Recipes for Running Spark Streaming Apps in Production

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Spark Summit 2015

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Spark Streaming

Scalable, fault-tolerant stream processing system

High-level API

joins, windows, …
often 5x less code

Fault-tolerant

Exactly-once semantics,
even for stateful ops

Integration

Integrates with MLlib, SQL,
DataFrames, GraphX

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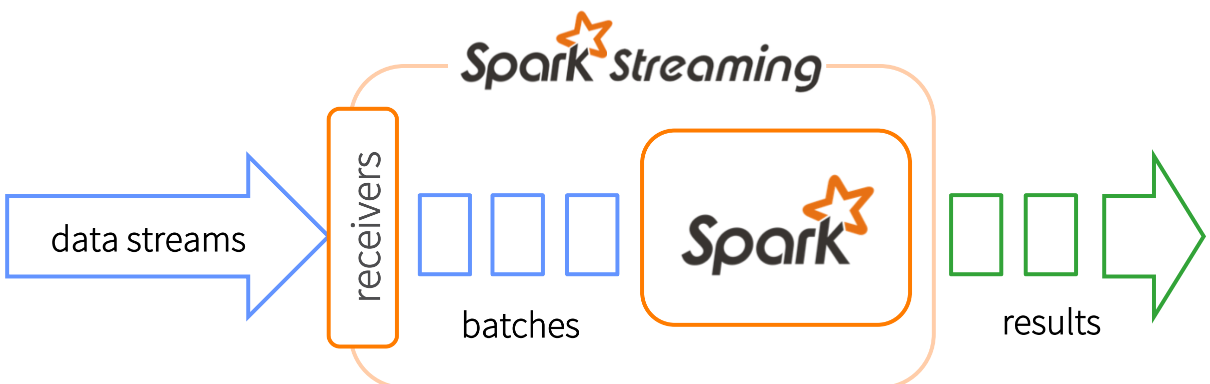
Spark Streaming

Receivers receive data streams and chop them up into batches

Spark processes the batches and pushes out the results



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Word Count with Kafka

```
val context = new StreamingContext(conf, Seconds(1))

val lines = KafkaUtils.createStream(context, ...)
```

entry point of streaming functionality

create DStream from Kafka data

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Word Count with Kafka

```
val context = new StreamingContext(conf, Seconds(1))

val lines = KafkaUtils.createStream(context, ...)

val words = lines.flatMap(_.split(" "))
```

split lines into words

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Word Count with Kafka

```
val context = new StreamingContext(conf, Seconds(1))

val lines = KafkaUtils.createStream(context, ...)

val words = lines.flatMap(_.split(" "))

val wordCounts = words.map(x => (x, 1))
                      .reduceByKey(_ + _)

wordCounts.print()

context.start()
```

count the words

print some counts on screen

start receiving and transforming the data

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Word Count with Kafka

```scala
object WordCount {
  def main(args: Array[String]) {
    val context = new StreamingContext(new SparkConf(), Seconds(1))
    val lines = KafkaUtils.createStream(context, ...)
    val words = lines.flatMap(_.split(" "))
    val wordCounts = words.map(x => (x,1)).reduceByKey(_ + _)
    wordCounts.print()
    context.start()
    context.awaitTermination()
  }
}
```

Got it working on a small Spark cluster on little data

What's next??

How to get it production-ready?

Fault-tolerance and Semantics

Performance and Stability

Monitoring and Upgrading

Deeper View of Spark Streaming

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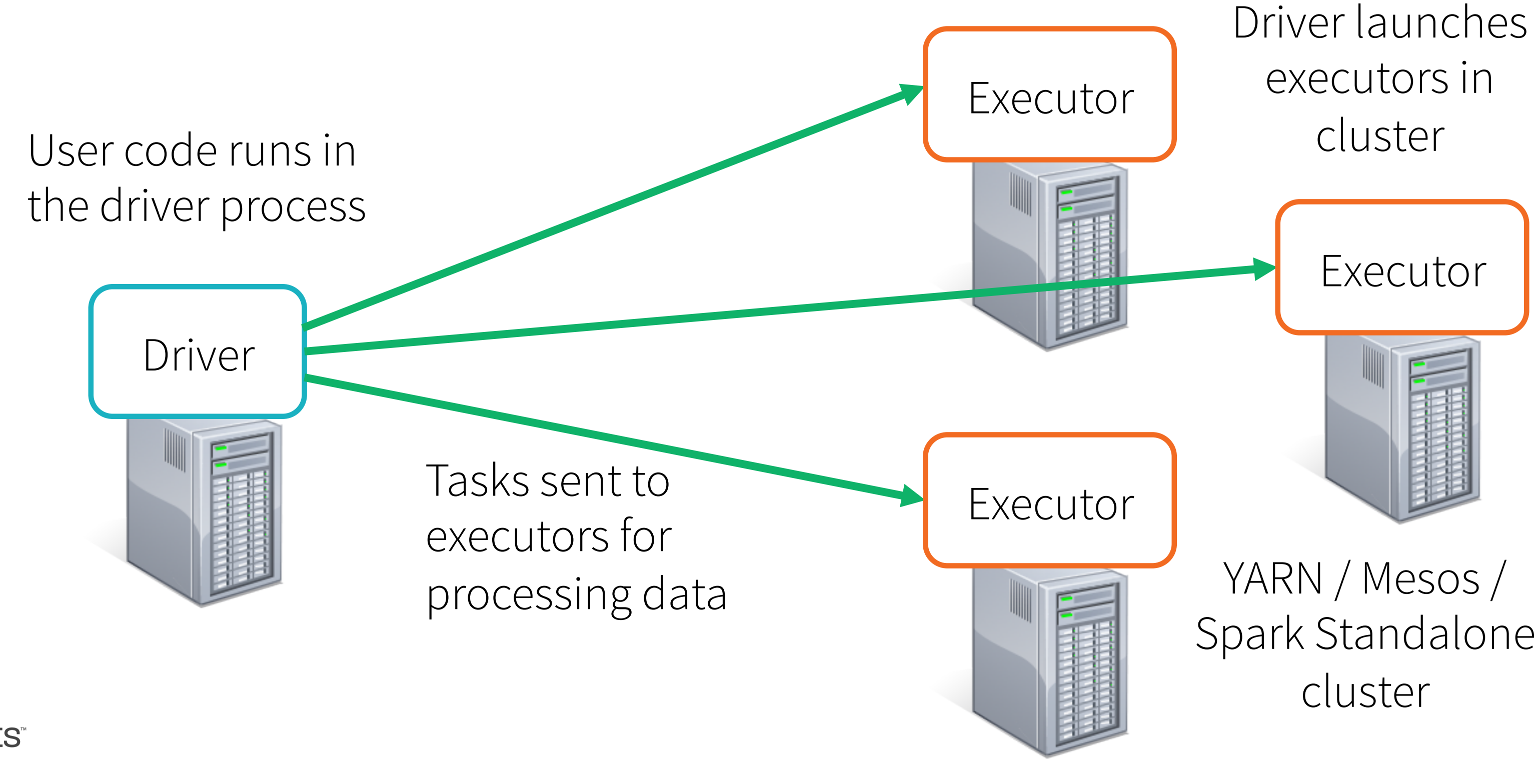
Any Spark Application



