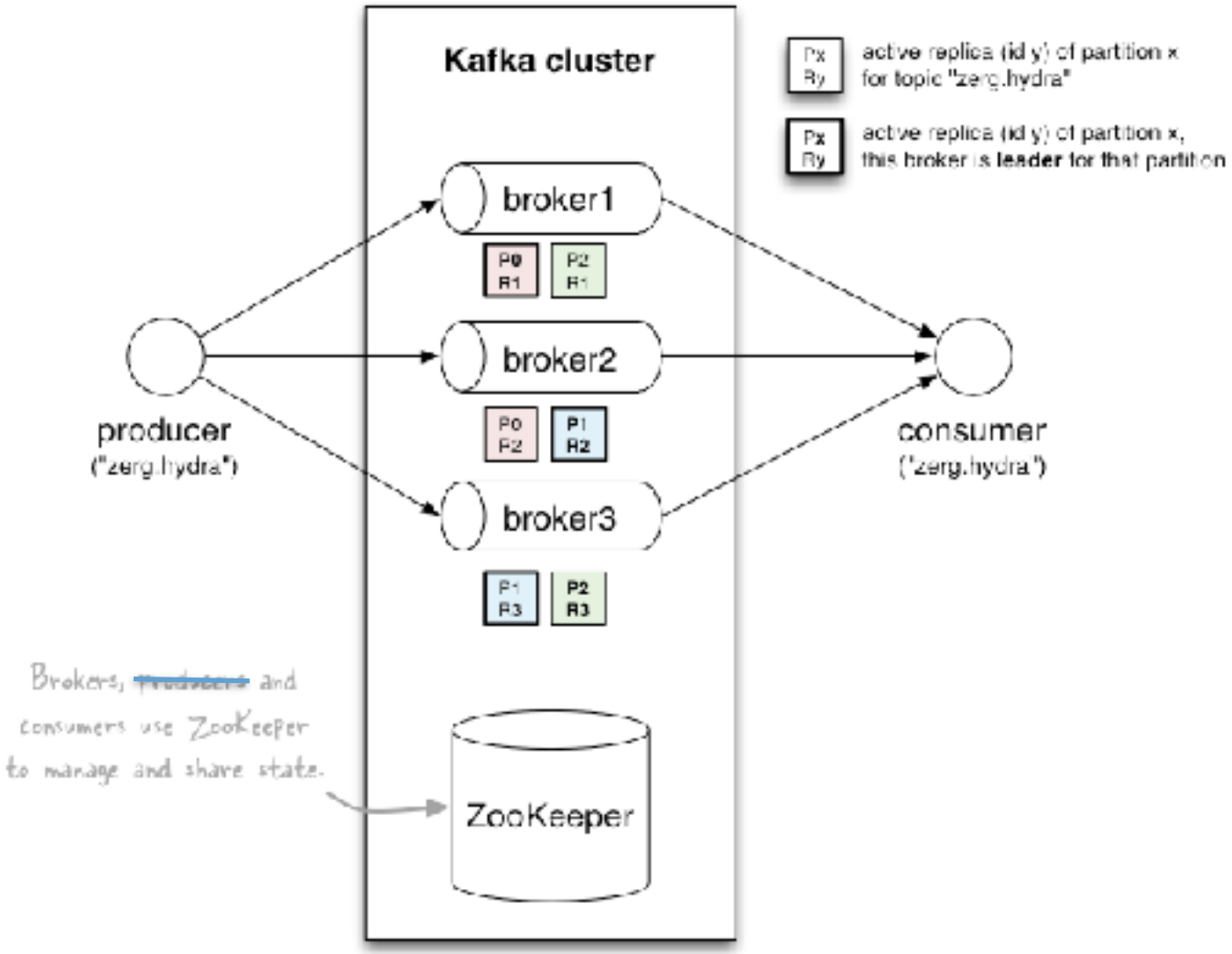
# A first look

- The who is who
  - Producers write data to brokers.
  - Consumers read data from brokers.
  - All this is distributed.



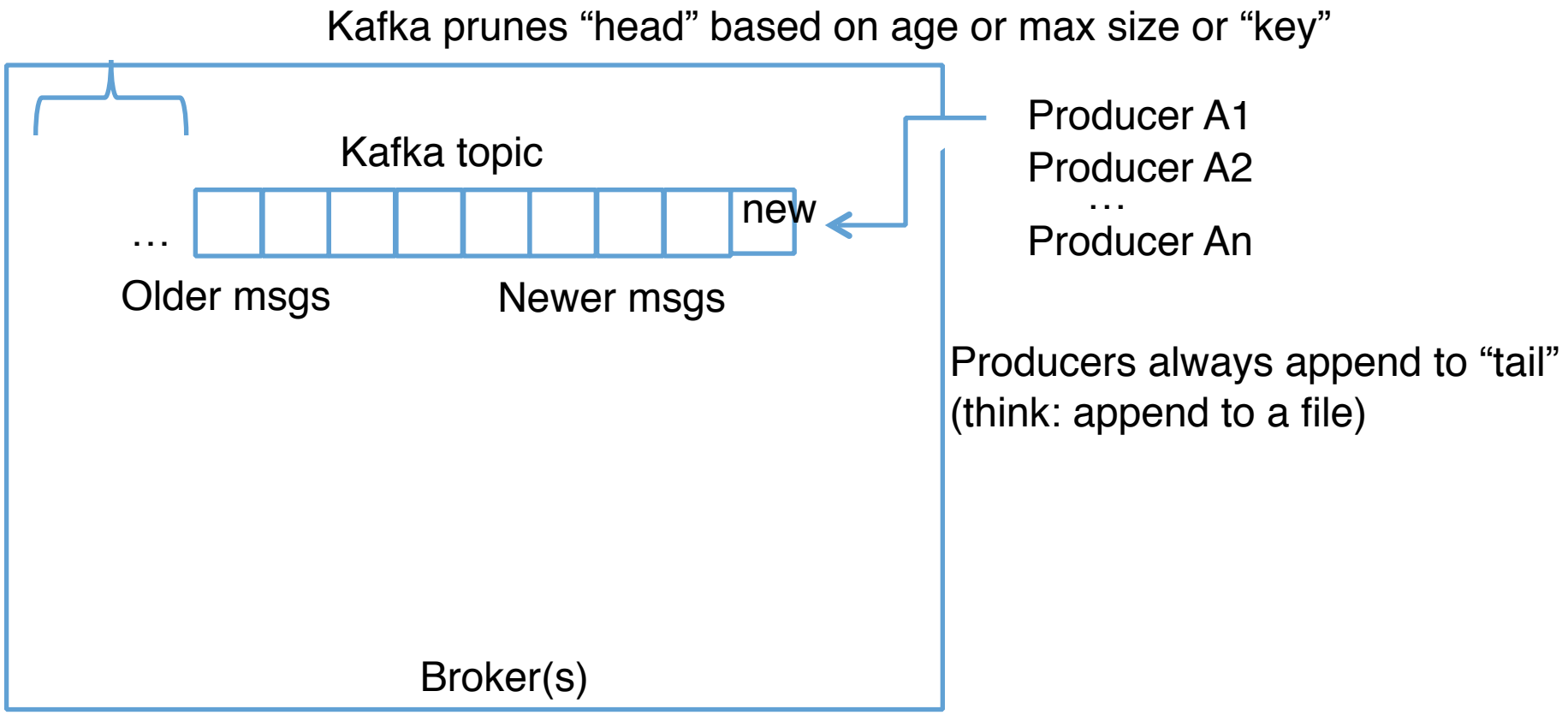

- The data
  - Data is stored in topics.
  - Topics are split into partitions, which are replicated.

