Cloud based Data Analytics

Lecture 3

Content

- In this lecture, we will discuss:

- Overview of Spark
- Spark concepts
- Spark operations
- Job execution
- Fundamentals of Scala/Pyspark
- Hadoop vs Spark
- Spark Installation

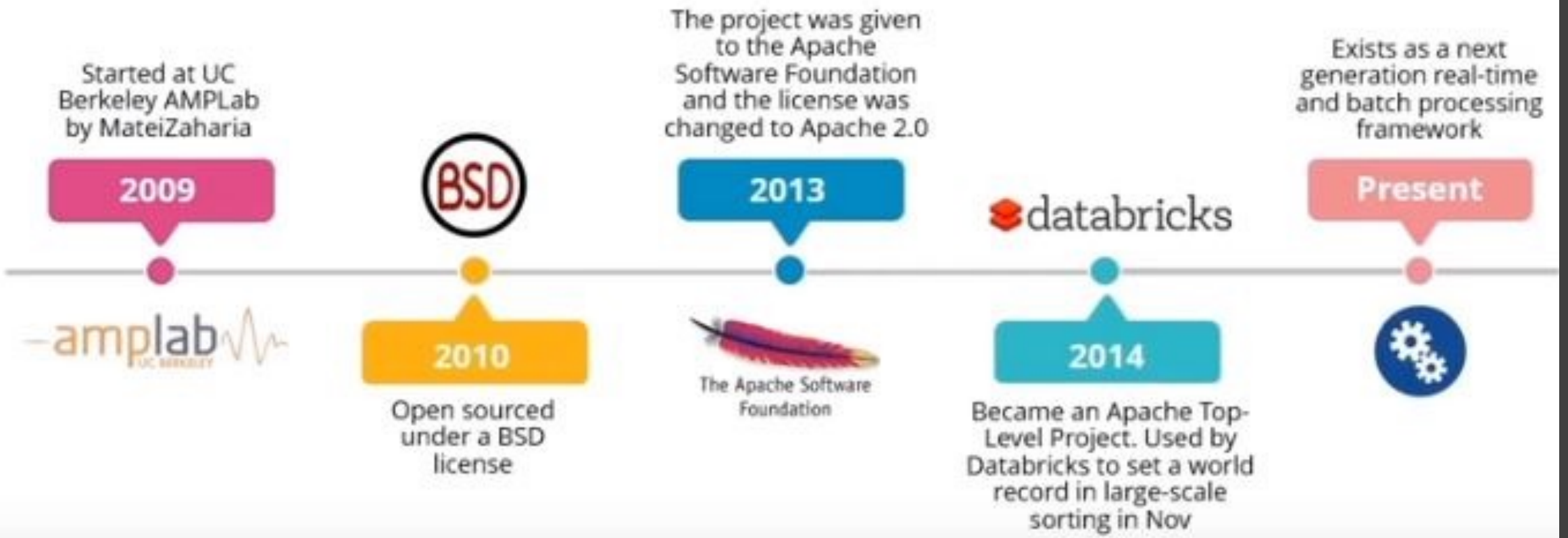
Introduction to Spark

Introduction

- In this part, we will discuss history of spark, ‘framework of spark’ Resilient Distributed Datasets (RDDs) and Spark execution

History of Spark

The history of Spark is explained below:



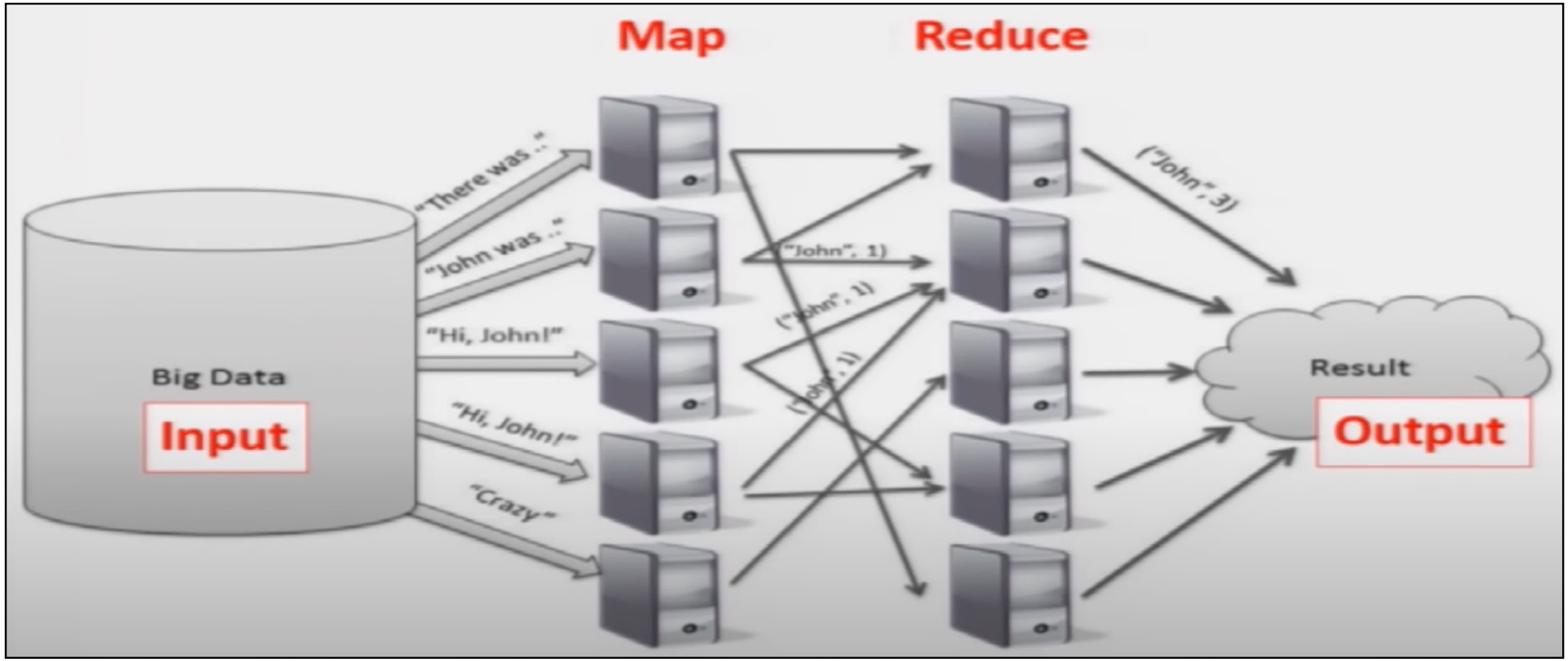
Need of Spark

- Spark is a big data analytics framework that was originally developed at the University of California, Berkeley's AMPLab, in 2009. Since then, it has gained a lot of attraction both in academia and in industry.

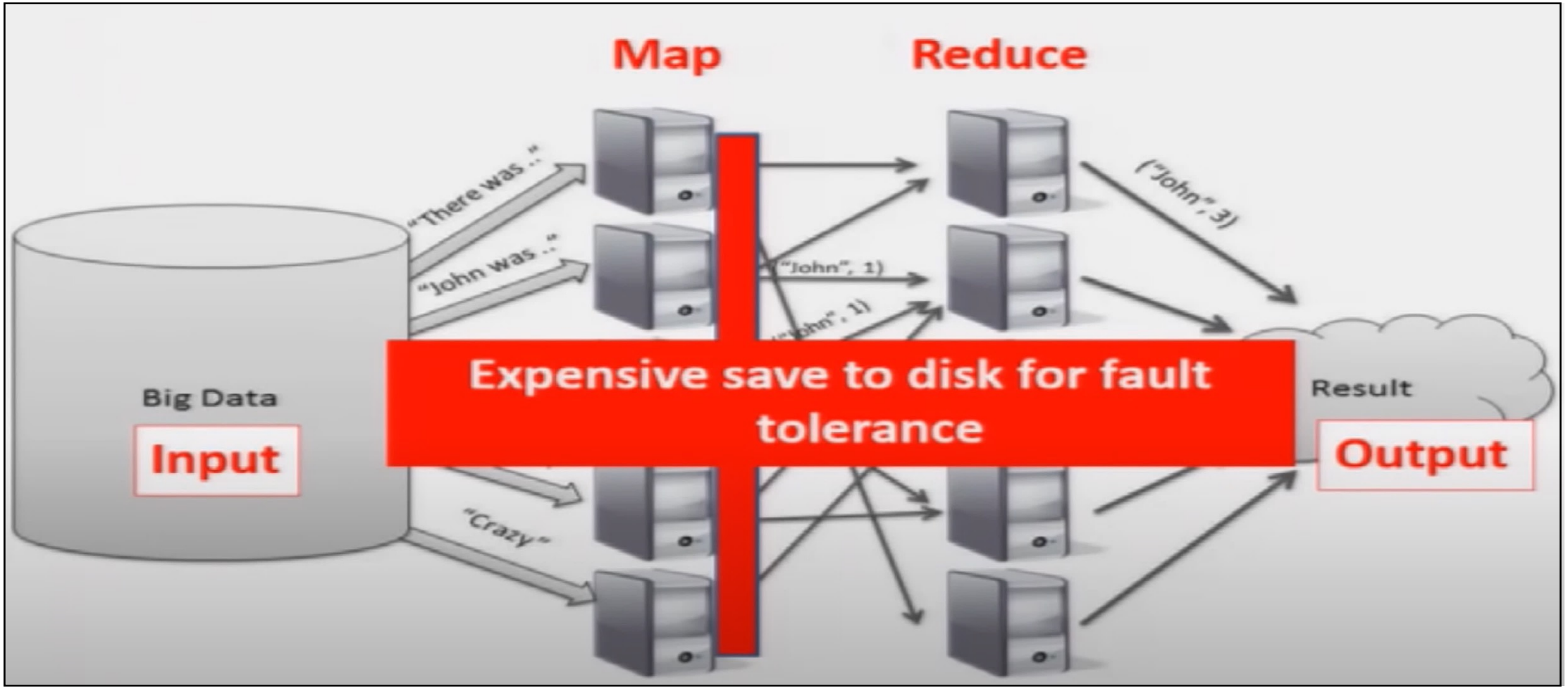
- It is another system for big data analytics

- Isn't MapReduce enough?
  - Simplifies batch processing on large commodity clusters

Need of Spark



Need of Spark



Need of Spark

- MapReduce can be expensive for some applications e.g.,
  - Iterative
  - Interactive
- Lacks efficient data sharing
- Specialized frameworks did evolve for different programming models
  - Bulk Synchronous Processing (Pregel)
  - Iterative MapReduce (Hadoop)

Solution: Resilient Distributed Datasets (RDDs)