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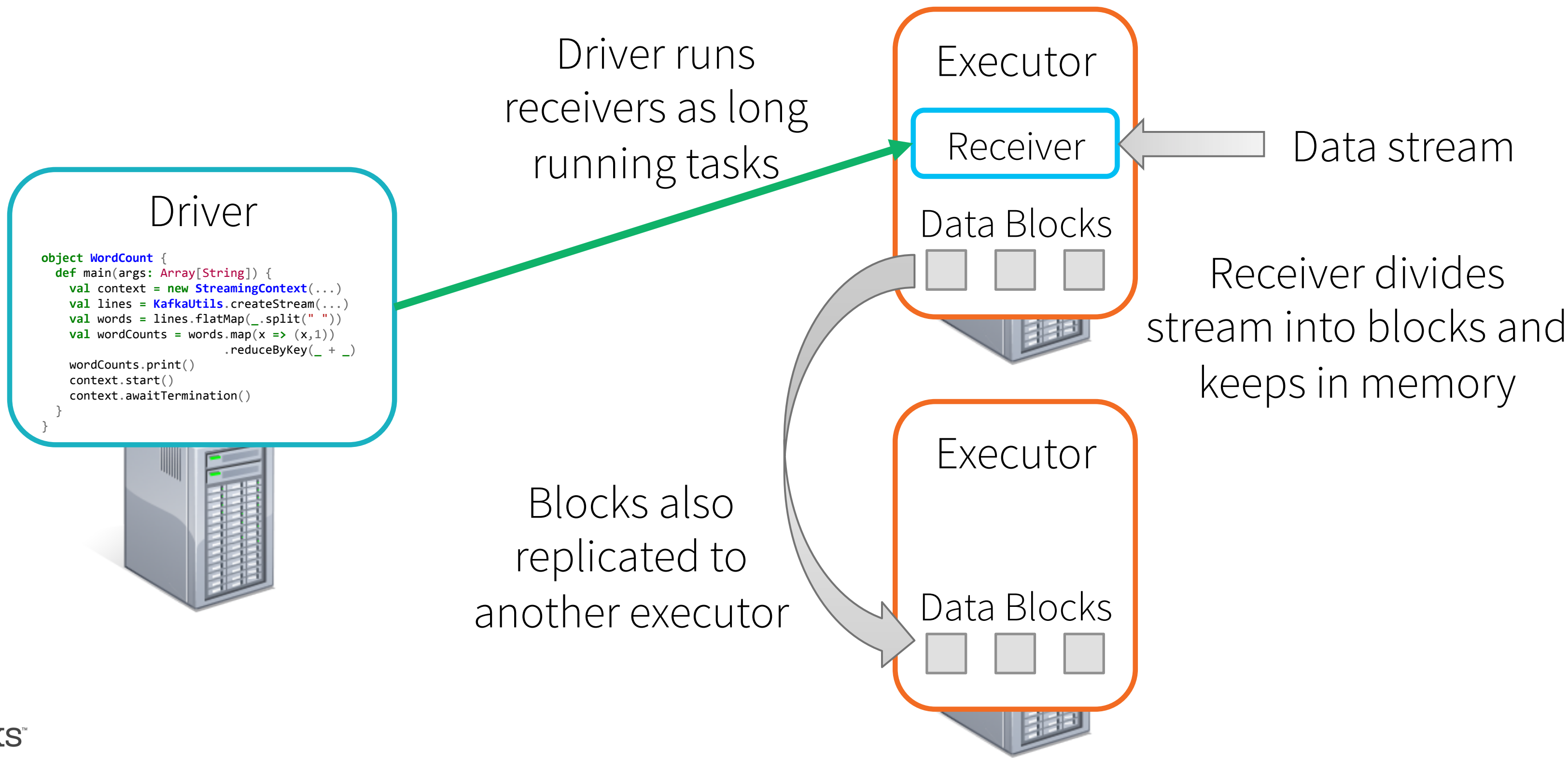
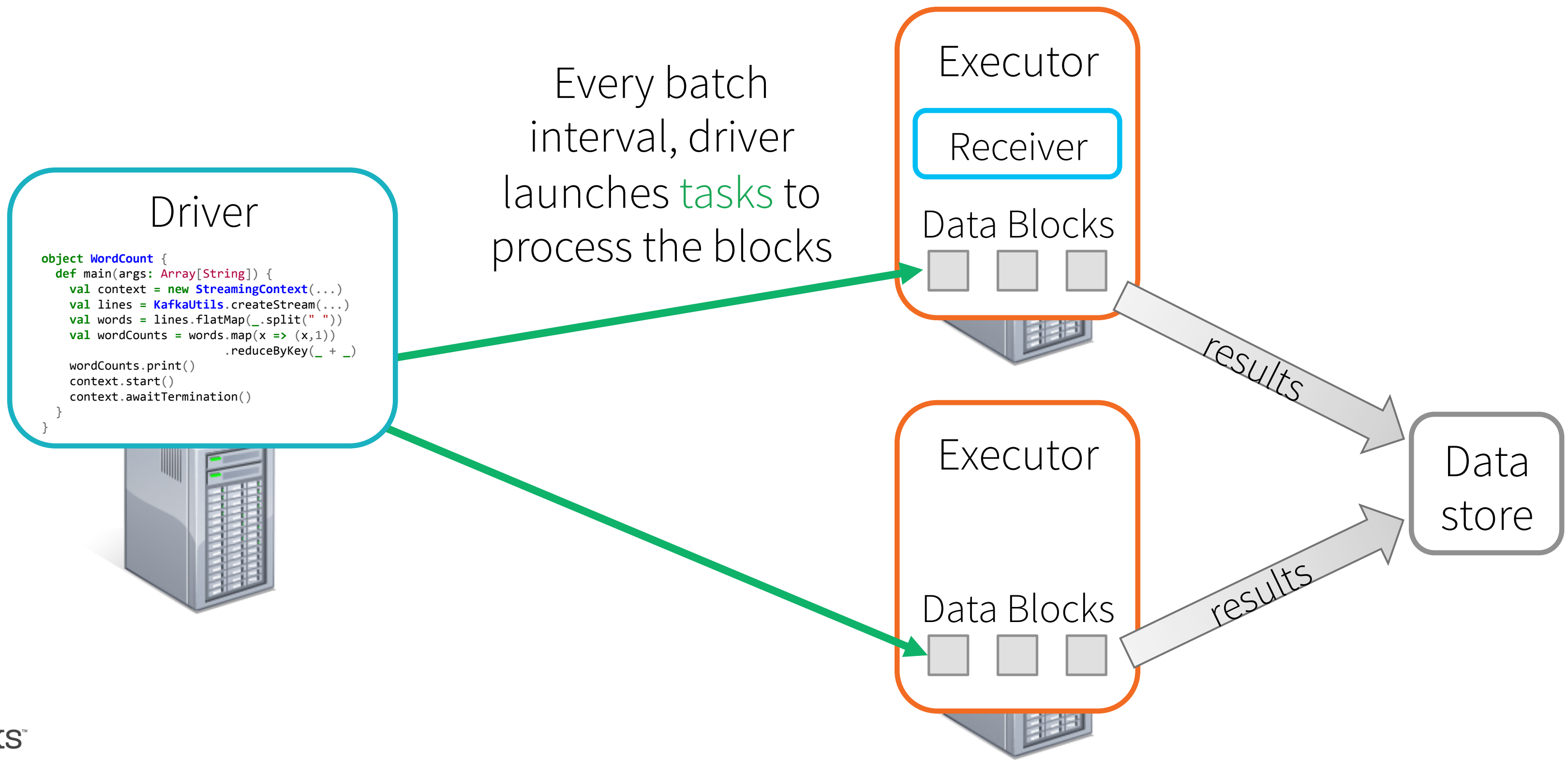
Spark Streaming Application: Receive data



Spark Streaming Application: Process data



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Fault-tolerance and Semantics

Performance and Stability

Monitoring and upgrading

Failures? Why care?