# A first look

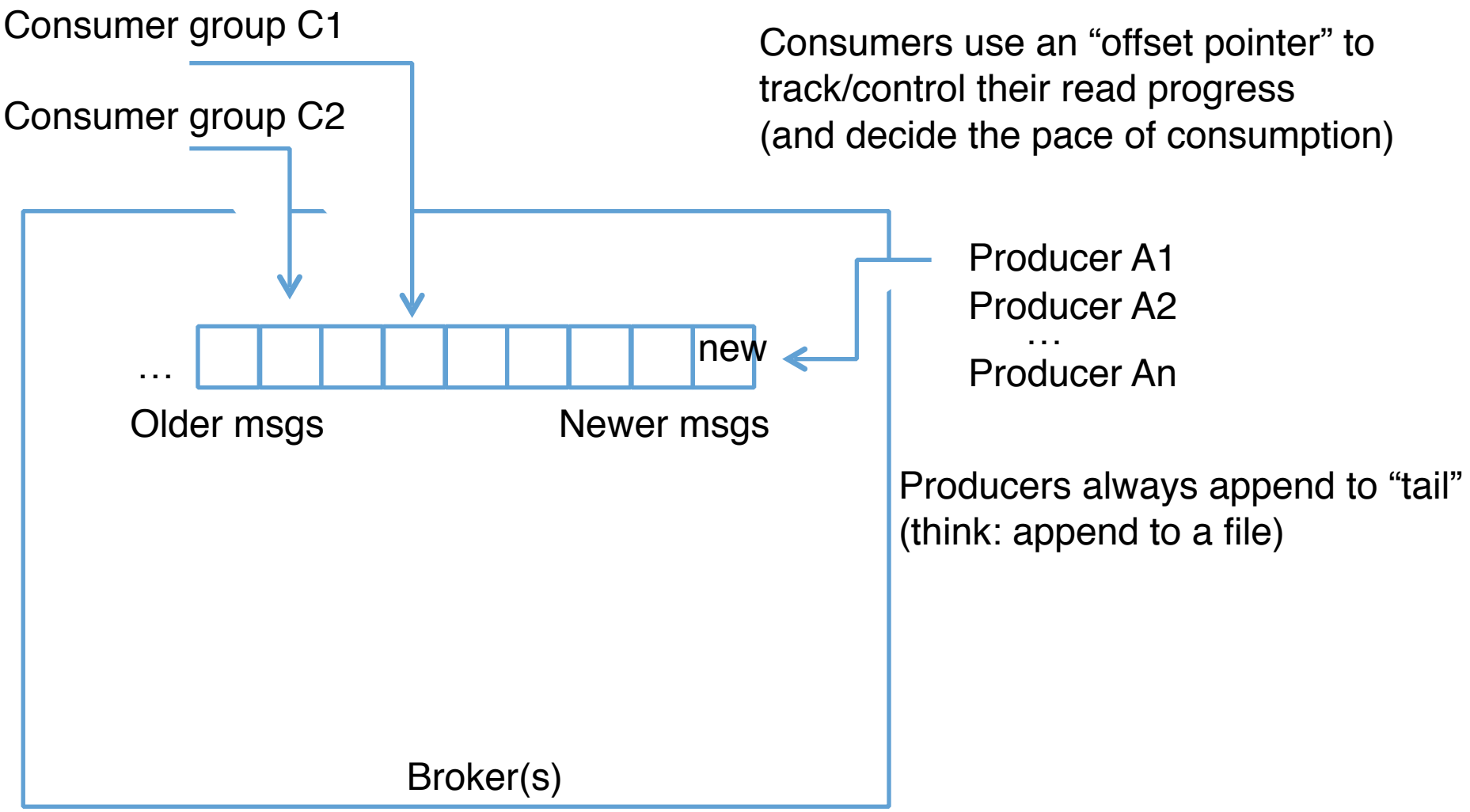

Kafka cluster
Px Ry
active replica (id y) of partition x for topic "zerg.hydra"
Px Ry
active replica (id y) of partition x, this broker is leader for that partition
broker1
P0 R1
P2 R1
broker2
P0 P2
P1 R2
broker3
P1 R3
P2 R3
producer ("zerg.hydra")
consumer ("zerg.hydra")
Brokers, ~~Producers~~ and consumers use ZooKeeper to manage and share state.
ZooKeeper

# Topics

- Topic:  feed name to which messages are published
  - Example: “zerg.hydra”



# Topics


Consumer group C1
Consumer group C2
Consumers use an “offset pointer” to track/control their read progress (and decide the pace of consumption)
Producer A1
Producer A2
…
Producer An
…
new
Older msgs
Newer msgs
Producers always append to “tail” (think: append to a file)
Broker(s)

# Topics

- Creating a topic
  - CLI

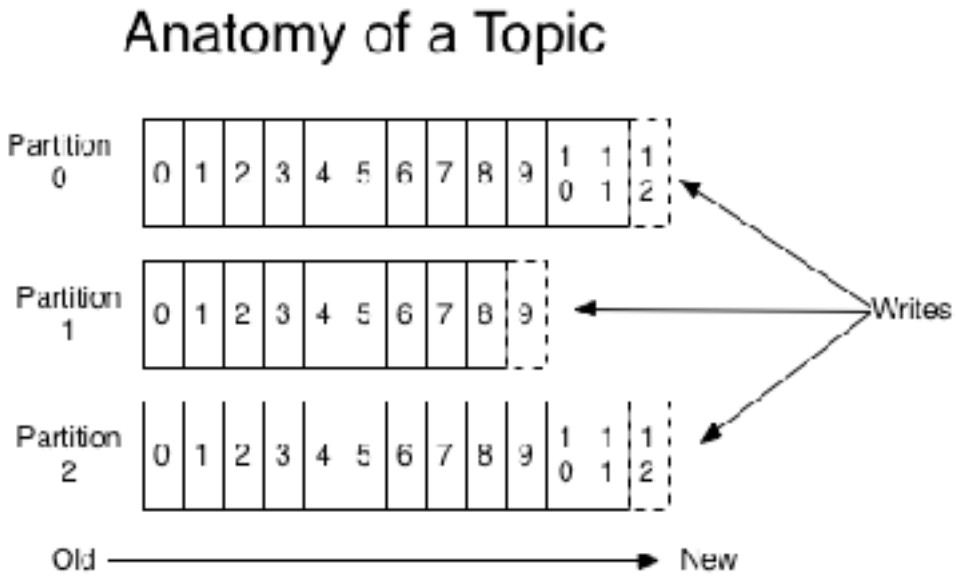
```
$ kafka-topics.sh --zookeeper zookeeper1:2181 --create --topic zerg.hydra
--partitions 3 --replication-factor 2 \
    --config x=y
```

  - API
    https://github.com/miguno/kafka-storm-starter/blob/develop/src/main/scala/com/miguno/kafkastorm/storm/KafkaStormDemo.scala
  - Auto-create via auto.create.topics.enable = true

- Modifying a topic
  - https://kafka.apache.org/documentation.html#basic_ops_modify_topic

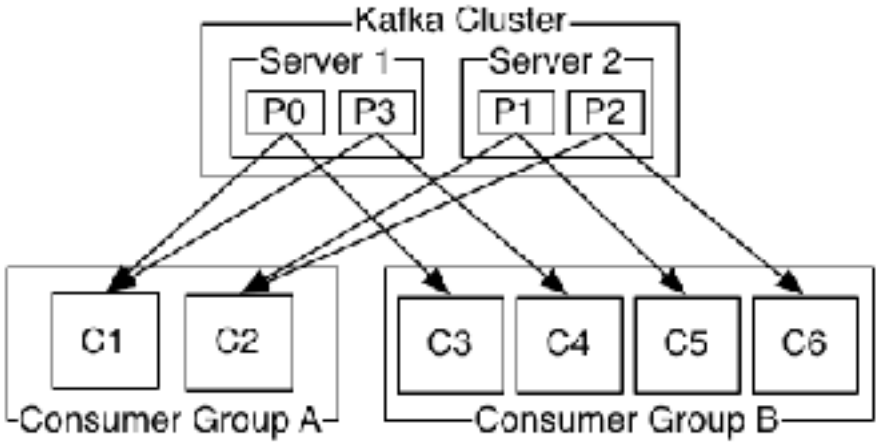
# Partitions

- A topic consists of partitions.
- Partition: ordered + immutable sequence of messages that is continually appended to



# Partitions

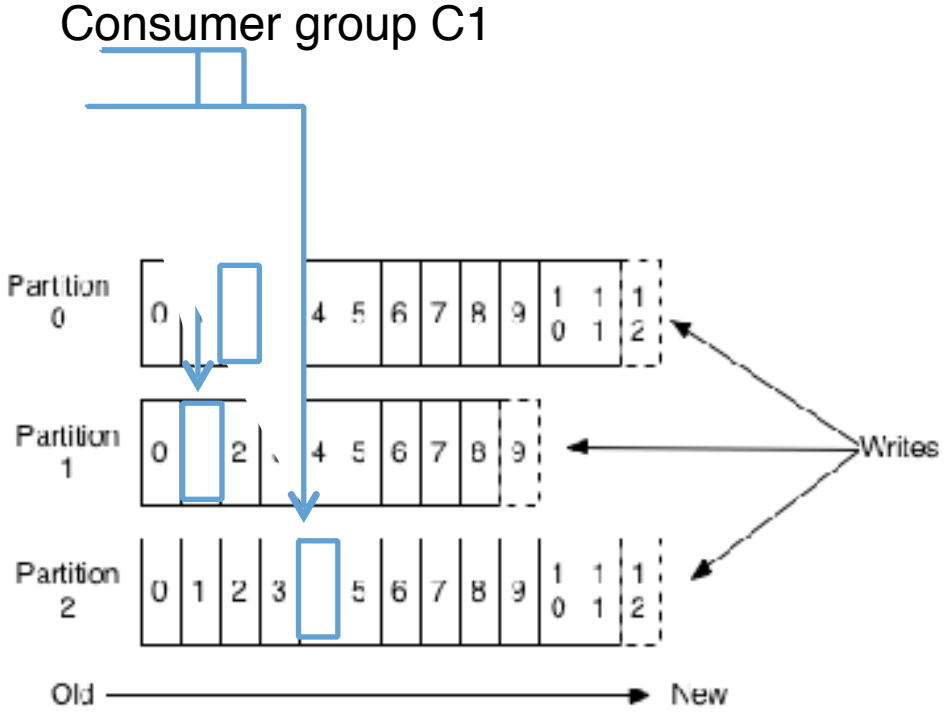
- #partitions of a topic is configurable
- #partitions determines max consumer (group) parallelism
  - Cf. parallelism of Storm's KafkaSpout via builder.setSpout(,,N)




  - Consumer group A, with 2 consumers, reads from a 4-partition topic
  - Consumer group B, with 4 consumers, reads from the same topic