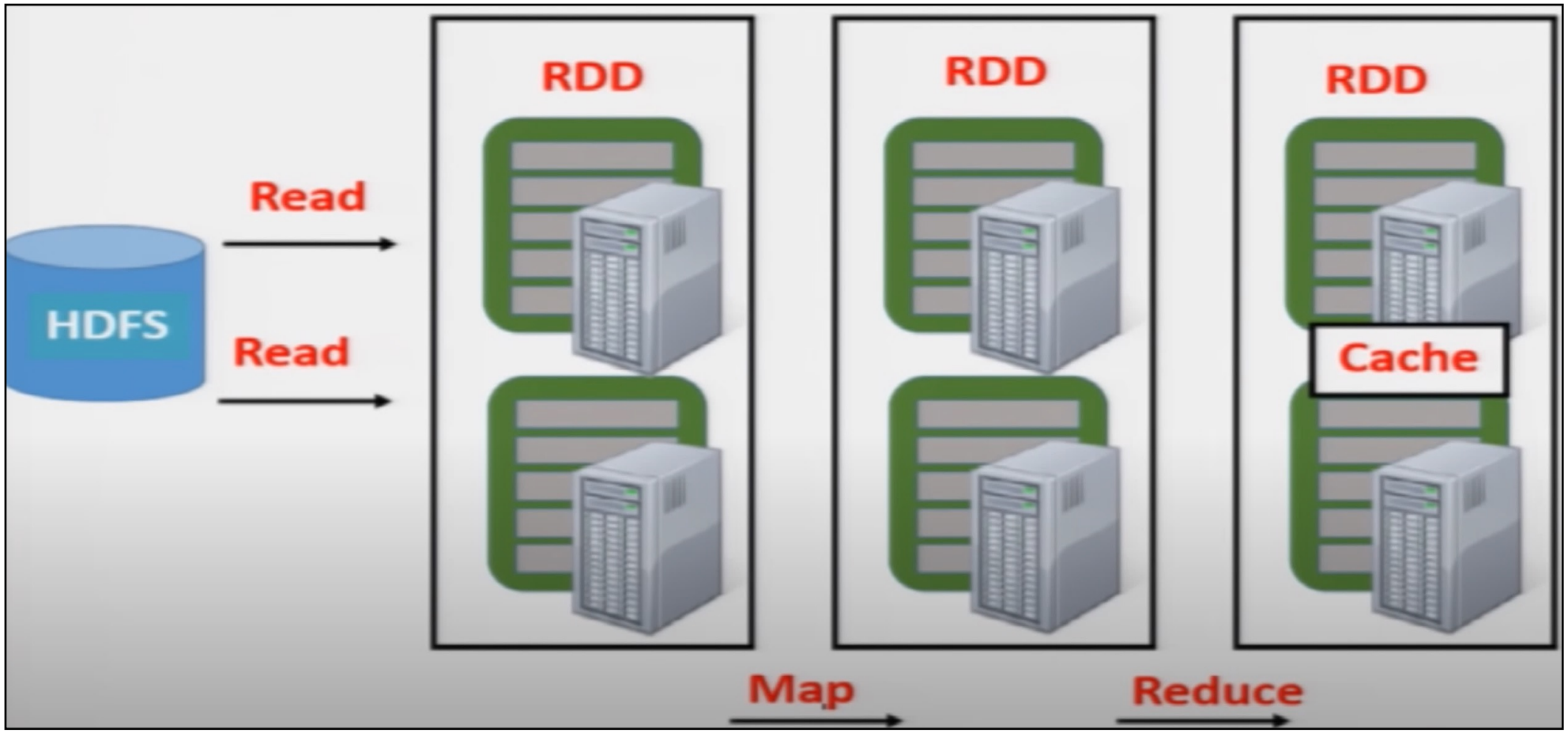
Resilient Distributed Datasets (RDDs)

Immutable, partitioned collection of records

Built through coarse grained transformations (map, join….)

Can be cached for efficient reuse

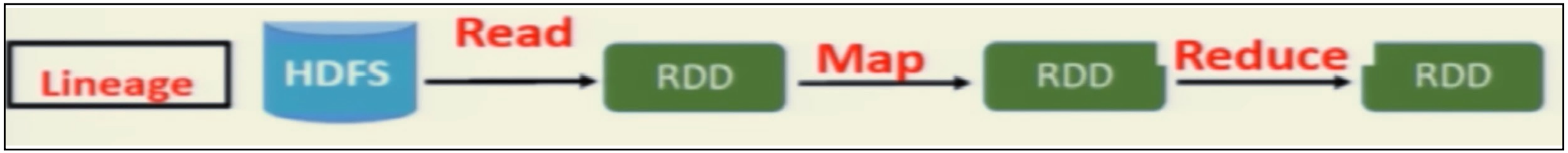
Need of Spark

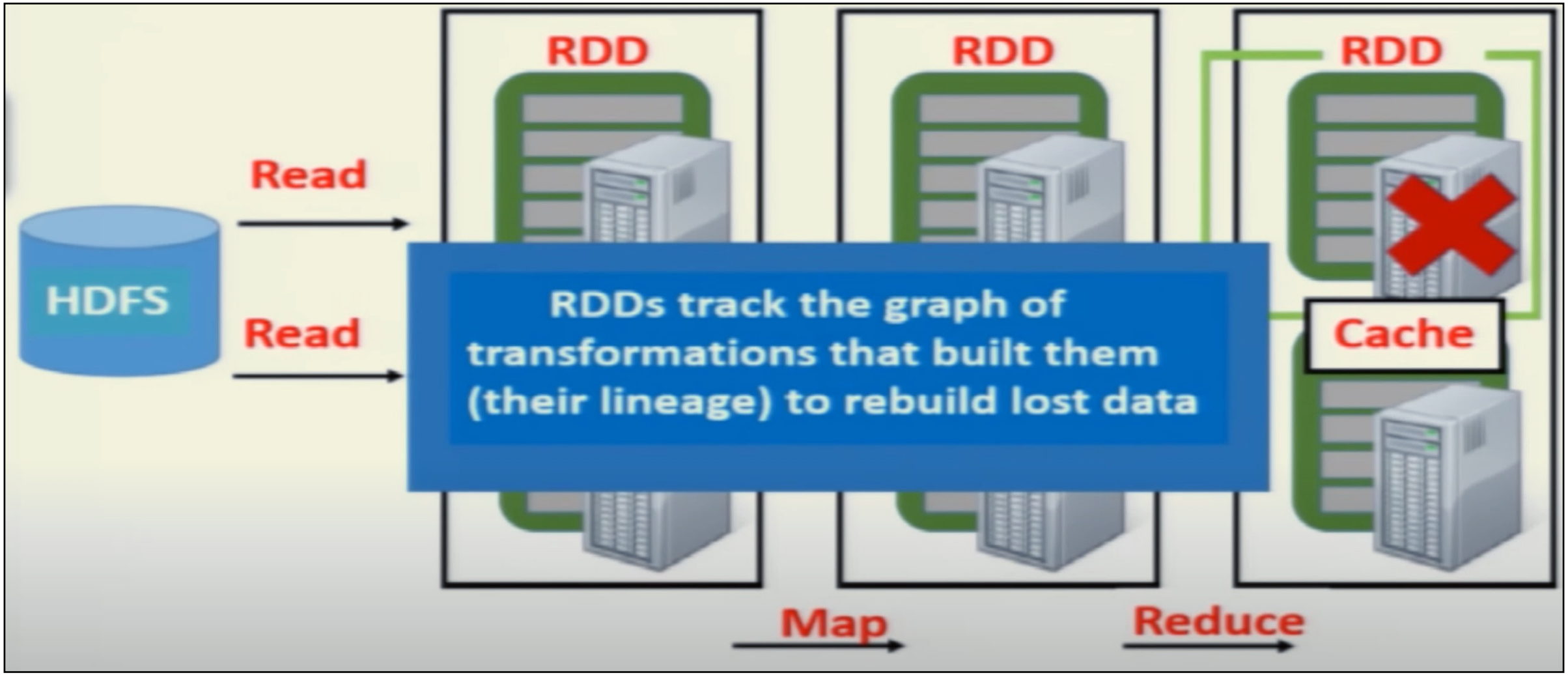


Solution: Resilient Distributed Datasets (RDDs)

- Resilient Distributed Datasets (RDDs)
  - Immutable, partitioned collection of records
  - Built through coarse grained transformations (map, join, …)

- Fault Recovery
  - Lineage!
    - Log coarse grained operation applied to a partitioned dataset
    - Simply recompute the lost partition if failure occurs!
    - No cost if no failure


Lineage
HDFS
Read
RDD
Map
RDD
Reduce
RDD


RDD
RDD
RDD
Read
HDFS
Read
RDDs track the graph of transformations that built them (their lineage) to rebuild lost data
Cache
Map
Reduce

Solution: Resilient Distributed Datasets (RDDs)

- Resilient Distributed Datasets (RDDs)
  - Immutable, partitioned collection of records
  - Built through coarse grained transformations (map, join, …)

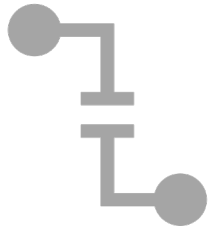
- Fault Recovery
  - Lineage!
    - Log coarse grained operation applied to a partitioned dataset
    - Simply recompute the lost partition if failure occurs!
    - No cost if no failure

What you can do with Spark?

Resilient Distribute Datasets (RDDs) Operations

Transformations e.g., filter, join, map, group-by …

Actions e.g., count, print ….



Control

Partitioning: Spark also gives you control over how you can partition your RDDs.

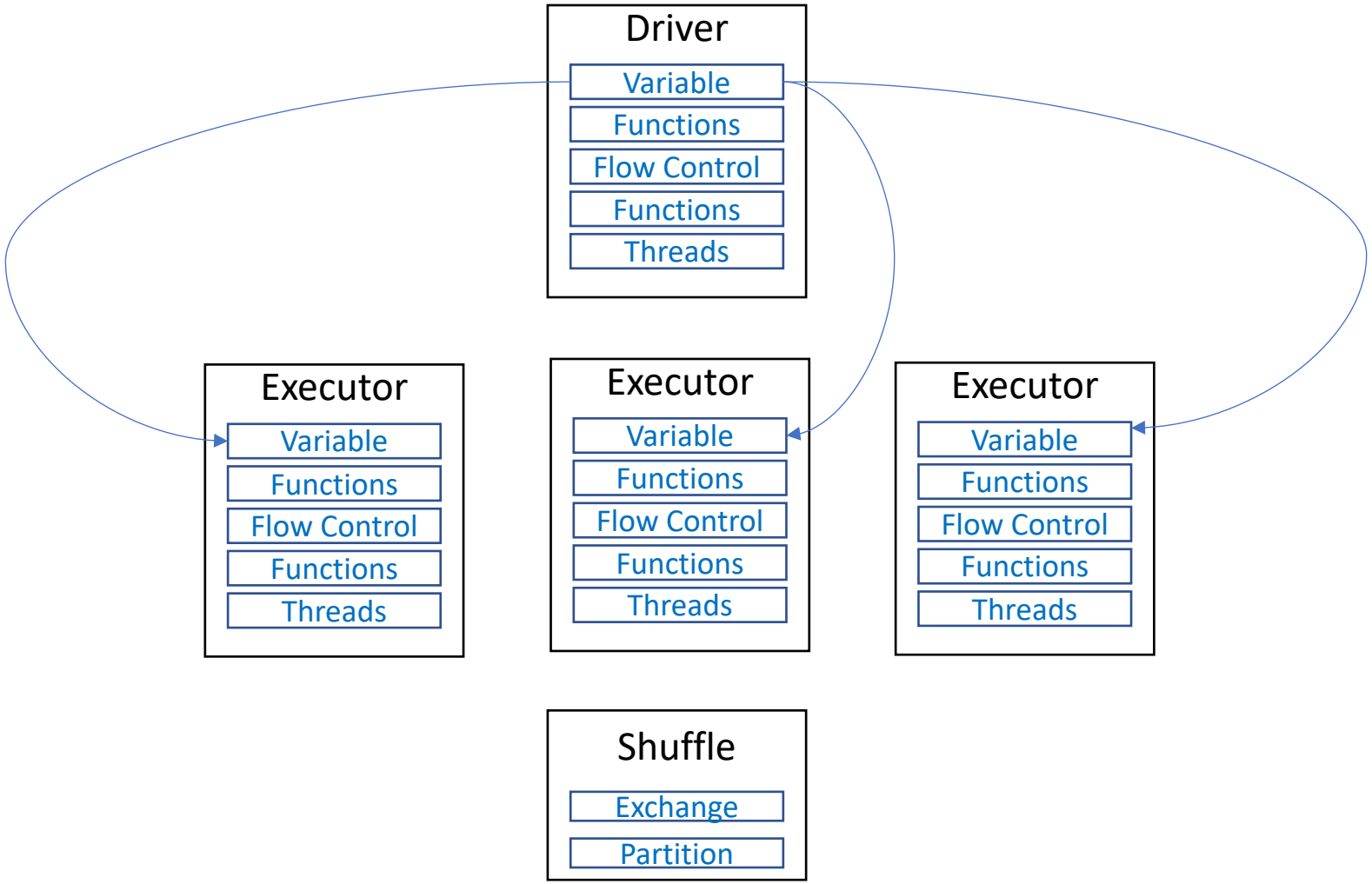
Persistence: Allows you to choose whether you want to persist RDD onto disk or not.