Many streaming applications need zero data loss guarantees despite any kind of failures in the system

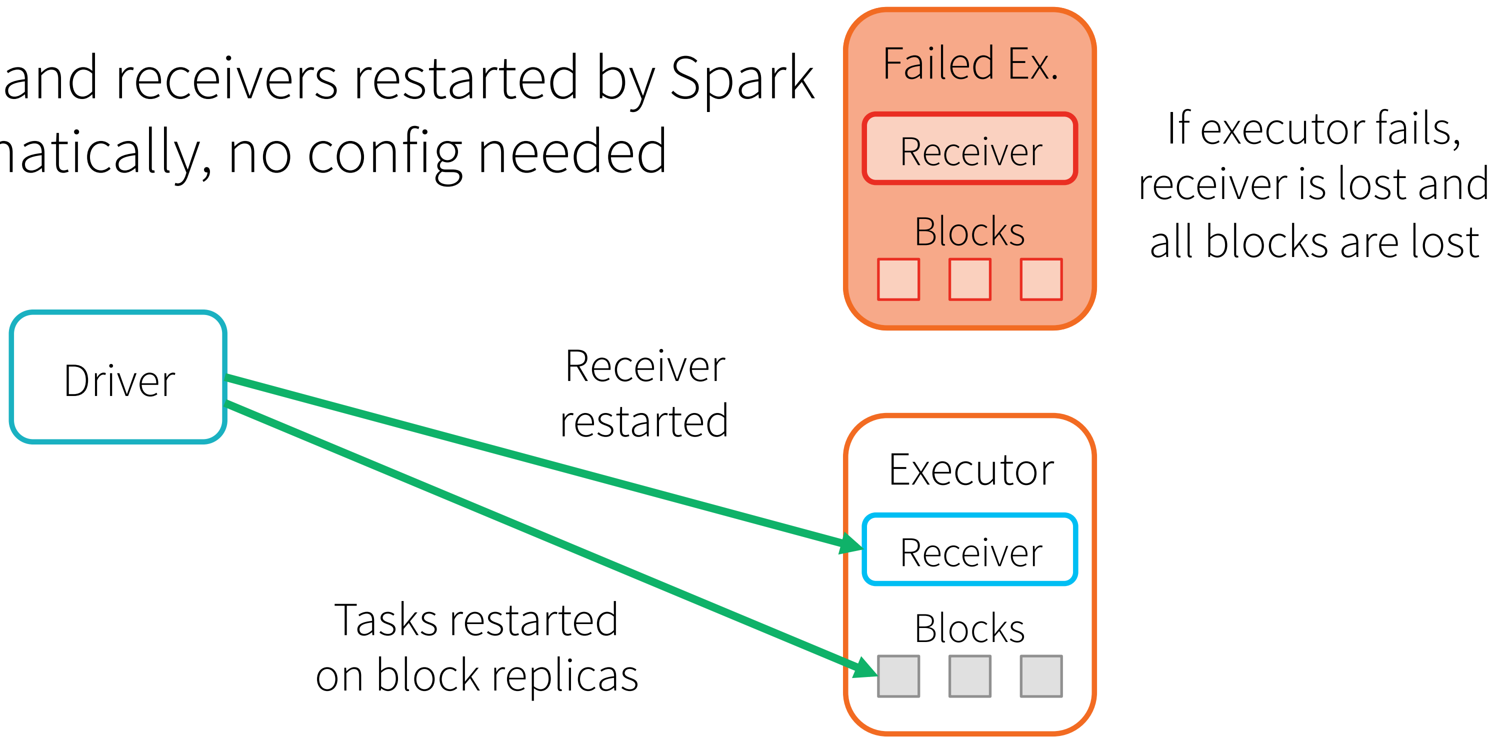
- At least once guarantee – every record processed at least once
- Exactly once guarantee – every record processed exactly once

Different kinds of failures – executor and driver

Some failures and guarantee requirements need additional configurations and setups

What if an executor fails?

Tasks and receivers restarted by Spark automatically, no config needed



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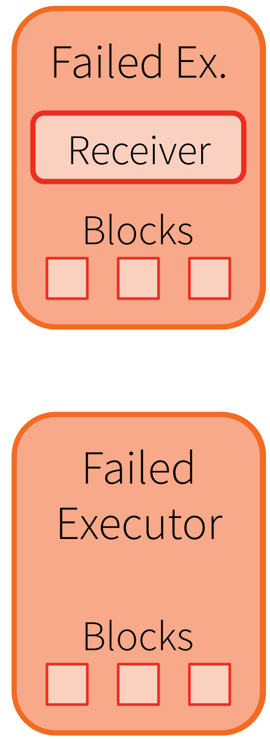
What if the driver fails?

When the driver fails, all the executors fail

All computation, all received blocks are lost

How do we recover?



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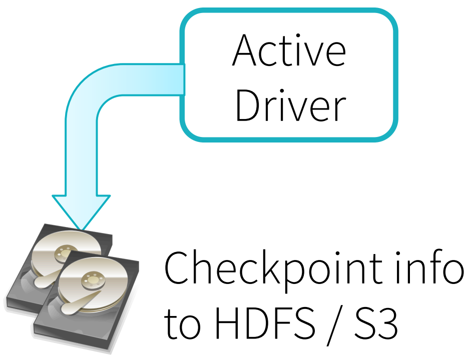
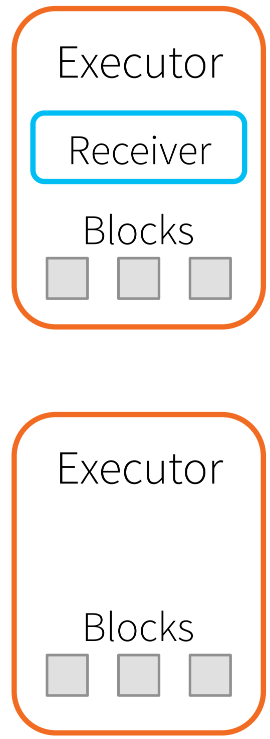
Recovering Driver with Checkpointing

DStream Checkpointing:

Periodically save the DAG of DStreams to fault-tolerant storage





Recovering Driver w/ DStream Checkpointing

DStream Checkpointing:

Periodically save the DAG of DStreams to fault-tolerant storage

Failed Driver

Restarted Driver

New executors launched and receivers restarted

New Executor

Receiver

New Executor

Failed driver can be restarted from checkpoint information

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Recovering Driver w/ DStream Checkpointing

1. Configure automatic driver restart
   All cluster managers support this

2. Set a checkpoint directory in a HDFS-compatible file system
   ```
   streamingContext.checkpoint(hdfsDirectory)
   ```

3. Slightly restructure of the code to use checkpoints for recovery

Configurating Automatic Driver Restart

Spark Standalone – Use spark-submit with “cluster” mode and “--supervise”

See http://spark.apache.org/docs/latest/spark-standalone.html

YARN – Use spark-submit in “cluster” mode

See YARN config “yarn.resourcemanager.am.max-attempts”

Mesos – Marathon can restart Mesos applications

Restructuring code for Checkpointing

Create
+
Setup

```
val context = new StreamingContext(...)
val lines = KafkaUtils.createStream(...)
val words = lines.flatMap(...)
...
```

```
def creatingFunc(): StreamingContext = {
   val context = new StreamingContext(...)
   val lines = KafkaUtils.createStream(...)
   val words = lines.flatMap(...)
   ...
   context.checkpoint(hdfsDir)
}
```