# Partition offsets

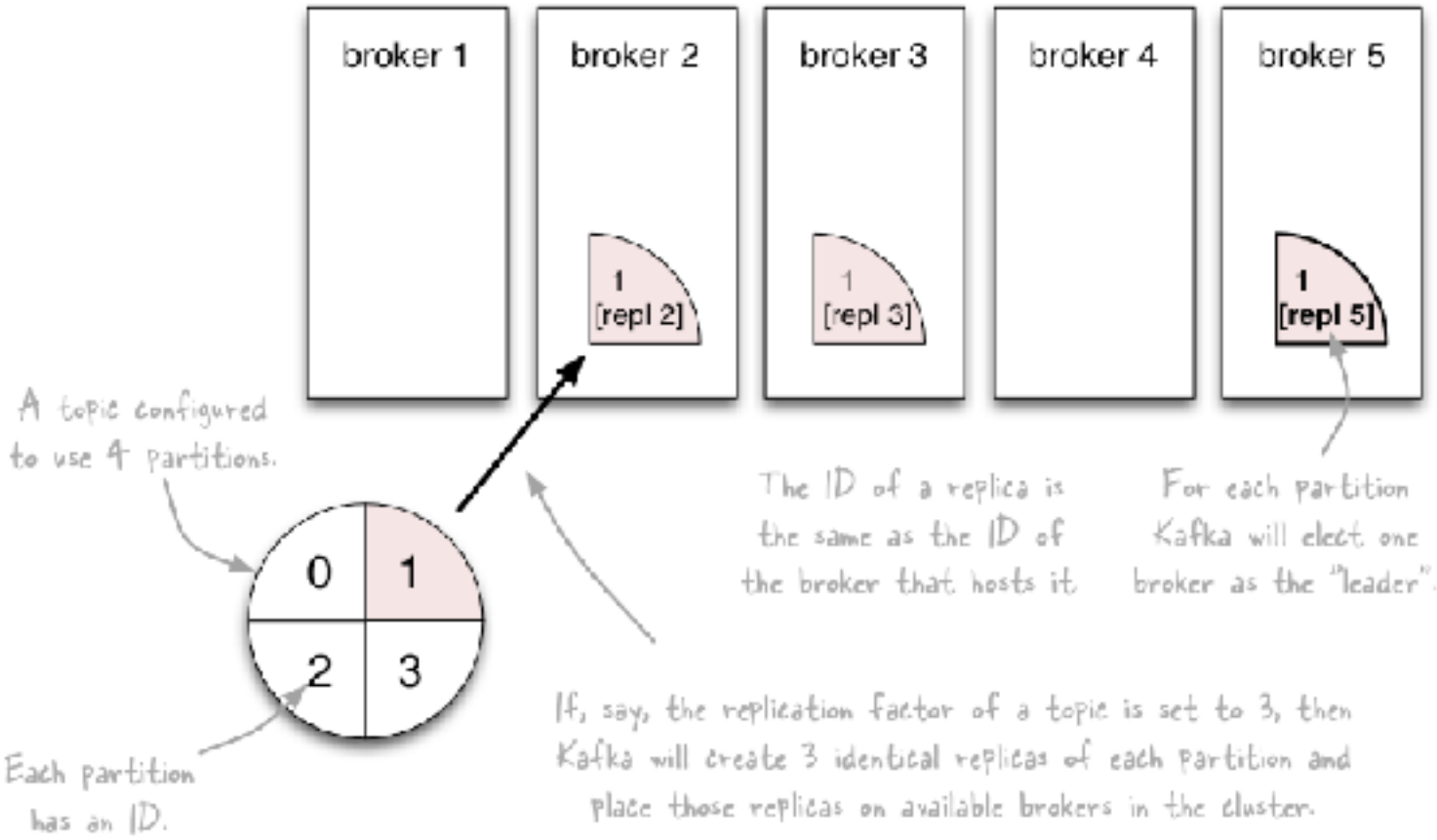
- Offset:  messages in the partitions are each assigned a unique (per partition) and sequential id called the offset
  - Consumers track their pointers via (offset, partition, topic) tuples



# Replicas of a partition

- Replicas: “backups” of a partition
  - They exist solely to prevent data loss.
  - Replicas are never read from, never written to.
    - They do NOT help to increase producer or consumer parallelism!
  - Kafka tolerates (numReplicas - 1) dead brokers before losing data
    - LinkedIn: numReplicas == 2
      - 1 broker can die

# Topics vs. Partitions vs. Replicas



# Inspecting the current state of a topic

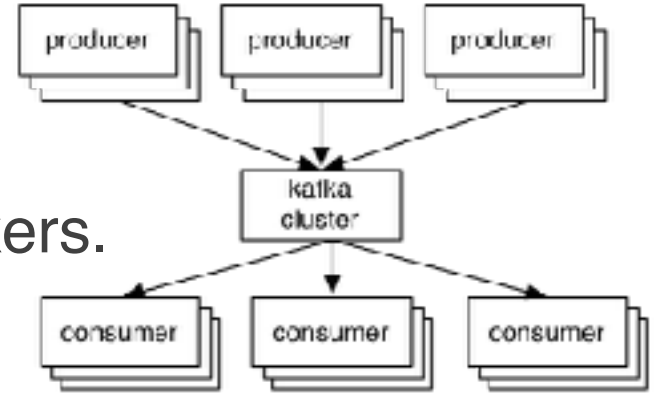
- --describe the topic

```
$ kafka-topics.sh --zookeeper zookeeper1:2181 --describe --topic zerg.hydra
Topic:zerg2.hydra PartitionCount:3 ReplicationFactor:2 Configs:
  Topic: zerg2.hydra Partition: 0 Leader: 1 Replicas: 1,0 Isr: 1,0
  Topic: zerg2.hydra Partition: 1 Leader: 0 Replicas: 0,1 Isr: 0,1
  Topic: zerg2.hydra Partition: 2 Leader: 1 Replicas: 1,0 Isr: 1,0
```

  - Leader: brokerID of the currently elected leader broker
    - Replica ID's = broker ID's
  - ISR = "in-sync replica", replicas that are in sync with the leader
  - In this example:
    - Broker 0 is leader for partition 1.
    - Broker 1 is leader for partitions 0 and 2.
    - All replicas are in-sync with their respective leader

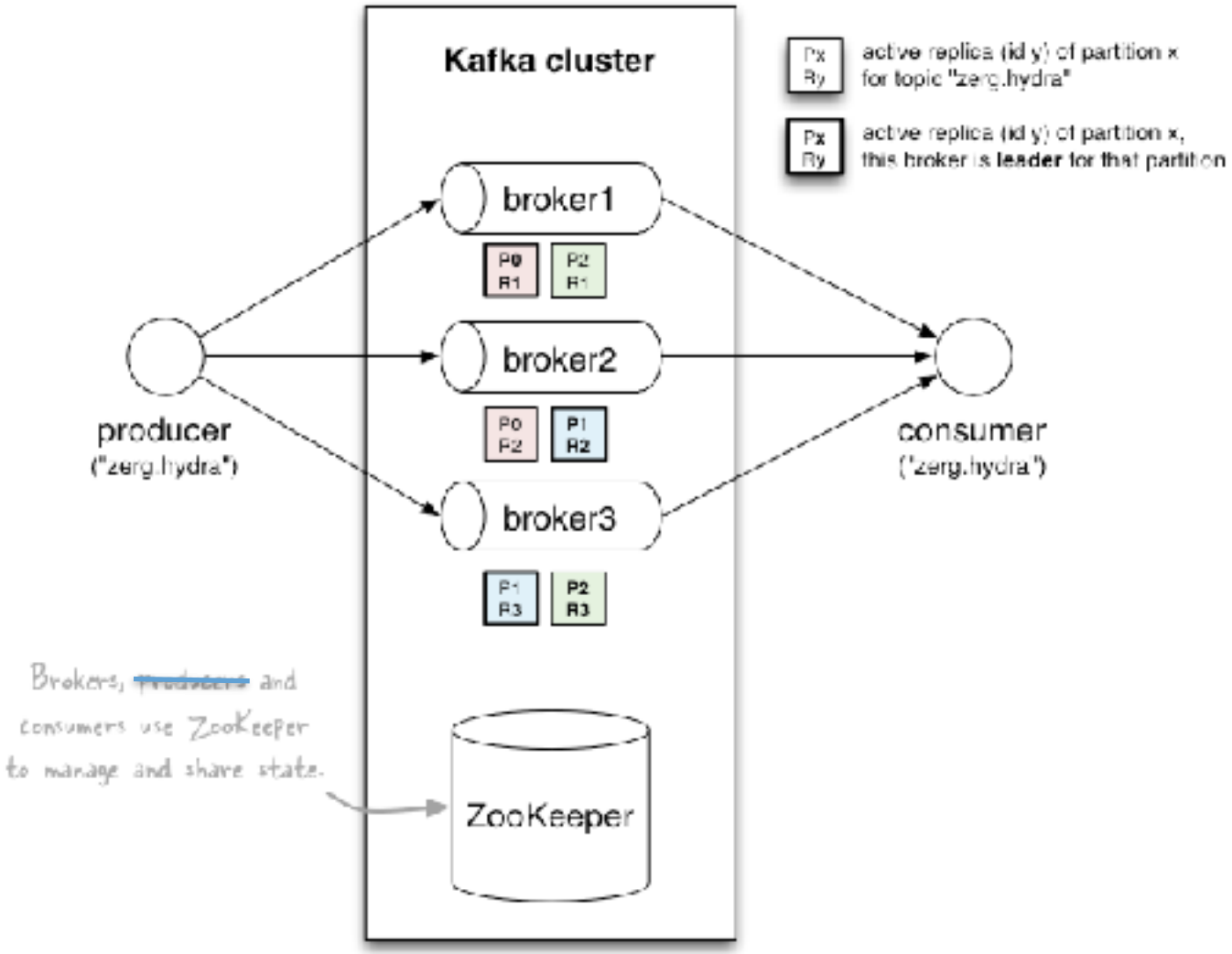
# Let’s recap

- The who is who
  - Producers write data to brokers.
  - Consumers read data from brokers.
  - All this is distributed.