Spark Applications

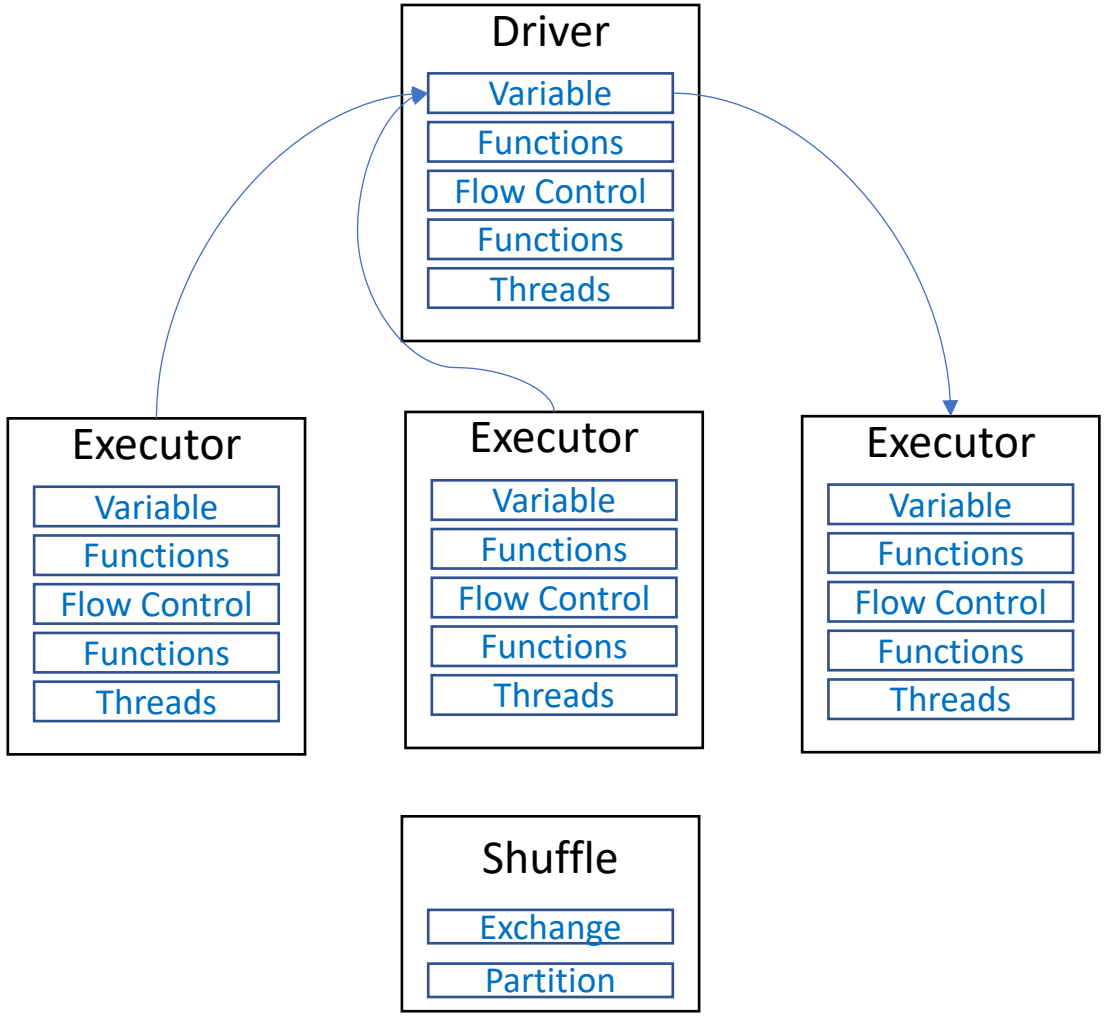
- Twitter Spam Classification
- EM Algorithm for traffic congestion
- K-Means Clustering
- Alternating Least Squares Matrix Factorization
- In-Memory OLAP aggregation on Hive data
- SQL on Spark

Spark Execution

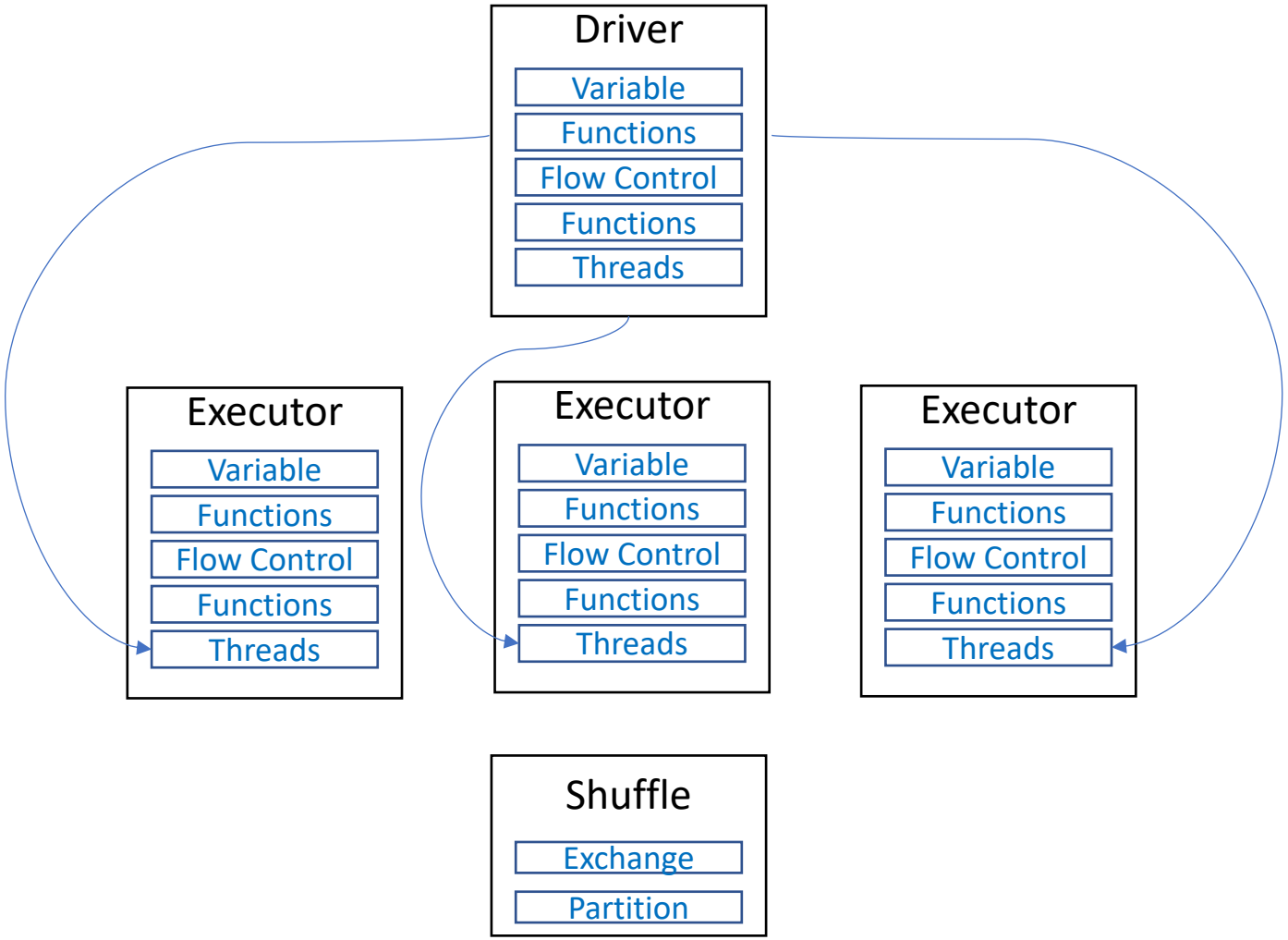
Spark Execution – Distributed Programming (Broadcast)



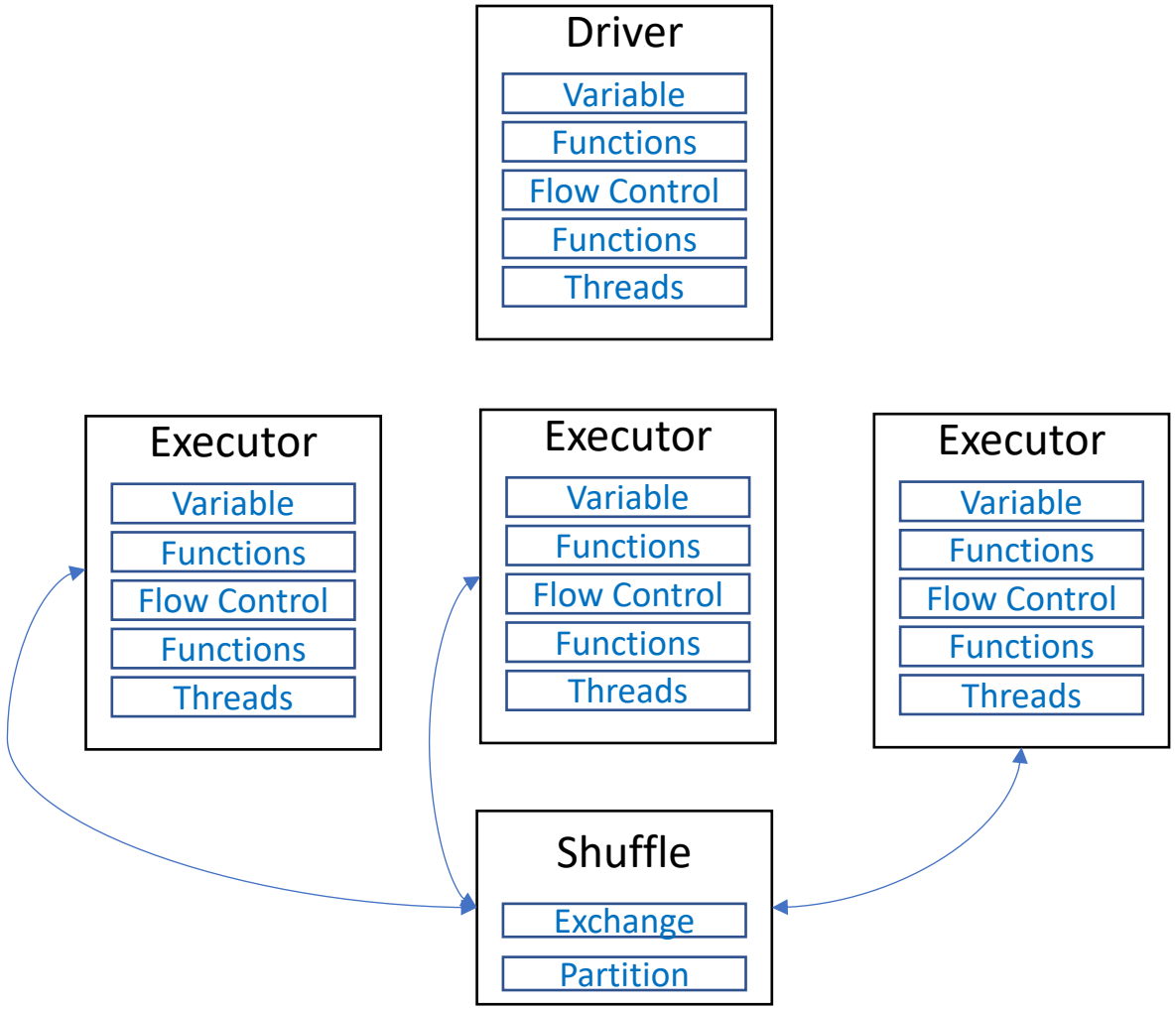
Distributed Programming (Take)