Put all setup code into a function that returns a new StreamingContext

Start

```
context.start()
```

```
val context =
StreamingContext.getOrCreate(
  hdfsDir, creatingFunc)
context.start()
```

Get context setup from HDFS dir OR *create* a new one with the function

Restructuring code for Checkpointing

StreamingContext.getOrCreate():

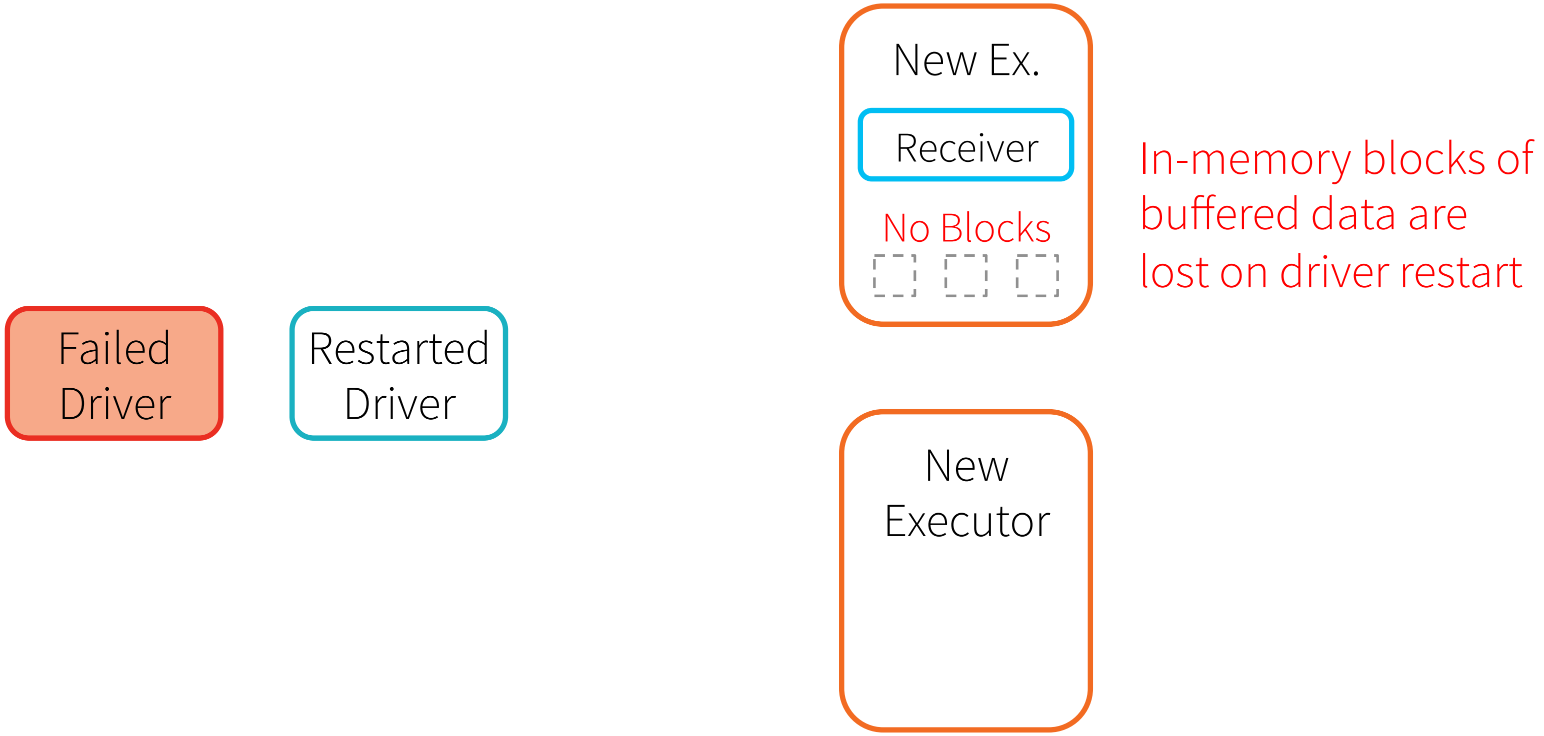
If HDFS directory has checkpoint info
    recover context from info
else
    call **`creatingFunc()`** to create
    and setup a new context

```
def creatingFunc(): StreamingContext = {
   val context = new StreamingContext(...)
   val lines = KafkaUtils.createStream(...)
   val words = lines.flatMap(...)
   ...
   context.checkpoint(hdfsDir)
}
```

Restarted process can figure out whether to recover using checkpoint info or not

```
val context =
StreamingContext.getOrCreate(
  hdfsDir, creatingFunc)
context.start()
```

Received blocks lost on Restart!



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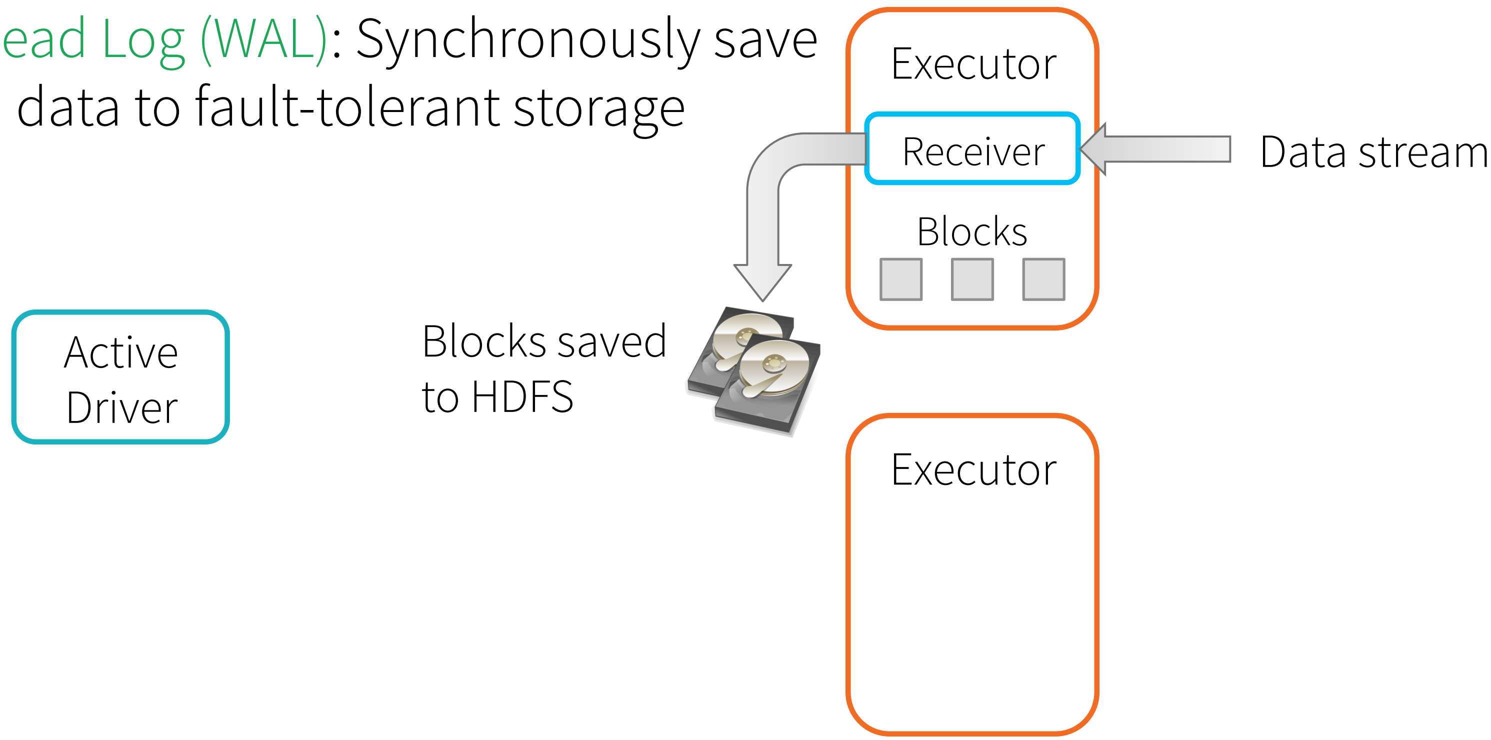
Recovering data with Write Ahead Logs