- The data
  - Data is stored in topics.
  - Topics are split into partitions which are replicated.

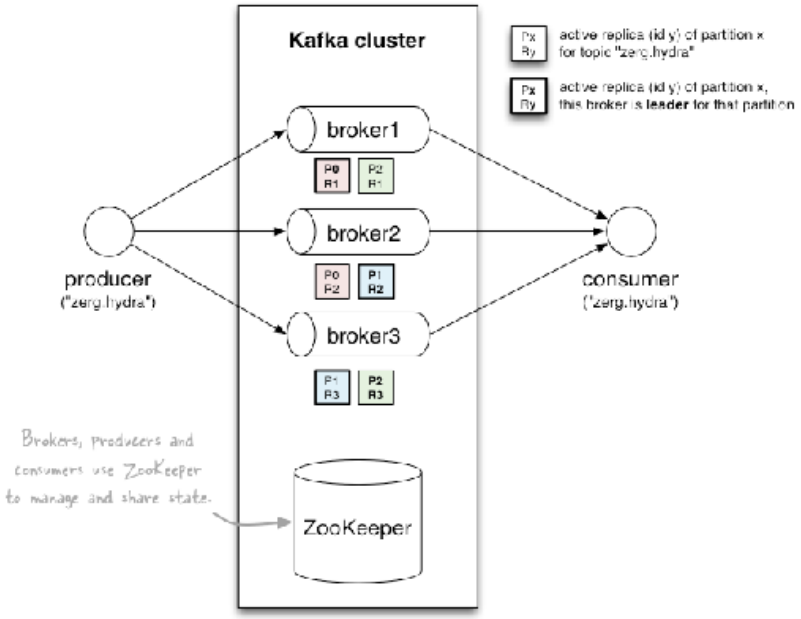
# Putting it all together



# PART 3: OPERATING KAFKA

# Kafka architecture

- Kafka brokers
  - You can run clusters with 1+ brokers.
  - Each broker in a cluster must have a unique broker.id.



# Kafka architecture

- Kafka requires ZooKeeper
- ZooKeeper
  - v0.9+: used by brokers only
    - Consumers will use special Kafka topics instead of ZooKeeper
      - Will substantially reduce the load on ZooKeeper for large deployments

# Sample Kafka broker hardware specs

- Solely dedicated to running Kafka, run nothing else.
  - 1 Kafka broker instance per machine
- 2x 4-core Intel Xeon (info outdated?)
- 64 GB RAM (up from 24 GB)
  - Only 4 GB used for Kafka broker, remaining 60 GB for page cache
  - Page cache is what makes Kafka fast
- 1 GigE (?) NICs
- EC2 example: m2.2xlarge @ $0.34/hour, with provisioned IOPS

# Sample ZooKeeper hardware specs

- ZooKeeper servers
  - Solely dedicated to running ZooKeeper, run nothing else.
    - 1 ZooKeeper instance per machine
  - SSD's dramatically improve performance
  - 1 GigE (?) NICs
- ZooKeeper in LinkedIn's architecture
  - 5-node ZK ensembles = tolerates 2 dead nodes
  - 1 ZK ensemble for all Kafka clusters within a data center
    - LinkedIn runs multiple data centers, with multiple Kafka clusters

# Operating Kafka

- Typical operations tasks include:
  - Adding or removing brokers
    - Example: ensure a newly added broker actually receives data, which requires moving partitions from existing brokers to the new broker
    - Kafka provides helper scripts (cf. below) but still manual work involved
  - Balancing data/partitions to ensure best performance
  - Add new topics, re-configure topics
    - Example: Increasing #partitions of a topic to increase max parallelism
  - Apps management: new producers, new consumers
- See Ops-related references at the end of this part

# Lessons learned from Kafka at LinkedIn

- Biggest challenge has been to manage hyper growth
  - Growth of Kafka adoption: more producers, more consumers, …
  - Growth of data: more LinkedIn.com users, more user activity, …

- Typical tasks at LinkedIn
  - Educating and coaching Kafka users.
  - Expanding Kafka clusters, shrinking clusters.
  - Monitoring consumer apps – “Hey, my stuff stopped. Kafka’s fault!”

# Kafka security

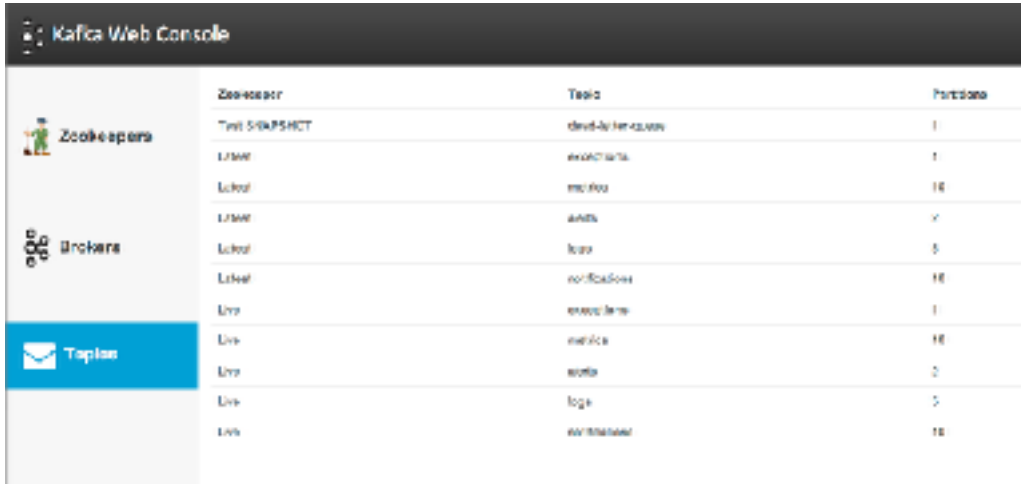
- Original design was not created with security in mind.
- Discussion started in June 2014 to add security features.
  - Covers transport layer security, data encryption at rest, non-repudiation, A&A, …
  - See [DISCUSS] Kafka Security Specific Features
- At the moment there's basically no security built-in.

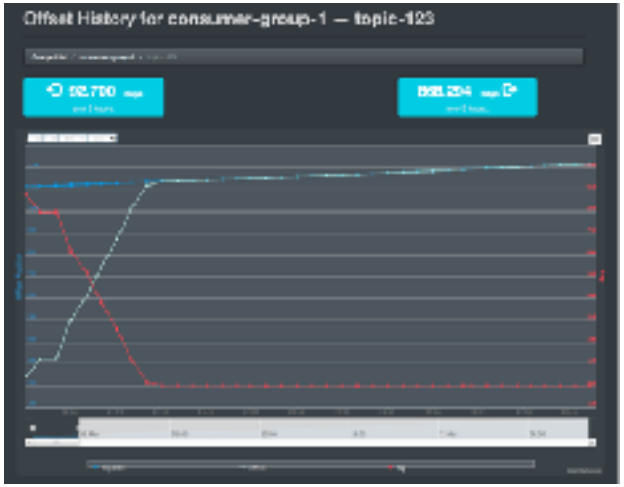
- Proposal:
  - https://cwiki.apache.org/confluence/display/KAFKA/Security

# MONITORING KAFKA

# Monitoring Kafka

- Nothing fancy built into Kafka (e.g. no UI) but see:
  - https://cwiki.apache.org/confluence/display/KAFKA/System+Tools
  - https://cwiki.apache.org/confluence/display/KAFKA/Ecosystem



# Monitoring Kafka

- Use of standard monitoring tools recommended
  - Graphite
    - Puppet module: https://github.com/miguno/puppet-graphite
    - Java API, also used by Kafka: http://metrics.codahale.com/
  - JMX
    - https://kafka.apache.org/documentation.html#monitoring
- Collect logging files into a central place

# Monitoring Kafka apps

- Almost all problems are due to:
  - Consumer lag
  - Rebalancing

# Monitoring Kafka apps: consumer lag

- Lag is a consumer problem
  - Too slow, too much GC, losing connection to ZK or Kafka, …
  - Bug or design flaw in consumer
  - Operational mistakes: e.g. you brought up 6 servers in parallel, each one in turn triggering rebalancing, then hit Kafka's rebalance limit;
    - cf. rebalance.max.retries (default: 4) & friends

# Monitoring Kafka itself (1 of 3)

- Under-replicated partitions
  - For example, because a broker is down.
  - Means cluster runs in degraded state.
    - FYI: LinkedIn runs with replication factor of 2 => 1 broker can die.

- Offline partitions
  - Even worse than under-replicated partitions!
  - Serious problem (data loss) if anything but 0 offline partitions.

# Monitoring Kafka itself (1 of 3)

- Data size on disk
  - Should be balanced across disks/brokers
  - Data balance even more important than partition balance
  - FYI: New script in v0.8.1 to balance data/partitions across brokers
- Broker partition balance
  - Count of partitions should be balanced evenly across brokers
  - See new script above.