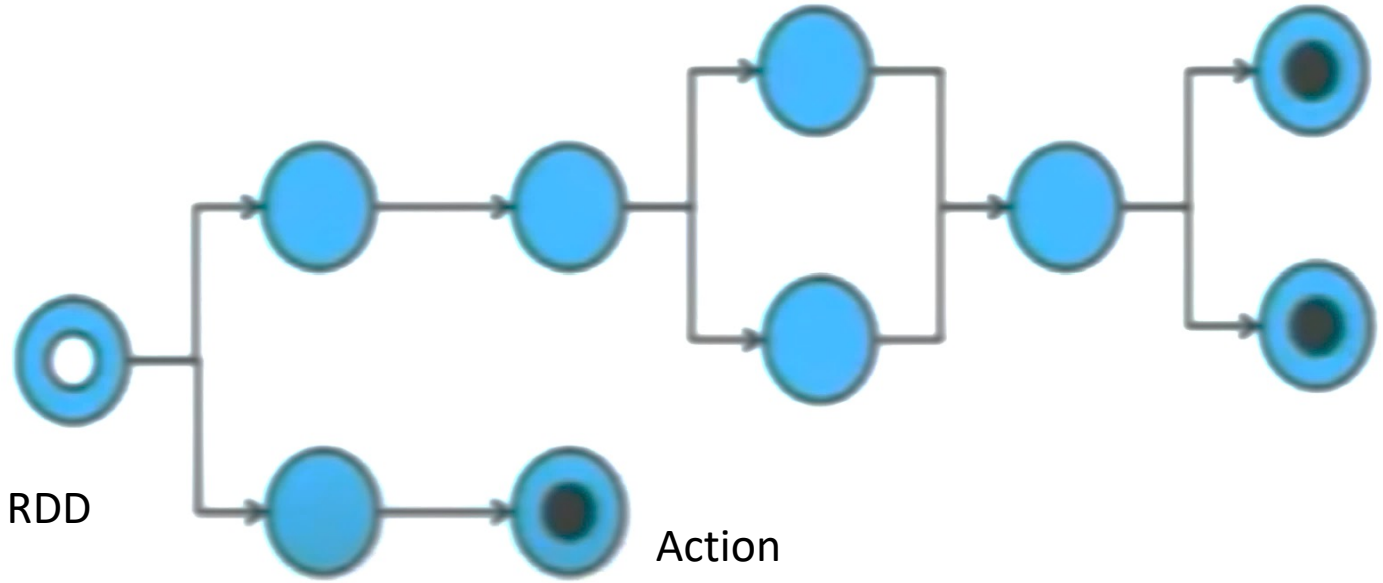
Distributed Programming (DAG Action)



Distributed Programming (Shuffle)



DAG (Directed Acyclic Graph)



RDD obtained using
Transformation

DAG (Directed Acyclic Graph)

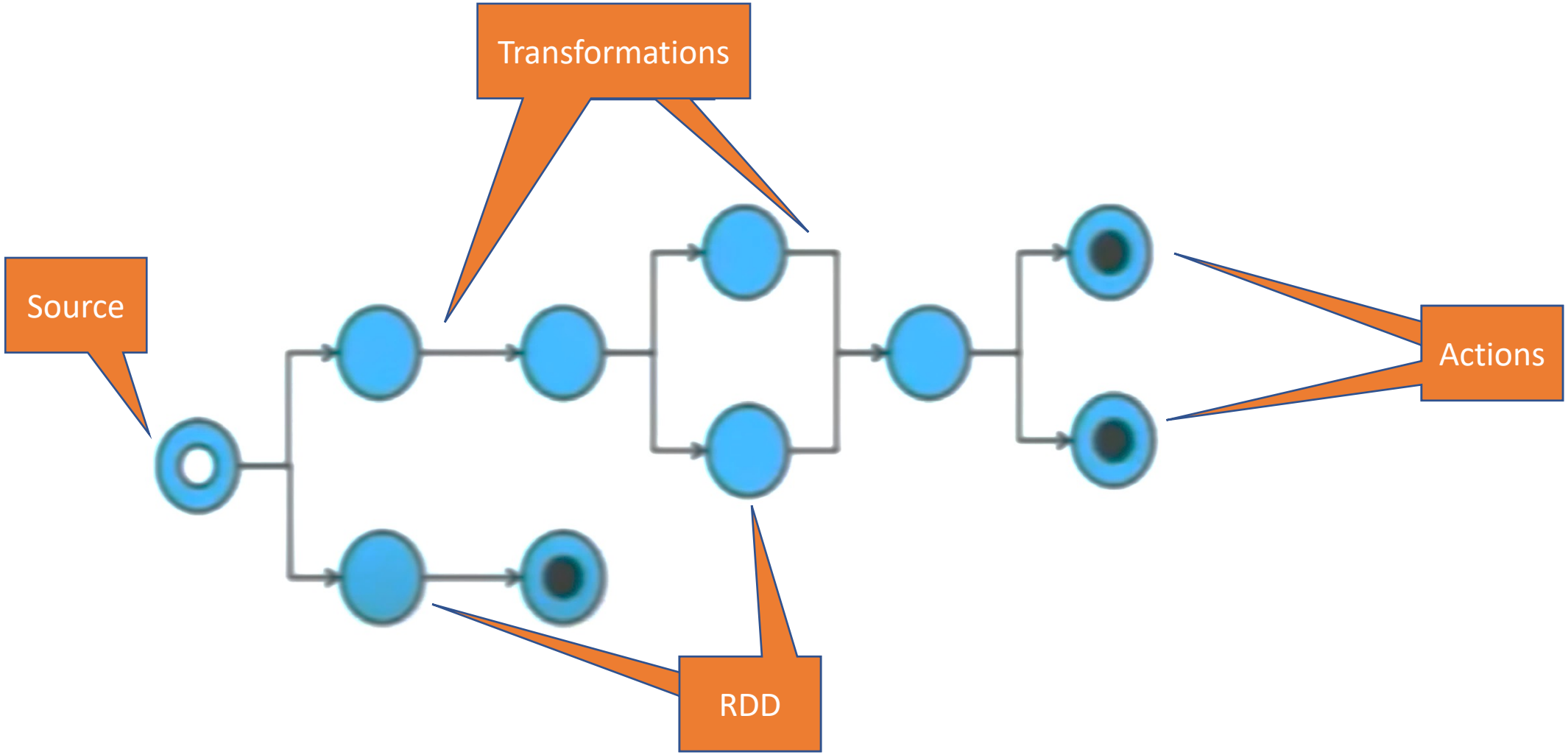
Action

- Count
- Take
- Foreach

Transformation

- Map
- ReduceByKey
- GroupByKey
- JoinByKey

DAG (Directed Acyclic Graph)



Spark Implementation

Spark Ideas

- Not limited to map-reduce model
- Facilitate system memory
  - Avoid saving intermediate results to disk
  - Cache data for repetitive queries (e.g., for machine learning)
- Compatible with Hadoop

RDD Abstraction

Resilient Distributed Datasets

Partitioned collection of records

Spread across the cluster

Read-Only

Caching dataset in memory

Different storage levels available

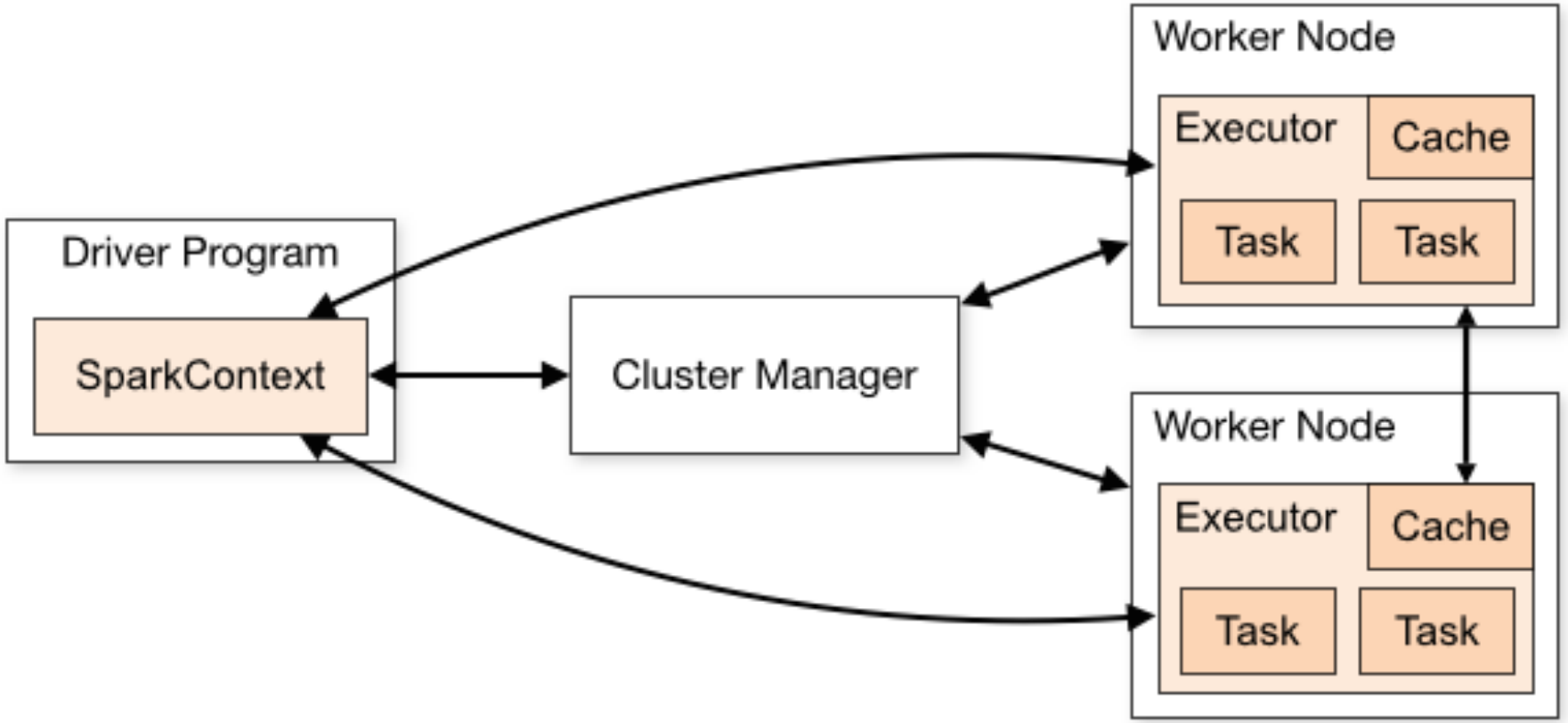
Fallback to disk possible

RDD Operations

- Transformations to build RDDs through deterministic operations on other RDDs
  - Transformations include map, filter, join
  - Lazy operation