Write Ahead Log (WAL): Synchronously save received data to fault-tolerant storage



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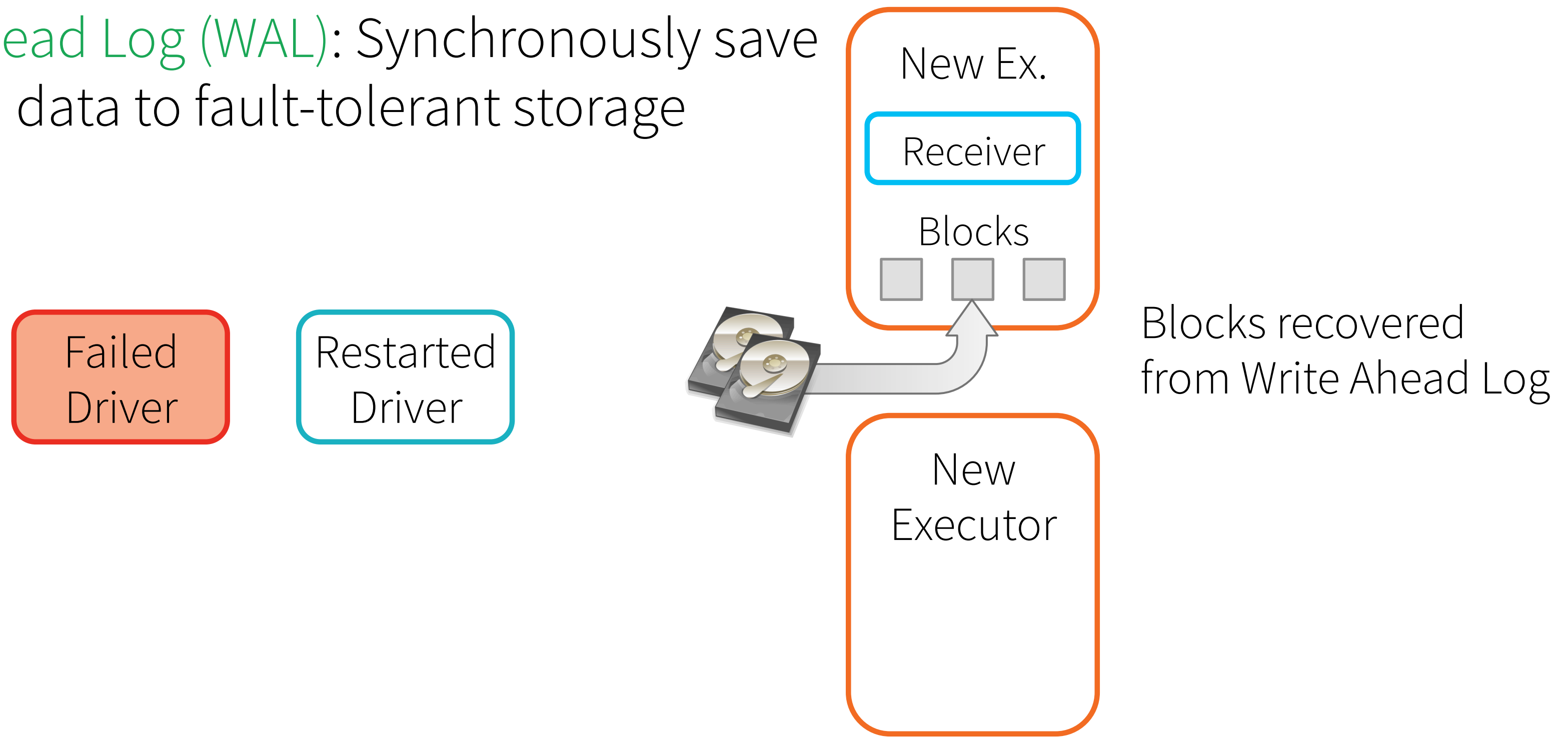
Recovering data with Write Ahead Logs

Write Ahead Log (WAL): Synchronously save received data to fault-tolerant storage



Recovering data with Write Ahead Logs

1. Enable checkpointing, logs written in checkpoint directory

2. Enabled WAL in SparkConf configuration
   `sparkConf.set("spark.streaming.receiver.writeAheadLog.enable", "true")`

3. Receiver should also be *reliable*
   Acknowledge source only after data saved to WAL
   Unacked data will be replayed from source by restarted receiver

4. Disable in-memory replication (already replicated by HDFS)
   Use `StorageLevel.MEMORY_AND_DISK_SER` for input DStreams

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RDD Checkpointing

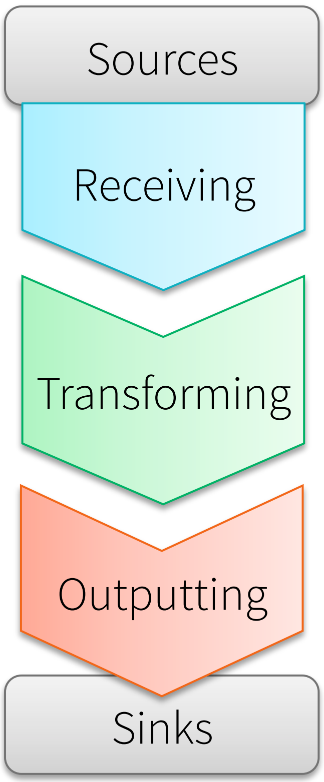
Stateful stream processing can lead to long RDD lineages

Long lineage = bad for fault-tolerance, too much recomputation

RDD checkpointing saves RDD data to the fault-tolerant storage to limit lineage and recomputation

More: http://spark.apache.org/docs/latest/streaming-programming-guide.html#checkpointing

Fault-tolerance Semantics



Zero data loss = every stage processes each event at least once despite any failure

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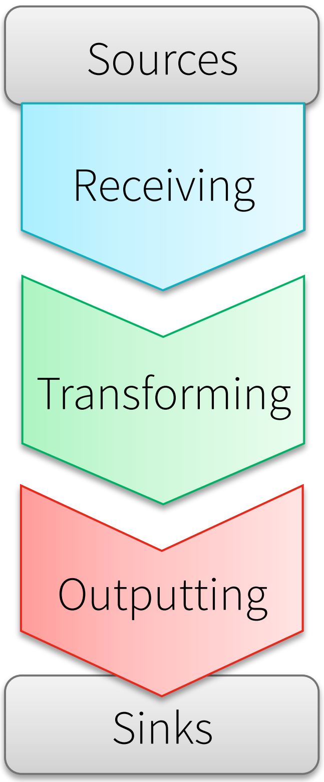
Fault-tolerance Semantics