# Monitoring Kafka itself (1 of 3)

- Leader partition count
  - Should be balanced across brokers so that each broker gets the same amount of load
  - Only 1 broker is ever the leader of a given partition,
    - only this broker is going to talk to producers + consumers for that partition
  - Feature in v0.8.1 to auto-rebalance the leaders and partitions in case a broker dies
- Network utilization
  - Maxed network one reason for under-replicated partitions
  - LinkedIn doesn't run anything but Kafka on the brokers. Hence, when they max the network, they need to add

# Monitoring ZooKeeper

- Ensemble (= cluster) availability
  - LinkedIn run 5-node ensembles = tolerates 2 dead
  - Twitter run 13-node ensembles = tolerates 6 dead
- Latency of requests
  - Metric target is 0 ms when using SSD's in ZooKeeper machines.
    - Why? Because SSD's are so fast they typically bring down latency below ZK's metric granularity.
- Outstanding requests
  - Metric target is 0.
  - Why? Because ZK processes all incoming requests serially. Non-zero values mean that requests are backing up.

# "AUDITING" KAFKA

# “Auditing” Kafka

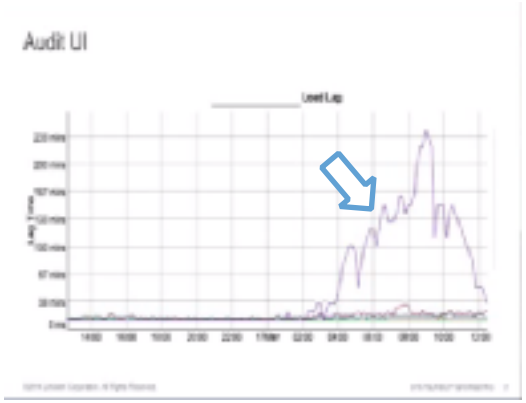
- LinkedIn's way to detect data loss etc. in Kafka
  - Not part of open source stack yet.  May come in the future.
  - In short: custom producer+consumer app that is hooked into monitoring.

- Value proposition
  - Monitor whether you're losing messages/data.
  - Monitor whether your pipelines can handle the incoming data load.

# LinkedIn's Audit UI: a first look

- Example 1: Count discrepancy
  - Caused by messages failing to reach a downstream Kafka cluster


- Example 2: Load lag



# “Auditing” Kafka

- Every producer is also writing messages into a special topic about how many messages it produced, every 10mins.
  - Example: "Over the last 10mins, I sent N messages to topic X.”
- Audit consumer
  - 1 audit consumer per Kafka cluster
  - Reads every single message out of “its” Kafka cluster. It then calculates counts for each topic, and writes those counts back into the same special topic, every 10mins.
    - Example: "I saw M messages in the last 10mins for topic X in THIS cluster”

# “Auditing” Kafka

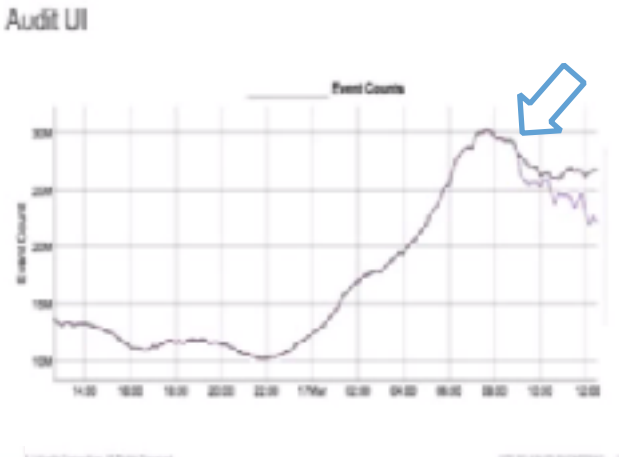
- Monitoring audit consumers
  - Completeness check
    - "#msgs according to producer == #msgs seen by audit consumer?"
  - Lag
    - "Can the audit consumers keep up with the incoming data rate?"
    - If audit consumers fall behind, then all your tracking data falls behind as well, and you don't know how many messages got produced.

# “Auditing” Kafka

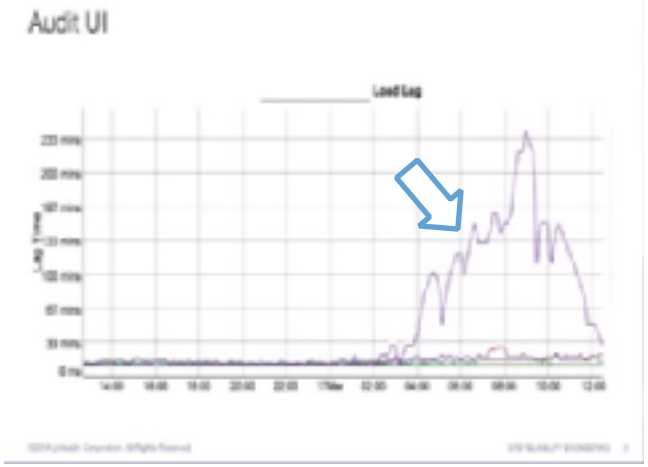
- Audit UI
  - Only reads data from that special "metrics/monitoring" topic, but this data is reads from every Kafka cluster at LinkedIn.
    - What they producers said they wrote in.
    - What the audit consumers said they saw.
  - Shows correlation graphs (producers vs. audit consumers)
    - For each tier, it shows how many messages there were in each topic over any given period of time.
    - If the percentage drops below 100%, then emails are sent to teams

# LinkedIn's Audit UI: a closing look

- Example 1: Count discrepancy
  - Caused by messages failing to reach a downstream Kafka cluster




- Example 2: Load lag



# KAFKA PERFORMANCE TUNING

# OS tuning

- Kernel tuning
  - Don’t swap!  vm.swappiness = 0 (RHEL 6.5 onwards: 1)
  - Allow more dirty pages but less dirty cache.
    - LinkedIn has lots of RAM in servers, most of it is for page cache (60 of 64 GB).  They let dirty pages built up, but cache should be available as Kafka does lots of disk and network I/O.
    - See vm.dirty_*_ratio & friends

# OS tuning

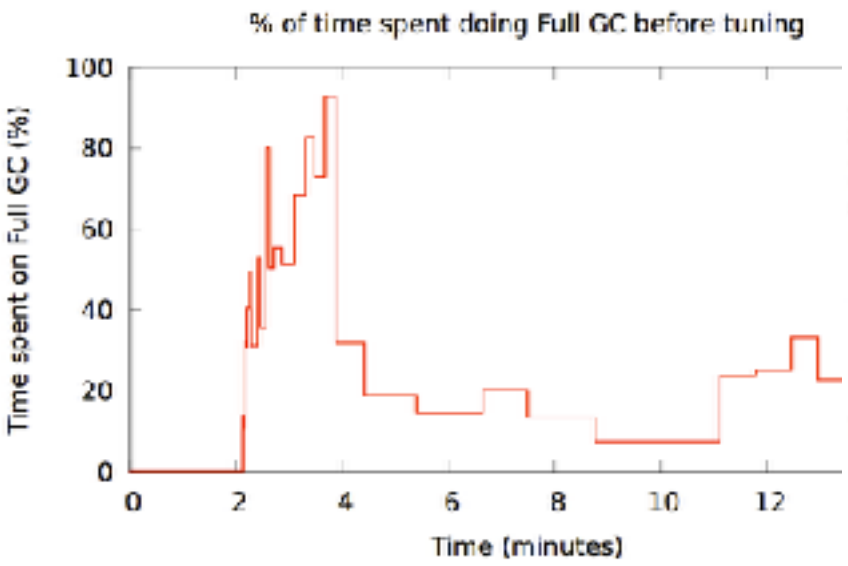
- Disk throughput
  - Longer commit interval on mount points. (ext3 or ext4?)
    - Normal interval for ext3 mount point is 30s (?) between flushes;  LinkedIn: 120s.  They can tolerate losing 2mins worth of data (because of partition replicas) so they rather prefer higher throughput here.
  - More spindles (RAID10 w/ 14 disks)

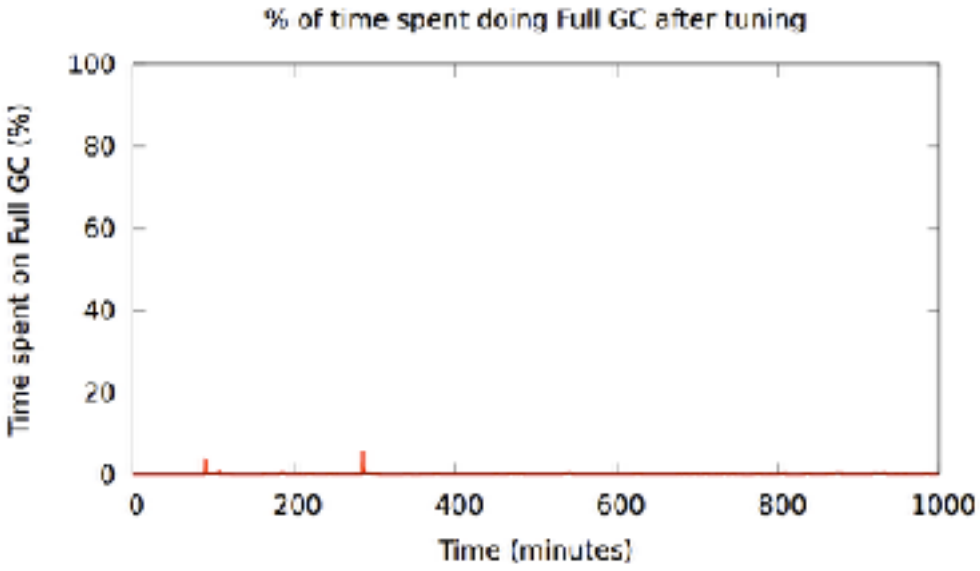
# Java/JVM tuning

- Biggest issue: garbage collection
  - And, most of the time, the only issue

- Goal is to minimize GC pause times
  - Aka “stop-the-world” events – apps are halted until GC finishes