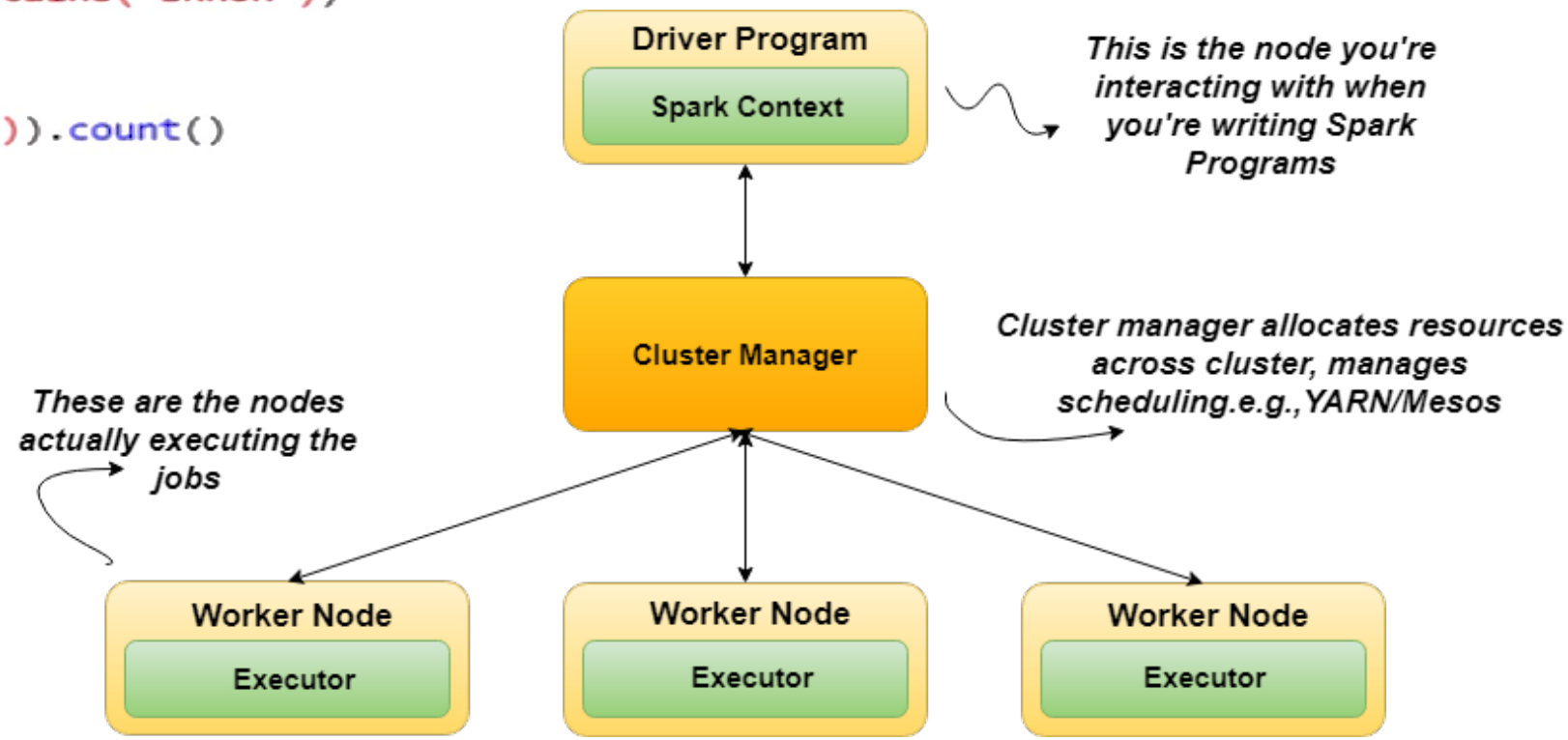
- Actions to return value or export data
  - Actions include count, collect, save
  - Triggers execution

Spark Components

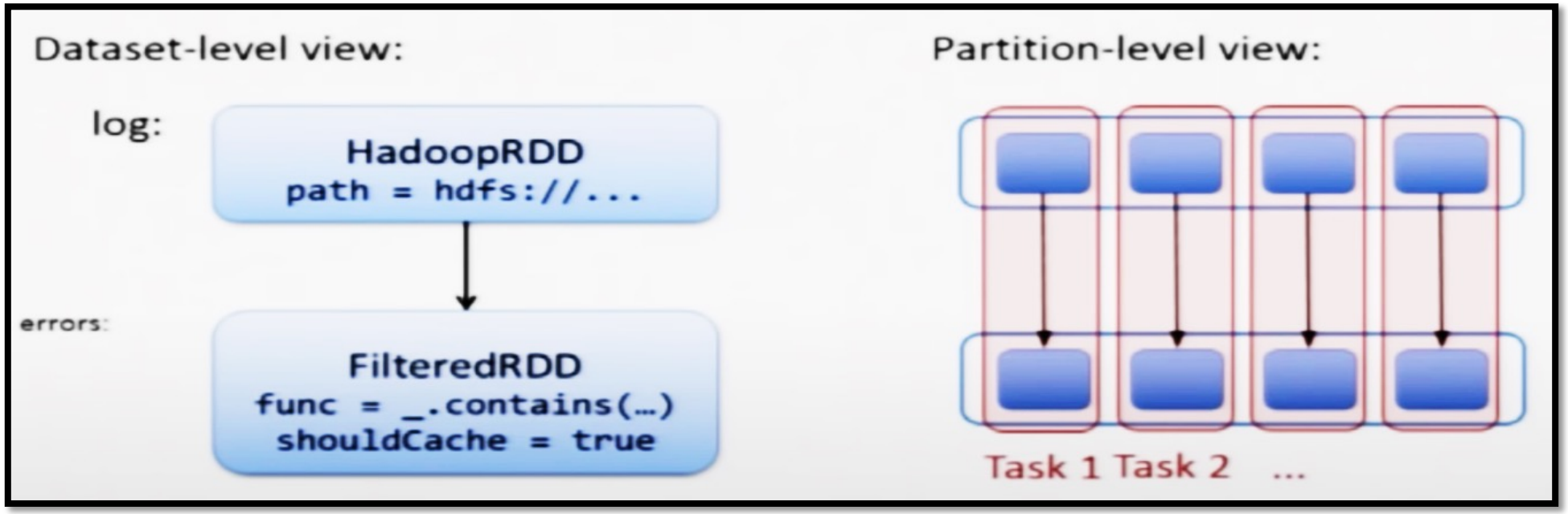


Job Example

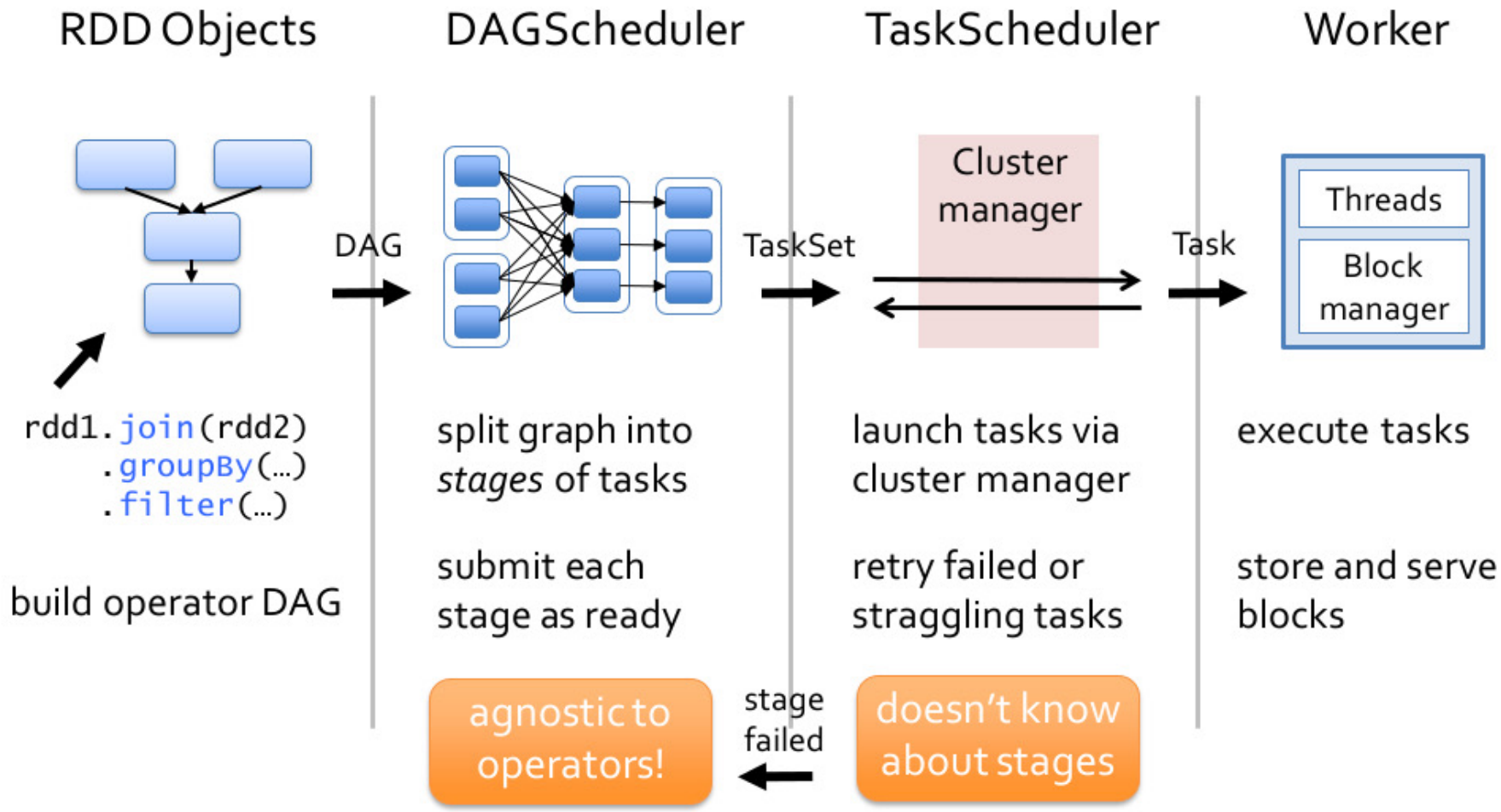
```
val log = sc.textFile("hdfs://...")
val errors = file.filter(_.contains("ERROR"))
errors.cache()

errors.filter(_.contains("I/O")).count()
```



RDD partition-level view



Job Scheduling



Summary

- Concept not limited to single pass map-reduce
- Avoid storing intermediate results on disk or HDFS
- Speedup computations when reusing datasets

What is Spark

What is Spark?