At least once, w/ Checkpointing + WAL + Reliable receivers

Exactly once, as long as received data is not lost

Exactly once, if outputs are idempotent or transactional

End-to-end semantics:
At-least once

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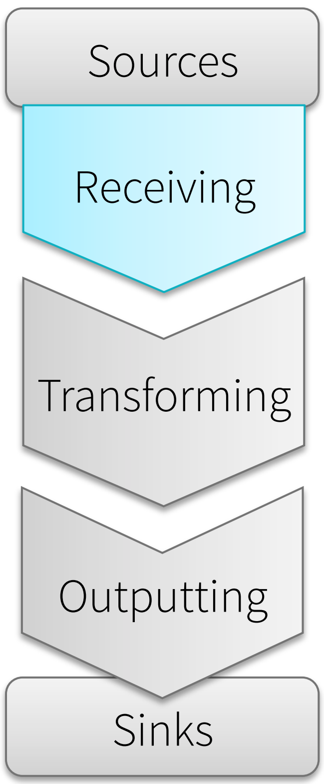
Fault-tolerance Semantics



Exactly once receiving with new Kafka Direct approach

- Treats Kafka like a replicated log, reads it like a file
- Does not use receivers
- No need to create multiple DStreams and union them
- No need to enable Write Ahead Logs

```
val directKafkaStream = KafkaUtils.createDirectStream(...)
```

https://databricks.com/blog/2015/03/30/improvements-to-kafka-integration-of-spark-streaming.html
http://spark.apache.org/docs/latest/streaming-kafka-integration.html

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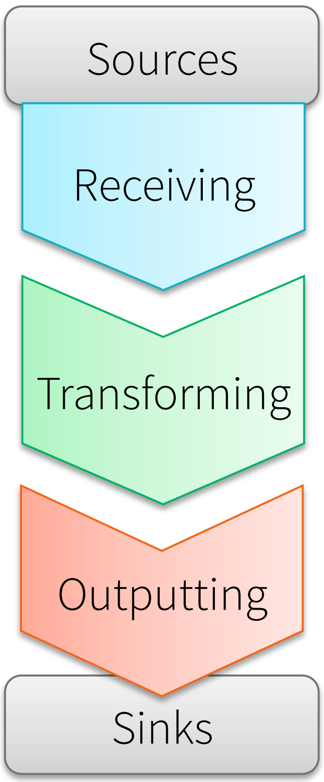
Fault-tolerance Semantics



Exactly once receiving with new Kafka Direct approach

Exactly once, as long as received data is not lost

Exactly once, if outputs are idempotent or transactional

End-to-end semantics:
Exactly once!

NETFLIX

The Netflix Tech Blog

Wednesday, March 11, 2015

Can Spark Streaming survive Chaos Monkey?

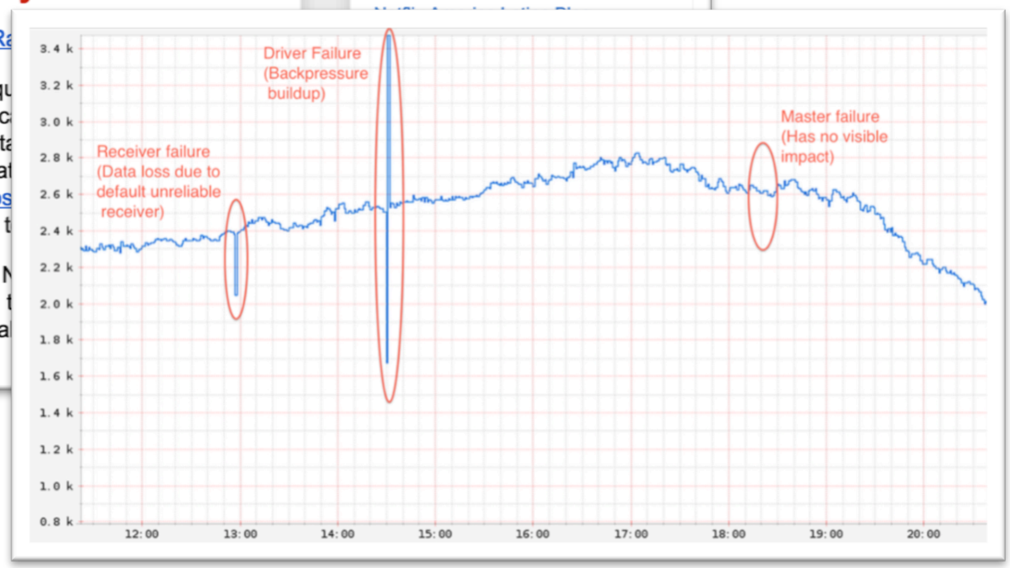
by Bharat Venkat, Prasanna Padmanabhan, Antony Arokiasamy, Ra

Netflix is a data-driven organization that places emphasis on the qu
processed. In our previous blog post, we highlighted our use c
processing in the context of online recommendations and data
Streaming as our choice of stream processor, we set out to evaluat
story for Spark Streaming in the AWS cloud environment. A Chaos
which randomly terminated instances or processes, was employed t

Spark on Amazon Web Services (AWS) is relevant to us as N
primarily out of the AWS cloud. Stream processing systems need t
be tolerant to failures. Instances on AWS are ephemeral, which ma
Spark's resiliency.

Links

Netflix US & Canada Blog



http://techblog.netflix.com/2015/03/can-spark-streaming-survive-chaos-monkey.html

Fault-tolerance and Semantics

Performance and Stability

Monitoring and Upgrading

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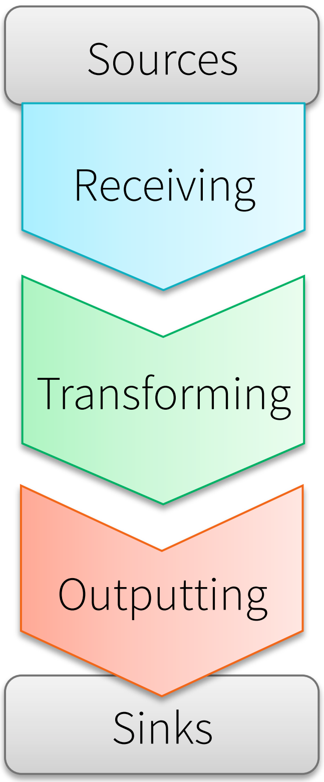
Achieving High Throughput



High throughput achieved by sufficient parallelism at all stages of the pipeline

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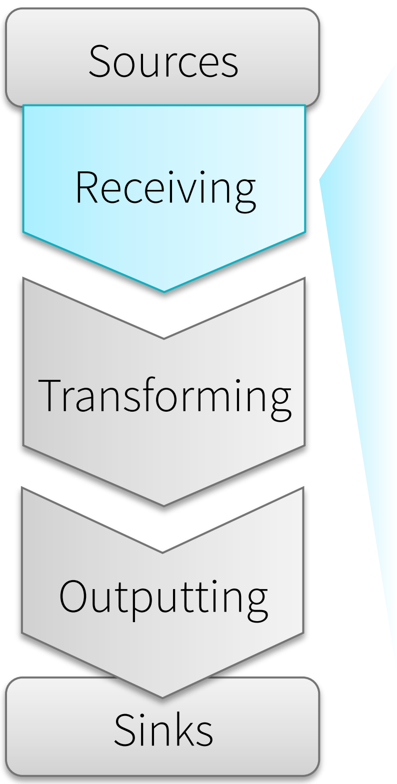
Scaling the Receivers