# Java garbage collection in Kafka @ Spotify




Before tuning

After tuning

# Java/JVM tuning

- Good news: use JDK7u51 or later and have a quiet life!
  - LinkedIn: Oracle JDK, not OpenJDK

- Silver bullet is new G1 “garbage-first” garbage collector
  - Available since JDK7u4.
  - Substantial improvement over all previous GC’s, at least for Kafka.

```
$ java -Xms4g -Xmx4g -XX:PermSize=48m -XX:MaxPermSize=48m
      -XX:+UseG1GC
      -XX:MaxGCPauseMillis=20
      -XX:InitiatingHeapOccupancyPercent=35
```

# Kafka configuration tuning

- Not to much to do beyond defaults.

- Key candidates for tuning:

| | |
|---|---|
| `num.io.threads` | *should be >= #disks (start testing with == #disks)* |
| `num.network.threads` | *adjust it based on (concurrent) #producers, #consumers, and replication factor* |

# Kafka usage tuning – lessons learned from others

- Don't break things up into separate topics unless the data in them is truly independent.
  - Consumer behavior can (and will) be extremely variable, don’t assume you will always be consuming as fast as you are producing.
- Keep time related messages in the same partition.
  - Consumer behavior can be extremely variable, don't assume the lag on all your partitions will be similar.
  - Design a partitioning scheme, so that the owner of one partition can stop consuming for a long period of time and your application will be minimally impacted (for example, partition by transaction id)

# Ops-related references

- Kafka FAQ
  - https://cwiki.apache.org/confluence/display/KAFKA/FAQ
- Kafka operations
  - https://kafka.apache.org/documentation.html#operations
- Kafka system tools
  - https://cwiki.apache.org/confluence/display/KAFKA/System+Tools
  - Consumer offset checker, get offsets for a topic, print metrics via JMX to console, read from topic A and write to topic B, verify consumer rebalance
- Kafka replication tools
  - https://cwiki.apache.org/confluence/display/KAFKA/

# PART 4: DEVELOPING KAFKA APPS

# WRITING DATA TO KAFKA

# Writing data to Kafka

- You use Kafka "producers" to write data to Kafka brokers.
  - Available for JVM (Java, Scala), C/C++, Python, Ruby, etc.
  - The Kafka project only provides the JVM implementation.
    - Has risk that a new Kafka release will break non-JVM clients.

- A simple example producer:

```
1  Properties props = new Properties();
2  props.put("metadata.broker.list", "...");
3  ProducerConfig config = new ProducerConfig(props);
4
5  Producer p = new Producer(ProducerConfig config);
6  KeyedMessage<K, V> msg = ...; // cf. later slides
7  p.send(KeyedMessage<K,V> message);
```

# Producers

- The Java producer API is very simple.

```
class kafka.javaapi.producer.Producer<K,V>
{
  public Producer(ProducerConfig config);

  /**
   * Sends the data to a single topic, partitioned by key, using either the
   * synchronous or the asynchronous producer.
   */
  public void send(KeyedMessage<K,V> message);

  /**
   * Use this API to send data to multiple topics.
   */
  public void send(List<KeyedMessage<K,V>> messages);

  /**
   * Close API to close the producer pool connections to all Kafka brokers.
   */
  public void close();
}
```

# Producers

- Two types of producers: "async" and "sync"

```
1  Properties props = new Properties();
2  props.put("producer.type", "async");
3  ProducerConfig config = new ProducerConfig(props);
```

  - Same API and configuration, different semantics.
  - What applies to a sync producer almost always applies to async, too.
  - Async producer == higher throughput.
- Important configuration settings for either producer type:

| | |
|---|---|
| ***client.id*** | ***identifies producer app, e.g. in system logs*** |
| ***producer.type*** | ***async or sync*** |
| ***request.required.acks*** | ***acking semantics, cf. next slides*** |
| ***serializer.class*** | ***configure encoder, cf. slides on Avro usage*** |
| ***metadata.broker.list*** | ***cf. slides on bootstrapping list of brokers*** |

# Sync producers

- Straight-forward so I won't cover sync producers here
  - Please go to https://kafka.apache.org/documentation.html

- Most important thing to remember: producer.send() will block!

# Async producer

- Sends messages in background = no blocking in client.
- Provides more powerful batching of messages (see later).
- Wraps a sync producer, or rather a pool of them.
  - Communication from async->sync producer happens via a queue.
    - Which explains why you may see kafka.producer.async.QueueFullException
  - Each sync producer gets a copy of the original async producer config, including the request.required.acks setting (see later).
  - Implementation details: Producer, async.AsyncProducer, async.ProducerSendThread, ProducerPool, async.DefaultEventHandler#send()

# Async producer

- Caveats
  - Async producer may drop messages if its queue is full.
    - Solution 1: Don't push data to producer faster than it is able to send to brokers.
    - Solution 2: Queue full == need more brokers, add them now! Use this solution in favor of solution 3 particularly if your producer cannot block (async producers).
    - Solution 3: Set queue.enqueue.timeout.ms to -1 (default). Now the producer will block indefinitely and will never willingly drop a message.
    - Solution 4: Increase queue.buffering.max.messages (default: 10,000).

# Producers

- Two aspects worth mentioning because they significantly influence Kafka performance:
  - Message acking
  - Batching of messages

# 1) Message acking

- Background:
  - In Kafka, a message is considered committed when “any required” ISR (in-sync replicas) for that partition have applied it to their data log.
  - Message acking is about conveying this “committed!” information back from the brokers to the producer client.
  - Meaning of “any required” is defined by request.required.acks.
- Only producers must configure acking
  - Exact behavior is configured via request.required.acks: determines when a produce request is considered completed.
  - Allows you to trade latency& durability

# 1) Message acking

- Consumers: Acking and how you configured it on the side of producers do not matter to consumers because only committed messages are ever given out to consumers. They don’t need to worry about potentially seeing a message that could be lost if the leader fails.

# 1) Message acking

- Typical values of request.required.acks
  - 0: producer never waits for an ack from the broker.
    - Lowest latency but the weakest durability.
  - 1: producer gets an ack after the leader replica has received the data.
    - Gives better durability as the we wait until the lead broker acks the request. Only msgs that were written to the now-dead leader but not yet replicated will be lost.
  - -1: producer gets an ack after all ISR have received the data.
    - Best durability: Kafka guarantees no data will be lost as long as at least one ISR remains.

# 1) Message acking

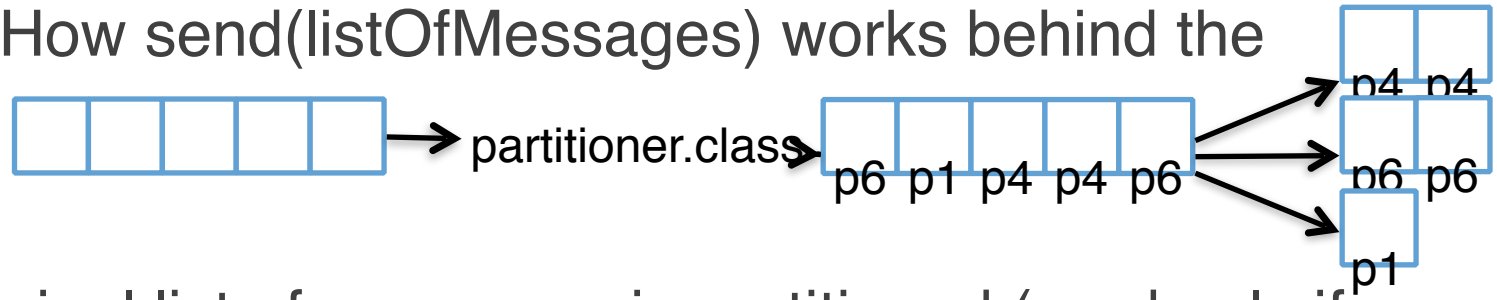
- Beware of interplay with request.timeout.ms!
  - "The amount of time the broker will wait trying to meet the `request.required.acks` requirement before sending back an error to the client.”
  - Caveat: Message may be committed even when broker sends timeout error to client (e.g. because not all ISR ack’ed in time). One reason for this is that the producer acknowledgement is independent of the leader-follower replication, and ISR’s send their acks to the leader, the latter of which will reply to the client.