- Fast, expressive cluster computing system compatible with Apache Hadoop
  - Works with any Hadoop-supported storage system (HDFS, S3, SequenceFile and Avro etc.)
- Improves **efficiency** through:
  - In-memory computing primitives
  - General computation graphs

Up to 100x faster

- Improves **usability** through:
  - Rich APIs in Java, Python, R and Scala
  - Interactive shell

Often 2-10x less code

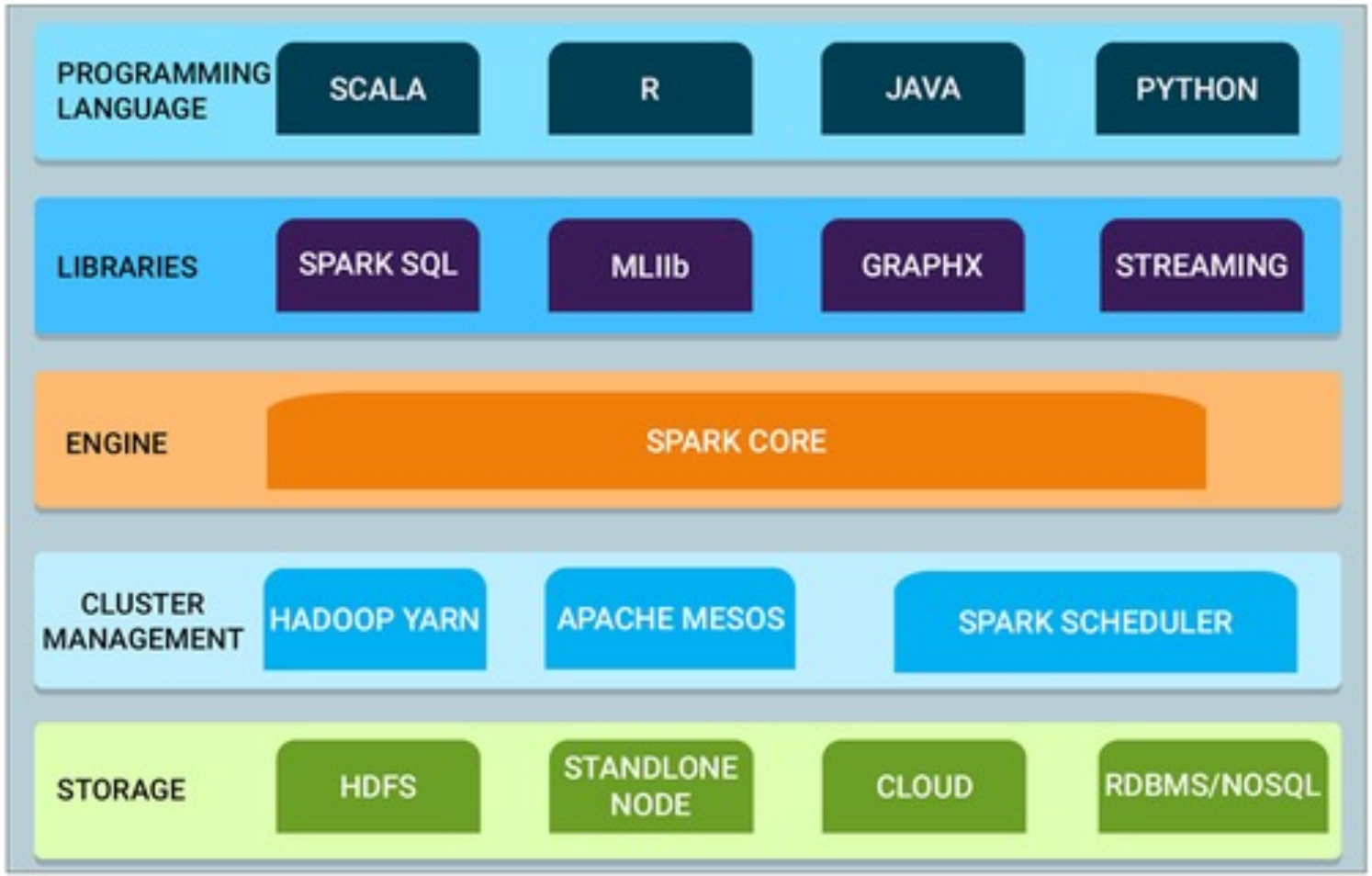
How to Run it

- Local multicore: just a library in your program
- Private cluster: Mesos, YARN, Standalone Mode
- EC2: scripts for launching a Spark cluster
- Databricks: run spark in unified Data Analytics Platform - One cloud platform for massive scale data engineering and collaborative data science
- Azure Synapse Analytics: is a limitless analytics service that brings together enterprise data warehousing and Big Data analytics

Spark


Spark
vs
hadoop
Speed
Powerful
Caching
Polyglot
Spark
Features
hadoop
Deployment

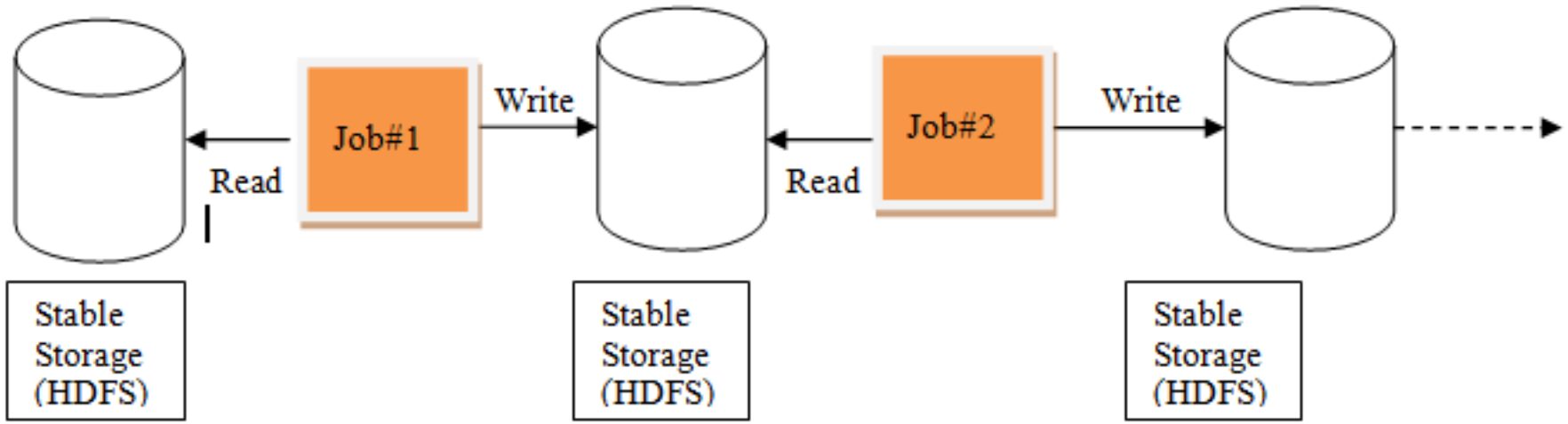
Spark Components



Why RDD?

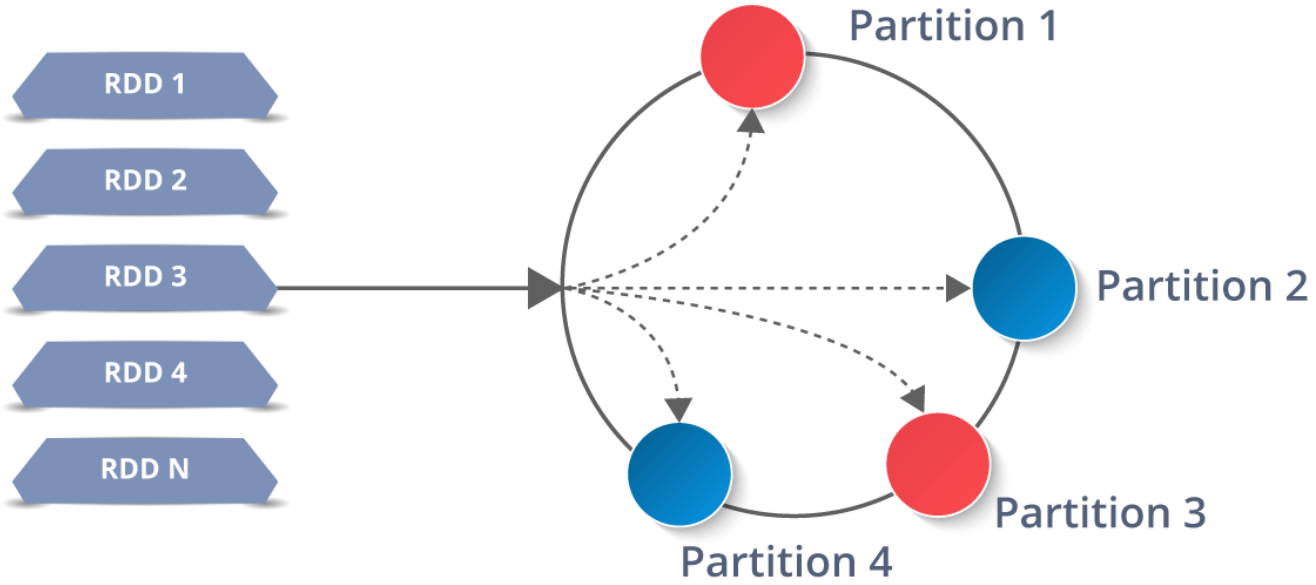
- Iterative Process
- Reusing Data
- Sharing Data