Sources must be configured with parallel data streams

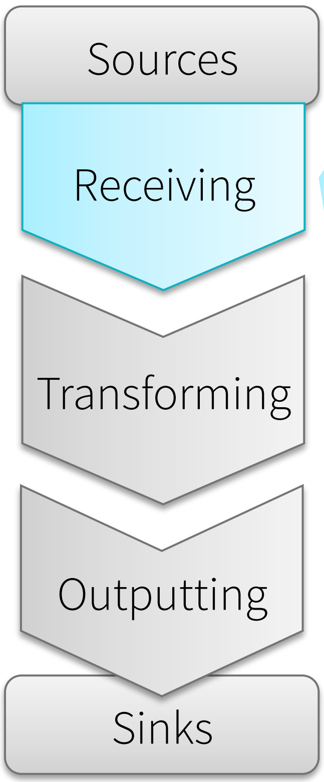
- #partitions in Kafka topics, #shards in Kinesis streams, …

Streaming app should have multiple receivers that receive the data streams in parallel

- Multiple input DStreams, each running a receiver
- Can be unioned together to create one DStream

```
val kafkaStream1 = KafkaUtils.createStream(...)
val kafkaStream2 = KafkaUtils.createStream(...)
val unionedStream = kafkaStream1.union(kafkaStream2)
```

Scaling the Receivers



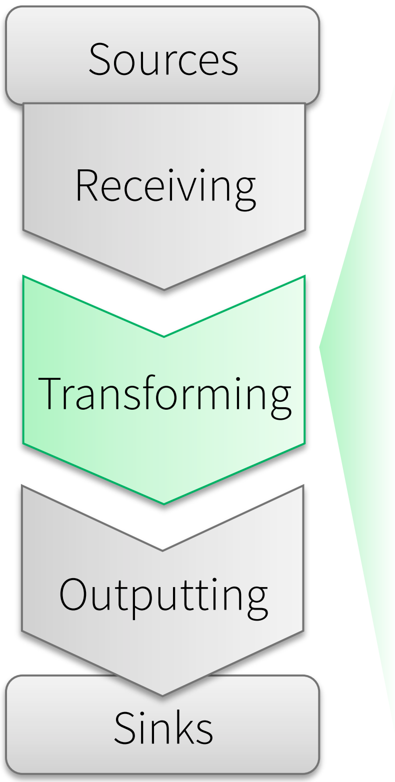
Sufficient number of executors to run all the receivers

- Absolute necessity: #cores > #receivers
- Good rule of thumb: #executors > #receivers, so that no more than 1 receiver per executor, and network is not shared between receivers

Kafka Direct approach does not use receivers

- Automatically parallelizes data reading across executors
- Parallelism = # Kafka partitions

Stability in Processing



For stability, must process data as fast as it is received

Must ensure avg batch processing times < batch interval

Previous batch is done by the time next batch is received

Otherwise, new batches keeps queueing up waiting for previous batches to finish, scheduling delay goes up

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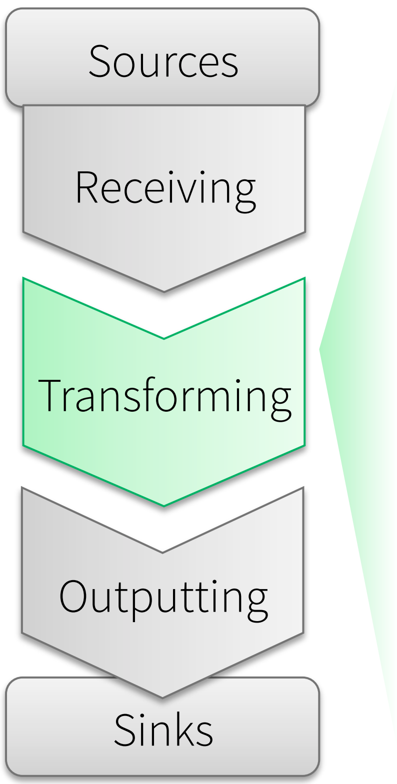
Reducing Batch Processing Times



More receivers!

Executor running receivers do lot of the processing

Repartition the received data to explicitly distribute load

```
unionedStream.repartition(40)
```

Set #partitions in shuffles, make sure its large enough

```
transformedStream.reduceByKey(reduceFunc, 40)
```

Get more executors and cores!

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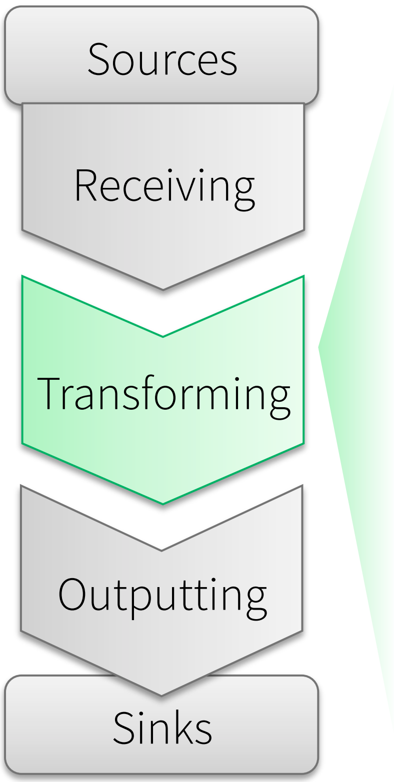
Reducing Batch Processing Times



Use Kryo serialization to serialization costs

- Register classes for best performance
- See configurations spark.kryo.*
  http://spark.apache.org/docs/latest/configuration.html#compression-and-serialization

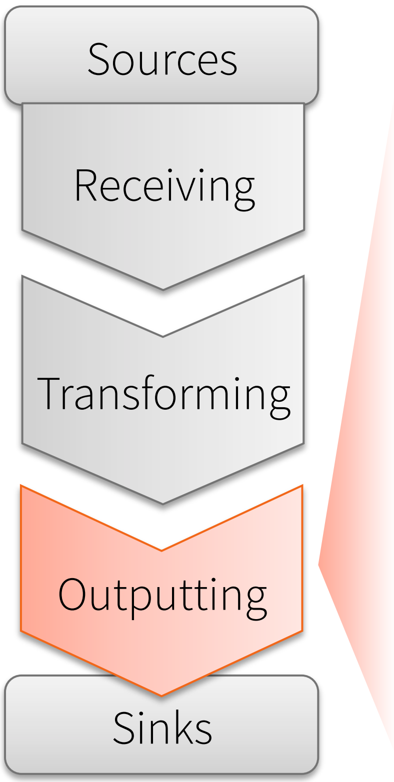
Larger batch durations improve stability

- More data aggregated together, amortized cost of shuffle

Limit ingestion rate to handle data surges

- See configurations spark.streaming.*maxRate*
  http://spark.apache.org/docs/latest/configuration.html#spark-streaming

Speeding up Output Operations



Write to data stores efficiently

foreach: inefficient

```
dataRDD.foreach { event =>
  // open connection
  // insert single event
  // close connection
}
```

foreachPartition: efficient

```
dataRDD.foreachPartition { partition =>
  // open connection
  // insert all events in partition
  // close connection
}
```