# 2) Batching of messages

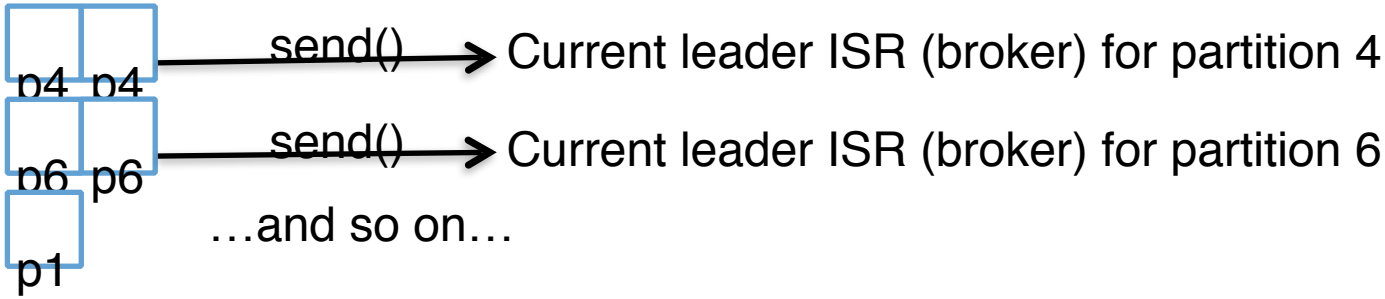
- Batching improves throughput
  - Tradeoff is data loss if client dies before pending messages have been sent.
- You have two options to “batch” messages in 0.8:
  - Use send(listOfMessages).
    - Sync producer: will send this list (“batch”) of messages right now. Blocks!
    - Async producer: will send this list of messages in background “as usual”, i.e. according to batch-related configuration settings. Does not block!
  - Use send(singleMessage) with async producer.
    - For async the behavior is the same as send(listOfMessages).

# 2) Batching of messages

- Option 1: How send(listOfMessages) works behind the scenes




  - The original list of messages is partitioned (randomly if the default partitioner is used) based on their destination partitions/topics




  - Each post-split batch is sent to the respective leader broker/ISR (the individual send()'s happen sequentially), and each is acked by its respective leader broker according to request.required.acks.

# 2) Batching of messages

- Option 2: Async producer
  - Standard behavior is to batch messages
  - Semantics are controlled via producer configuration settings
    - batch.num.messages
    - queue.buffering.max.ms + queue.buffering.max.messages
    - queue.enqueue.timeout.ms
    - And more, see producer configuration docs.
- Remember: Async producer simply wraps sync producer!
  - But the batch-related config settings above have no effect on “true” sync producers, i.e. when used without a wrapping async producer.

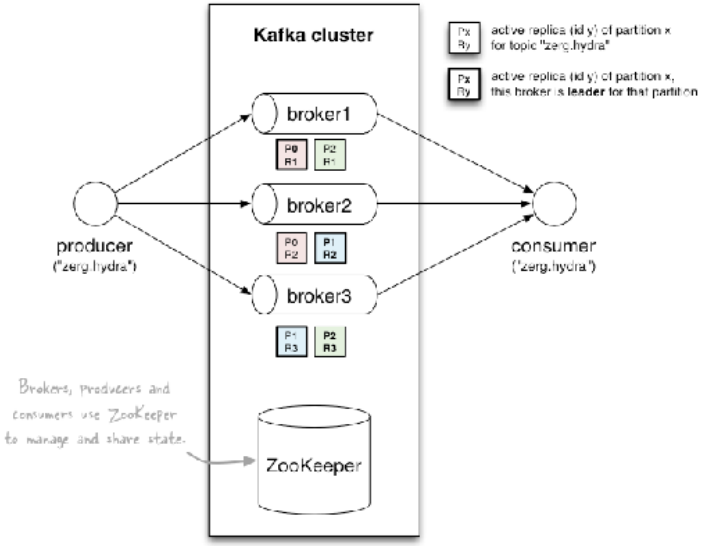
# FYI: upcoming producer configuration changes

| Kafka 0.8 | Kafka 0.9 (unreleased) |
|---|---|
| `metadata.broker.list` | `bootstrap.servers` |
| `request.required.acks` | `acks` |
| `batch.num.messages` | `batch.size` |
| `message.send.max.retrie` | `retries` |

(This list is not complete, see Kafka docs for details.)

# Write operations behind the scenes

- When writing to a topic in Kafka, producers write directly to the partition leaders (brokers) of that topic
  - Remember: Writes always go to the leader ISR of a partition!




- This raises two questions:
  - How to know the “right” partition for a given topic?
  - How to know the current leader broker/replica of a partition?

# 1) How to know the “right” partition when sending?

- In Kafka, a producer – i.e. the client – decides to which target partition a message will be sent.
  - Can be random ~ load balancing across receiving brokers.
  - Can be semantic based on message “key”, e.g. by user ID or domain name.
    - Here, Kafka guarantees that all data for the same key will go to the same partition

```
1  // Java example.  Topic is "zerg.hydra".
2  KeyedMessage<String, String> msg = new KeyedMessage<>("zerg.hydra", "myValue");
3  KeyedMessage<String, String> msg = new KeyedMessage<>("zerg.hydra", "myKey", "myValue");
```

- But there’s one catch with line 2 (i.e. no key) in Kafka 0.8.

# Keyed vs. non-keyed messages in Kafka 0.8

- If a key is not specified:

```
2  KeyedMessage<String, String> msg = new KeyedMessage<>("zerg.hydra", "myValue");
```

  - Producer will ignore any configured partitioner.
  - It will pick a random partition from the list of available partitions and stick to it for some time before switching to another one = NOT round robin or similar!
    - Why? To reduce number of open sockets in large Kafka deployments (KAFKA-1017).
    - Default: 10mins, cf.
    - See implementation in DefaultEventHandler#getPartition()

# Keyed vs. non-keyed messages in Kafka 0.8

- If there are fewer producers than partitions at a given point of time, some partitions may not receive any data. How to fix if needed?
  - Try to reduce the metadata refresh interval topic.metadata.refresh.interval.ms
  - Specify a message key and a customized random partitioner.
- In practice it is not trivial to implement a correct "random" partitioner in Kafka 0.8.
  - Partitioner interface in Kafka 0.8 lacks sufficient information to let a partitioner select a random and available partition. Same issue with DefaultPartitioner.

# Keyed vs. non-keyed messages in Kafka 0.8

- If a key is specified:
  - Key is retained as part of the msg, will be stored in the broker.
  - One can design a partition function to route the msg based on key.
  - The default partitioner assigns messages to a partition based on their key hashes, via key.hashCode % numPartitions.

# Keyed vs. non-keyed messages in Kafka 0.8

- Caveat:
  - If you specify a key for a message but do not explicitly wire in a custom partitioner via partitioner.class, your producer will use the default partitioner.
  - So without a custom partitioner, messages with the same key will still end up in the same partition! (cf. default partitioner's behavior above)

# 2) How to know the current leader of a partition?

- Producers: broker discovery aka bootstrapping
  - Producers don't talk to ZooKeeper, so it's not through ZK.
  - Broker discovery is achieved by providing producers with a "bootstrapping" broker list, cf. metadata.broker.list
    - These brokers inform the producer about all alive brokers and where to find current partition leaders. The bootstrap brokers do use ZK for that.

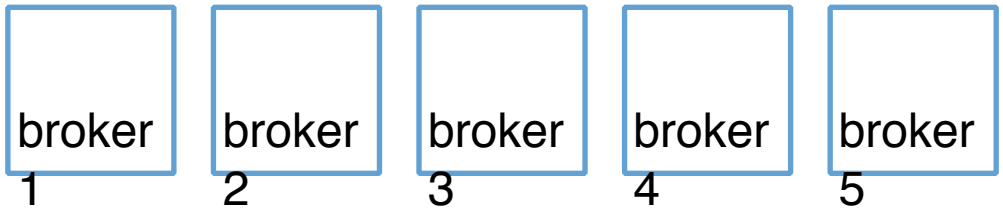
# 2) How to know the current leader of a partition?

- Impacts on failure handling
  - In Kafka 0.8 the bootstrap list is static/immutable during producer run-time. This has limitations and problems as shown in next slide.
  - The current bootstrap approach will improve in Kafka 0.9. This change will make the life of Ops easier.

# Bootstrapping in Kafka 0.8

- Scenario: N=5 brokers total, 2 of which are for bootstrap

```
1  Properties props = new Properties();
2  props.put("metadata.broker.list", "broker1:9092,broker2:9092");
3  ProducerConfig config = new ProducerConfig(props);
```



# Bootstrapping in Kafka 0.8

- Do's:
  - Take down one bootstrap broker (e.g. broker2), repair it, and bring it back.
  - In terms of impacts on broker discovery, you can do whatever you want to brokers 3-5.
- Don'ts:
  - Stop all bootstrap brokers 1+2.  If you do, the producer stops working!