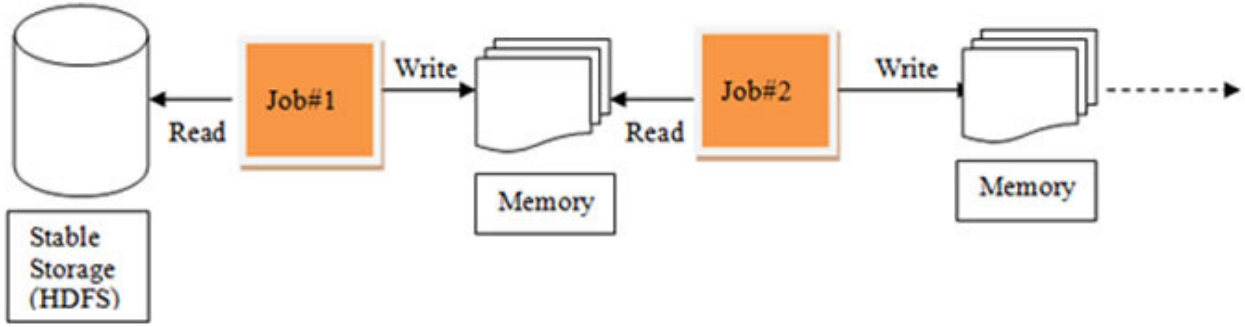
SLOW



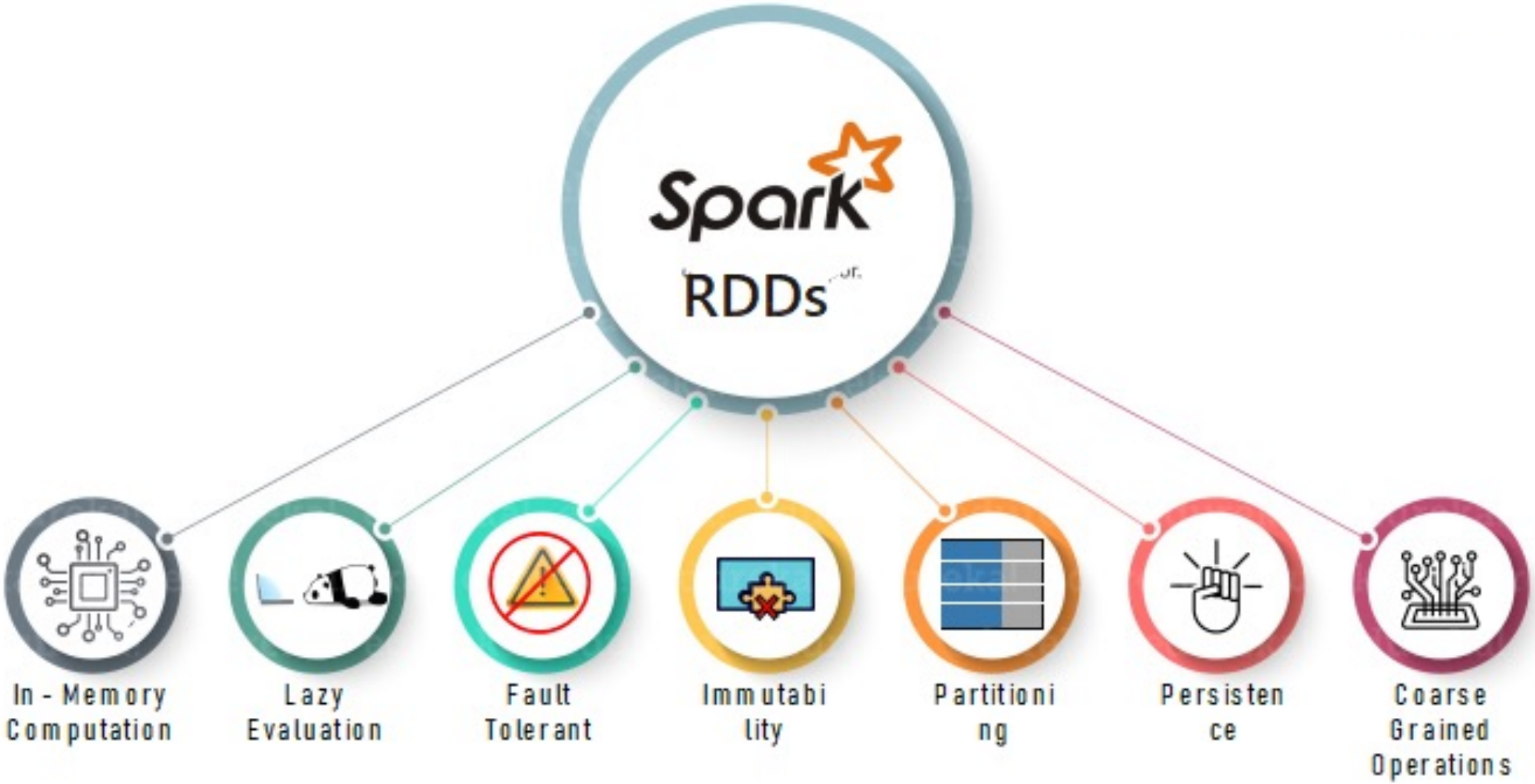
Spark RDD

- Resilient Distributed Datasets (**RDD**) is a fundamental data structure of Spark.
- At the core, an **RDD** is an immutable distributed collection of elements of your data, partitioned across nodes in your cluster that can be operated in parallel with a low-level API that offers transformations and actions.
- **RDDs** can contain any type of Python, Java, or Scala objects, including user-defined classes.
- Formally, an **RDD** is a read-only, partitioned collection of records.





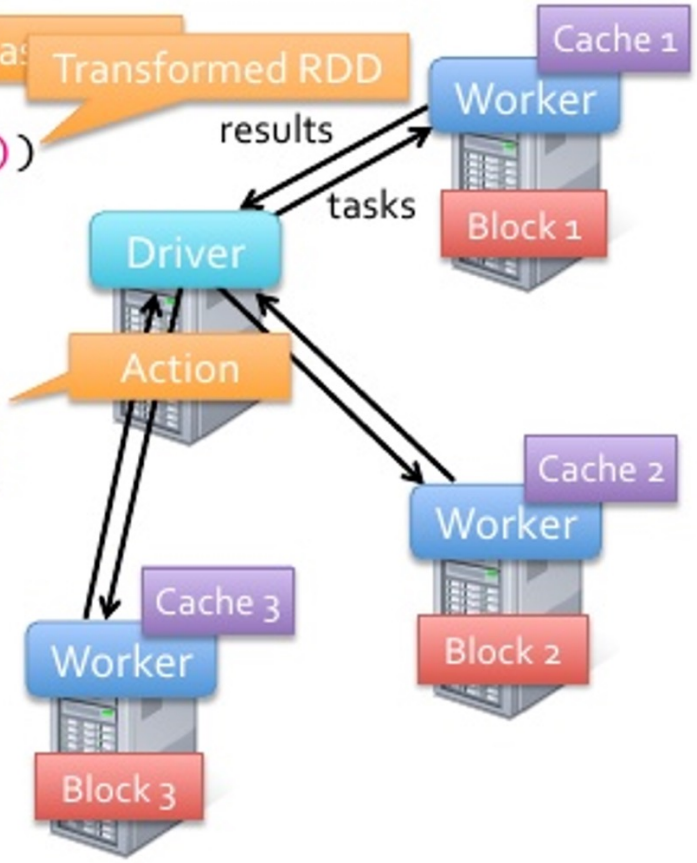
Features of the RDD



Example: Mining Console Logs

- Load error messages from a log memory, then interactively search for various patterns

```
lines = spark.textFile("hdfs://...")
errors = lines.filter(_.startsWith("ERROR"))
messages = errors.map(_.split('\t')(2))
cachedMsgs = messages.cache()

cachedMsgs.filter(_.contains("foo")).count
cachedMsgs.filter(_.contains("bar")).count
. . .
```

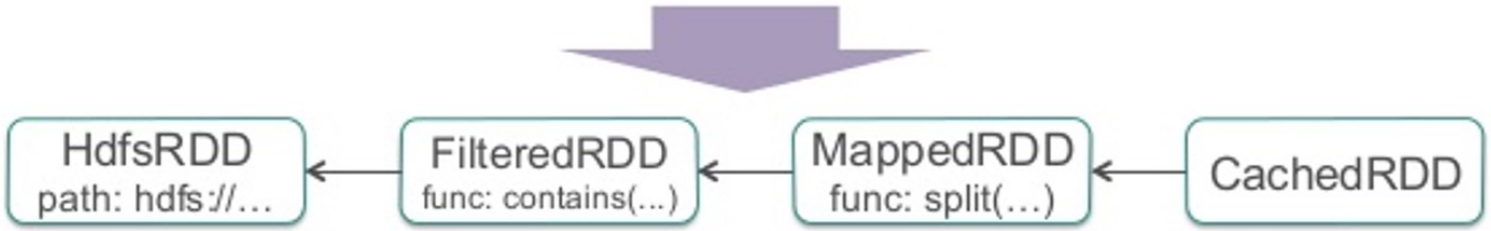


Result: scaled to 1 TB data in 5-7 sec
(vs 170 sec for on-disk data)

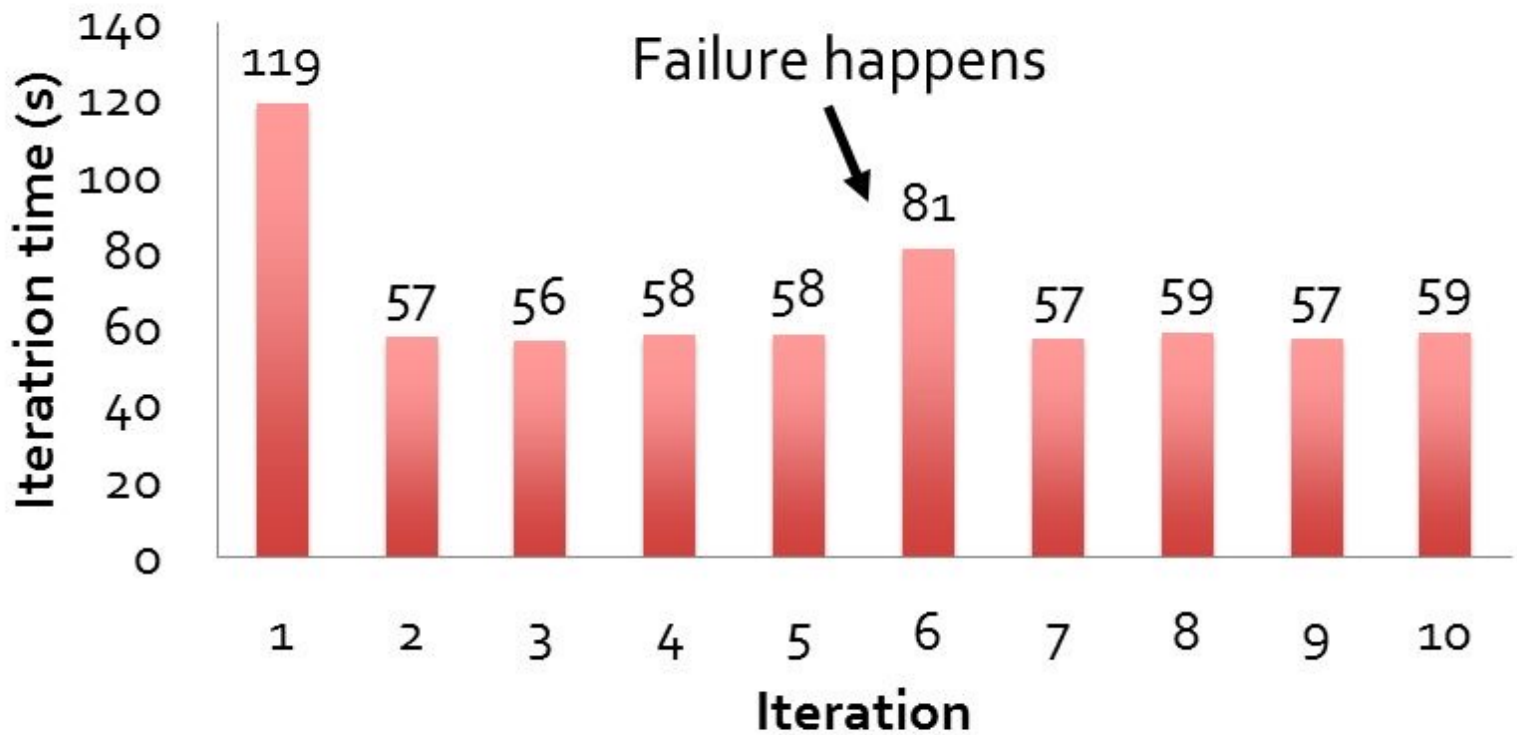
RDD Fault Tolerance

- RDDs track the transformations used to build them (their lineage) to recompute lost data.