foreachPartition + connection pool: more efficient

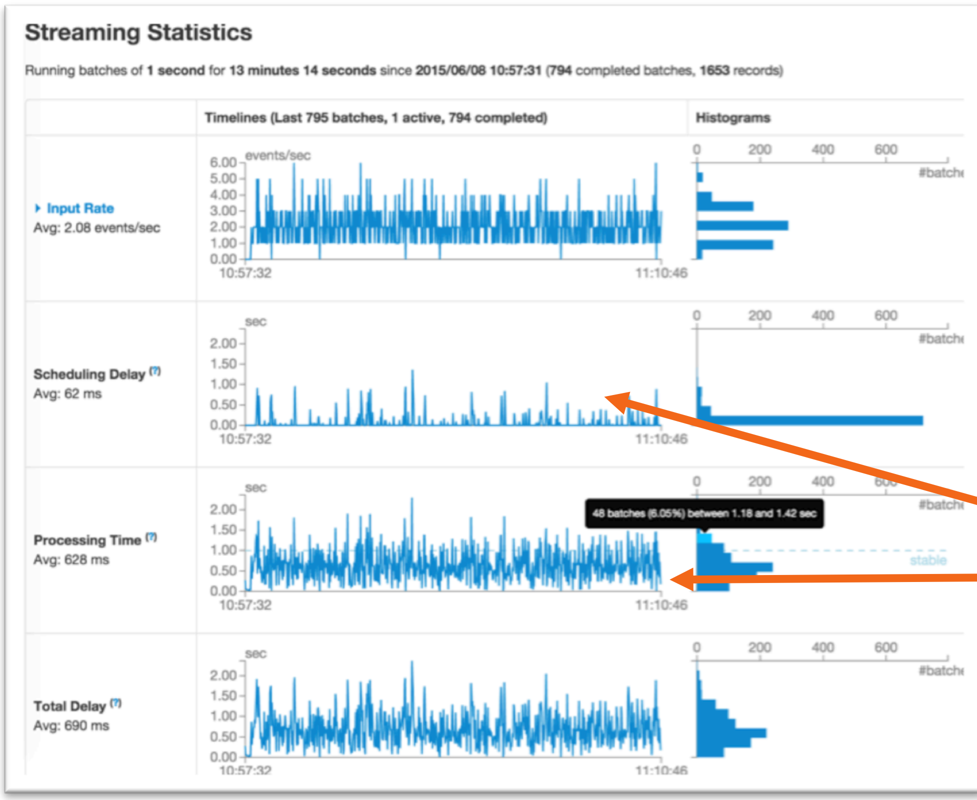
```
dataRDD.foreachPartition { partition =>
  // initialize pool or get open connection from pool in executor
  // insert all events in partition
  // return connection to pool
}
```

Fault-tolerance and Semantics

Performance and Stability

Monitoring and Upgrading

Streaming in Spark Web UI



Stats over last 1000 batches

New in Spark 1.4

For stability

Scheduling delay should be approx 0

Processing Time approx < batch interval

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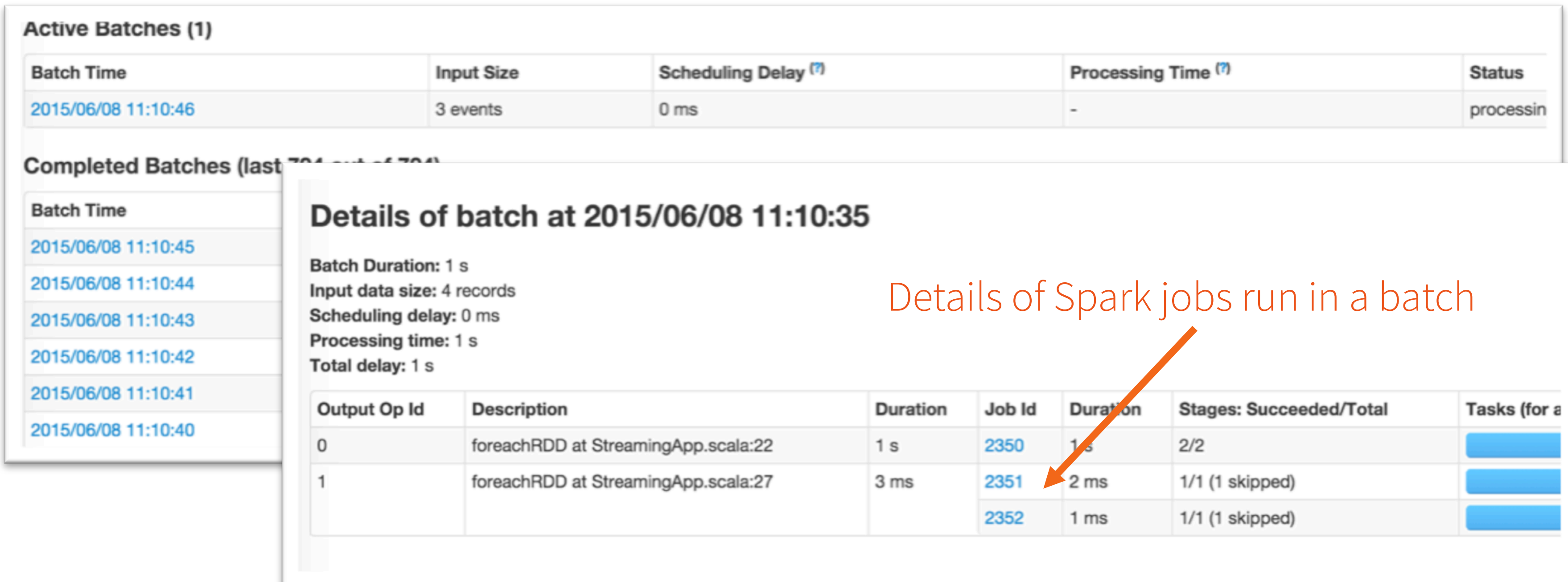
Streaming in Spark Web UI

Details of individual batches



Active Batches (1)

Batch Time	Input Size	Scheduling Delay (?)	Processing Time (?)	Status
2015/06/08 11:10:46	3 events	0 ms	-	processin

Completed Batches (last

Batch Time
2015/06/08 11:10:45
2015/06/08 11:10:44
2015/06/08 11:10:43
2015/06/08 11:10:42
2015/06/08 11:10:41
2015/06/08 11:10:40

Details of batch at 2015/06/08 11:10:35

Batch Duration: 1 s
Input data size: 4 records
Scheduling delay: 0 ms
Processing time: 1 s
Total delay: 1 s

Output Op Id	Description	Duration	Job Id	Duration	Stages: Succeeded/Total	Tasks (for a
0	foreachRDD at StreamingApp.scala:22	1 s	2350	1 s	2/2	
1	foreachRDD at StreamingApp.scala:27	3 ms	2351	2 ms	1/1 (1 skipped)	
			2352	1 ms	1/1 (1 skipped)	

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Operational Monitoring

Streaming app stats published through Codahale metrics

- Ganglia sink, Graphite sink, custom Codahale metrics sinks
- Can see long term trends, across hours and days

Configure the metrics using `$SPARK_HOME/conf/metrics.properties`

- Need to compile Spark with Ganglia LGPL profile for Ganglia support

(see http://spark.apache.org/docs/latest/monitoring.html#metrics)

Programmatic Monitoring

StreamingListener – Developer interface to get internal events

onBatchSubmitted, onBatchStarted, onBatchCompleted,
onReceiverStarted, onReceiverStopped, onReceiverError

Take a look at StreamingJobProgressListener (private class) for inspiration

Upgrading Apps

1. Shutdown your current streaming app gracefully

   Will process all data before shutting down cleanly

   ```
   streamingContext.stop(stopGracefully = true)
   ```

2. Update app code and start it again

Cannot upgrade from previous checkpoints if code changes or Spark version changes

Much to say I have ... but time I have not

Memory and GC tuning

Using SQLContext

DStream.transform operation

…

Refer to online guide

http://spark.apache.org/docs/latest/streaming-programming-guide.html


Spark 1.3.1 Overview Programming Guides API Docs Deploying

Spark Streaming Programming Guide

Overview

Spark Streaming is an extension of the core Spark API that enables scalable, high-throughp streams. Data can be ingested from many sources like Kafka, Flume, Twitter, ZeroMQ, Kine algorithms expressed with high-level functions like `map`, `reduce`, `join` and `window`. Finally, pr

Thank you

May the stream be with you

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