# READING DATA FROM KAFKA

# Reading data from Kafka

- You use Kafka “consumers” to read data from Kafka brokers.
  - Available for JVM (Java, Scala), C/C++, Python, Ruby, etc.
  - The Kafka project only provides the JVM implementation.
    - Has risk that a new Kafka release will break non-JVM clients.
- Three API options for JVM users:
  - High-level consumer API <<< in most cases you want to use this one!
  - Simple consumer API
  - Hadoop consumer API

# Reading data from Kafka

- Consumers pull from Kafka (there's no push)
  - Allows consumers to control their pace of consumption.
  - Allows to design downstream apps for average load, not peak load (cf. Loggly talk)
- Consumers are responsible to track their read positions aka "offsets"
  - High-level consumer API: takes care of this for you, stores offsets in ZooKeeper
  - Simple consumer API: nothing provided, it's totally up to you

# Reading data from Kafka

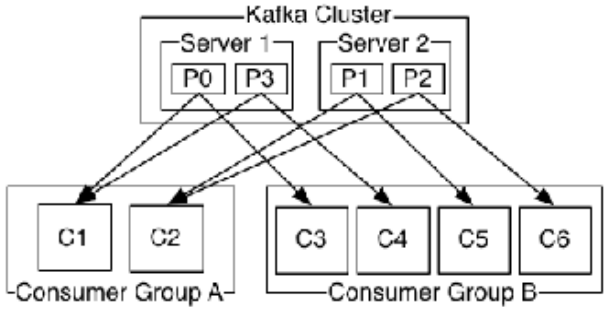
- What does this offset management allow you to do?
  - Consumers can deliberately rewind “in time” (up to the point where Kafka prunes), e.g. to replay older messages.
    - Cf. Kafka spout in Storm 0.9.2.
  - Consumers can decide to only read a specific subset of partitions for a given topic.
    - Cf. Loggly’s setup of (down)sampling a production Kafka topic to a manageable volume for testing
  - Run offline, batch ingestion tools that write (say) from Kafka to Hadoop HDFS every hour.
    - Cf. LinkedIn Camus, Pinterest, etc

# Reading data from Kafka

- Important consumer configuration settings

| | |
|---|---|
| ***`group.id`*** | ***assigns an individual consumer to a "group"*** |
| ***`zookeeper.connect`*** | ***to discover brokers/topics/etc., and to store consumer state (e.g. when using the high-level consumer API)*** |
| ***`fetch.message.max.bytes`*** | ***number of message bytes to (attempt to) fetch for each partition; must be >= broker's `message.max.bytes`*** |

# Reading data from Kafka




- Consumer “groups”
  - Allows multi-threaded and/or multi-machine consumption from Kafka topics.
  - Consumers “join” a group by using the same group.id
  - Kafka guarantees a message is only ever read by a single consumer in a group.
    - Kafka assigns the partitions of a topic to the consumers in a group so that each partition is consumed by exactly one consumer in the group.
    - Maximum parallelism of a consumer group: #consumers (in the group) <= #partitions

# Guarantees when reading data from Kafka

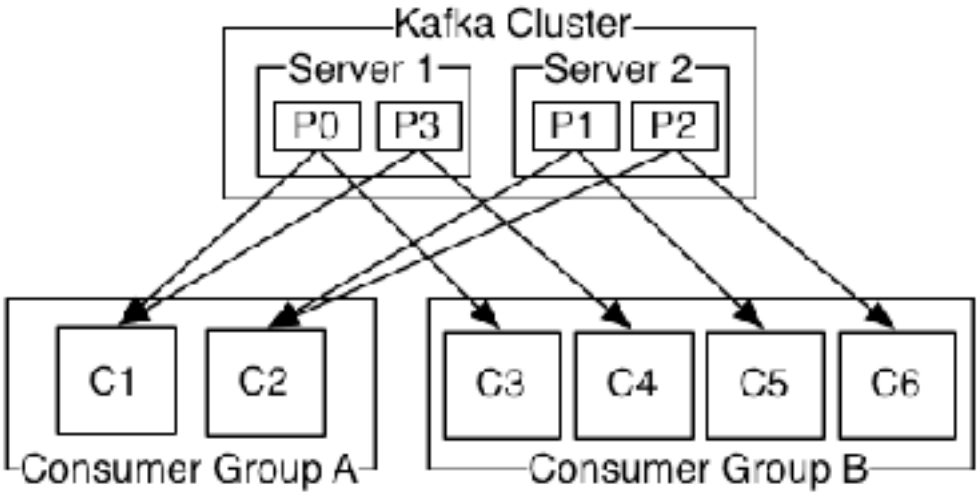
- A message is only ever read by a single consumer in a group.
  - Sees messages in the order they were stored in the log.
- Order of messages is only guaranteed within a partition.
  - No order guarantee across partitions, which includes no order guarantee per-topic.
  - If total order (per topic) is required you can consider, for instance:
    - Use #partition = 1. Good: total order. Bad: Only 1 consumer process at a time.
    - “Add” total ordering in your consumer application, e.g. a Storm topology.

# Guarantees when reading data from Kafka

- Some gotchas:
  - If you have multiple partitions per thread there is NO guarantee about the order you receive messages, other than that within the partition the offsets will be sequential.
    - Example: You may receive 5 messages from partition 10 and 6 from partition 11, then 5 more from partition 10 followed by 5 more from partition 10, even if partition 11 has data available.
  - Adding more processes/threads will cause Kafka to rebalance, possibly changing the assignment of a partition to a thread (whoops).

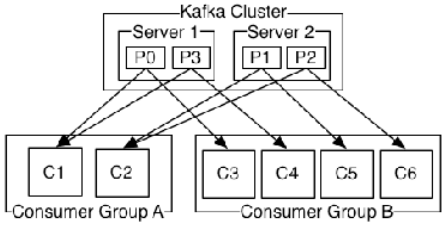
# Rebalancing: how consumers meet brokers

- Remember?




- The assignment of brokers – via the partitions of a topic – to consumers is quite important, and it is dynamic at run-time.

# Rebalancing: how consumers meet brokers




- Why “dynamic at run-time”?
  - Machines can die, be added, …
  - Consumer apps may die, be re-configured, added, …
- Whenever this happens a rebalancing occurs.
  - Rebalancing is a normal and expected lifecycle event in Kafka.
  - But it’s also a nice way to shoot yourself or Ops in the foot.
- Why is this important?
  - Most Ops issues are due to 1) rebalancing and 2) consumer lag.
  - So Dev + Ops must understand what goes on.

# Rebalancing: how consumers meet brokers

- Rebalancing?
  - Consumers in a group come into consensus on which consumer is consuming which partitions
    - required for distributed consumption
  - Divides broker partitions evenly across consumers, tries to reduce the number of broker nodes each consumer has to connect to
- When does it happen? Each time:
  - a consumer joins or leaves a consumer group, OR
  - a broker joins or leaves, OR
  - a topic “joins/leaves” via a filter, cf. createMessageStreamsByFilter()

# Rebalancing: how consumers meet brokers

- Examples:
  - If a consumer or broker fails to heartbeat to ZK
    - rebalance!
  - createMessageStreams() registers consumers for a topic, which results in a rebalance of the consumer-broker assignment.

# TESTING KAFKA APPS

# Testing Kafka apps

- Some hints:
  - Unit-test your individual classes like usual
  - When integration testing, use in-memory instances of Kafka and ZK
- Starting points:
  - Kafka's own test suite
    - 0.8.1: https://github.com/apache/kafka/tree/0.8.1/core/src/test
    - trunk: https://github.com/apache/kafka/tree/trunk/core/src/test/

# SERIALIZATION IN KAFKA

# Serialization in Kafka

- Kafka does not care about data format of msg payload
- Up to developer (= you) to handle serialization/ deserialization
  - Common choices in practice: Avro, JSON

```
/**
   *  Create a list of message streams of type T for each topic.
   *
   *  @param topicCountMap  a map of (topic, #streams) pair
   *  @param decoder a decoder that converts from Message to T
   *  @return a map of (topic, list of  KafkaStream) pairs.
   *          The number of items in the list is #streams. Each stream supports
   *          an iterator over message/metadata pairs.
   */
  public <K,V> Map<String, List<KafkaStream<K,V>>>
    createMessageStreams(Map<String, Integer> topicCountMap, Decoder<K> keyDecoder, Decoder<V> valueDecoder);

  /**
   *  Create a list of message streams of type T for each topic, using the default decoder.
   */
  public Map<String, List<KafkaStream<byte[], byte[]>>> createMessageStreams(Map<String, Integer> topicCountMap);
```

(Code above is from the High Level Consumer API)

# Serialization in Kafka: using Avro

- One way to use Avro in Kafka is via Twitter Bijection.
  - https://github.com/twitter/bijection
- Approach: Convert pojo to byte[], then send byte[] to Kafka.
  - Bijection in Scala:

```
5  val tweet = new Tweet("miguno", "Terran is the cheese race.", 1366190000)
6
7  // From POJO to byte array
8  val bytes = Injection[Tweet, Array[Byte]](tweet)
9
10 // From byte array back to POJO
11 val recovered_tweet = Injection.invert[Tweet, Array[Byte]](bytes)
```

  - Bijection in Java: https://github.com/twitter/bijection/wiki/Using-bijection-from-java

# DATA COMPRESSION IN KAFKA

# Data compression in Kafka

- But worth looking into!
- Interplay with batching of messages, e.g. larger batches typically achieve better compression ratios.

- Details about compression in Kafka:
  - https://cwiki.apache.org/confluence/display/KAFKA/Compression
  - Blog post by Neha Narkhede, Kafka committer @ LinkedIn: http://geekmantra.wordpress.com/2013/03/28/compression-in-kafka-gzip-or-snappy/

# WRAPPING UP

# Where to find help

- No (good) Kafka book available yet.
- Kafka documentation
  - http://kafka.apache.org/documentation.html
  - https://cwiki.apache.org/confluence/display/KAFKA/Index
- Kafka ecosystem, e.g. Storm integration, Puppet
  - https://cwiki.apache.org/confluence/display/KAFKA/Ecosystem
- Mailing lists
  - http://kafka.apache.org/contact.html
- Code examples
  - examples/ directory in Kafka, https://github.com/apache/