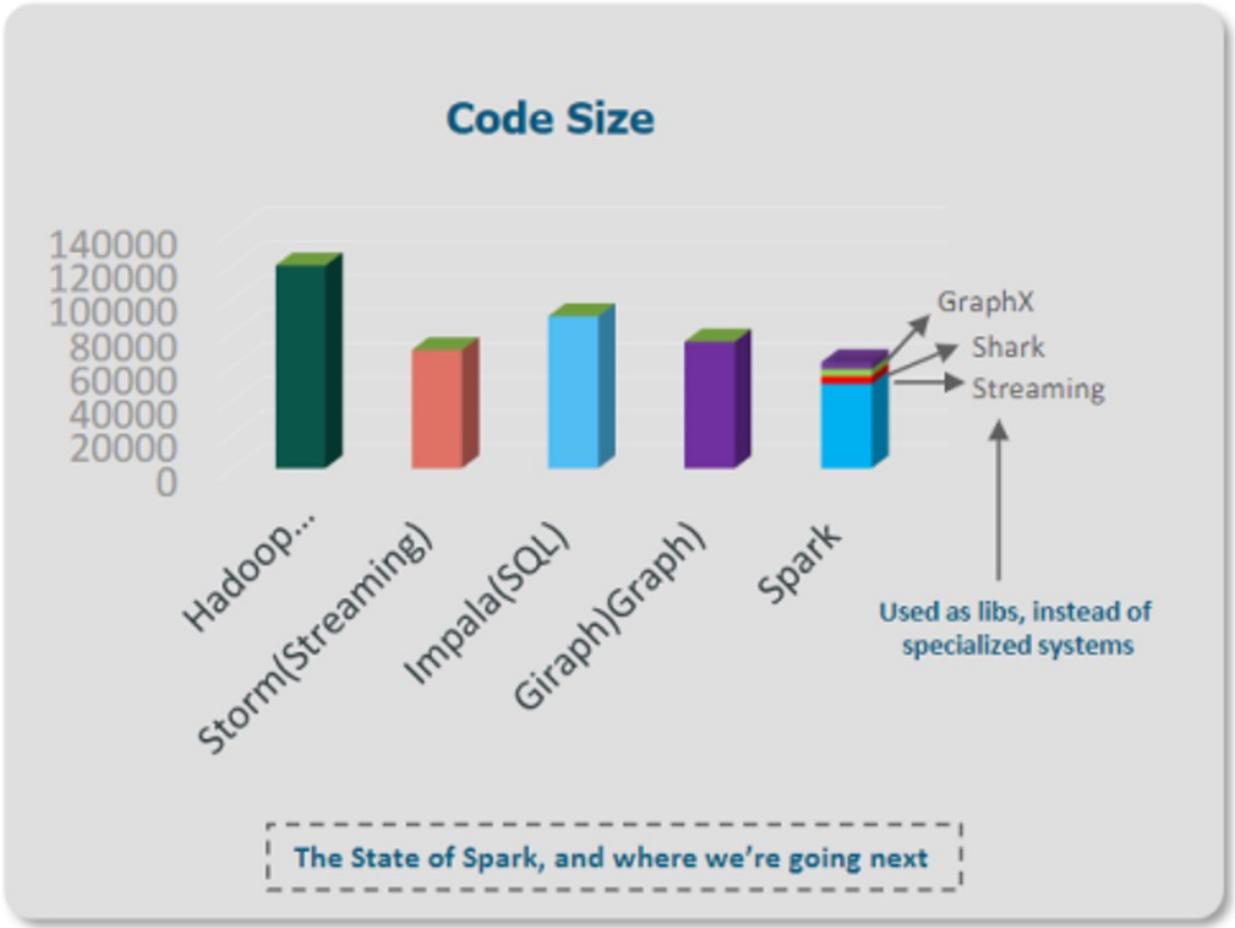
```
cachedMsgs = textFile(...).filter(_.contains("error"))
                          .map(_.split('\t')(2))
                          .cache()
```

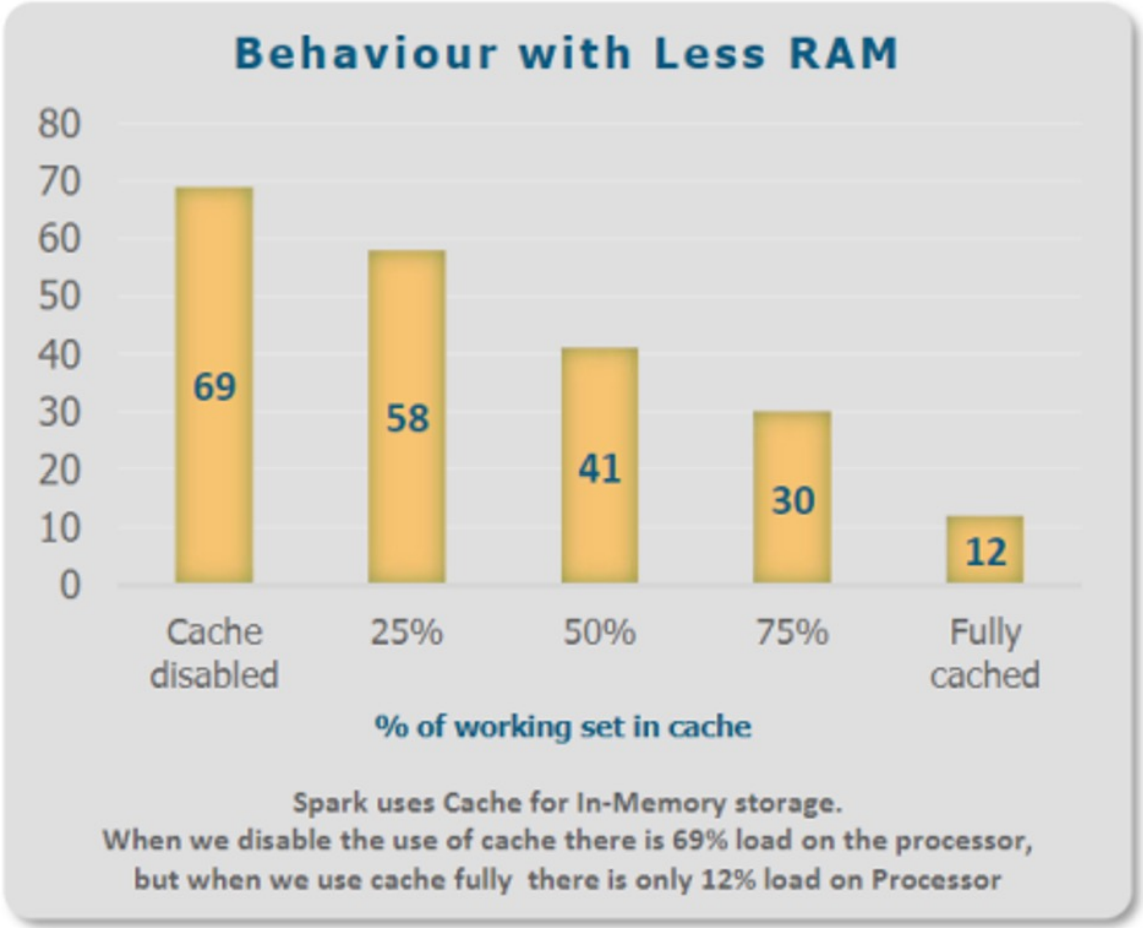


Fault Recovery Results



Spark


Code Size
140000
120000
100000
80000
60000
40000
20000
0
Hadoop...
Storm(Streaming)
Impala(SQL)
Giraph)Graph)
Spark
GraphX
Shark
Streaming
Used as libs, instead of specialized systems
The State of Spark, and where we're going next


Behaviour with Less RAM
80
70
60
50
40
30
20
10
0
69
58
41
30
12
Cache disabled
25%
50%
75%
Fully cached
% of working set in cache
Spark uses Cache for In-Memory storage.
When we disable the use of cache there is 69% load on the processor,
but when we use cache fully there is only 12% load on Processor

Summary

- Goal: Work with distributed collections as you would work with local ones
- Concept: Resilient Distributed Datasets (RDDs)
  - Immutable collection of objects spread across a cluster
  - Built through parallel transformations (map, filter etc.)
    - Lazy operations to build RDDs from other RDDs
  - Automatically rebuilt on failure
  - Controllable persistence (e.g., caching in RAM)
  - Actions (e.g., count, collect, save)
    - Return a result or write it to storage

Working with Spark

Available APIs

- Spark originally written in Scala, which allows concise function syntax and interactive use
- You can write in Python, Scala, Java and R
- Interactive interpreter: Scala and Python only
- Standalone applications: any
- Performance: Java and Scala are faster because of static typing

Which language should I use?

- Standalone programs can be written in any, but console is only Python and Scala
- Python Developers: can stay with Python for both
- Java Developers: consider using Scala for console (to learn API)

- Performance: Java/Scala will be faster (statistically typed) but Python code can do well for numerical work with NumPy

Learning Spark

- Easiest way: Spark Interpreter (Pyspark or spark-shell)
  - Special Python and Scala consoles for cluster use
- Runs in local mode on 1 thread by default but can control with Master environment var:

```
MASTER=local      ./spark-shell            # local, 1 thread
MASTER=local[2]   ./spark-shell            # local, 2 threads
MASTER=spark://host:port ./spark-shell  # Spark standalone
cluster
```

Hand on - interpreter

- Run Scala spark interpreter
- $ spark-shell

- Or Python Interpreter
- $ pyspark

Spark-Shell and PySpark

```
[snehadhanda@Snehas-MacBook-Air ~ % spark-shell
21/01/08 18:22:31 WARN Utils: Your hostname, Snehas-MacBook-Air.local resolves to a lo
opback address: 127.0.0.1; using 192.168.2.12 instead (on interface en0)
21/01/08 18:22:31 WARN Utils: Set SPARK_LOCAL_IP if you need to bind to another addres
s
21/01/08 18:22:32 WARN NativeCodeLoader: Unable to load native-hadoop library for your
 platform... using builtin-java classes where applicable
Using Spark's default log4j profile: org/apache/spark/log4j-defaults.properties
Setting default log level to "WARN".
To adjust logging level use sc.setLogLevel(newLevel). For SparkR, use setLogLevel(newL
evel).
21/01/08 18:22:41 WARN Utils: Service 'SparkUI' could not bind on port 4040. Attemptin
g port 4041.
21/01/08 18:22:41 WARN Utils: Service 'SparkUI' could not bind on port 4041. Attemptin
g port 4042.
Spark context Web UI available at http://192.168.2.12:4042
Spark context available as 'sc' (master = local[*], app id = local-1610148162229).
Spark session available as 'spark'.
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /___/ .__/\_,_/_/ /_/\_\   version 3.0.1
      /_/

Using Scala version 2.12.10 (Java HotSpot(TM) 64-Bit Server VM, Java 1.8.0_261)
Type in expressions to have them evaluated.
Type :help for more information.

scala>
```

Spark-Scala

PySpark

```
[snehadhanda@Snehas-MacBook-Air ~ % pyspark
Python 3.9.0 (v3.9.0:9cf6752276, Oct  5 2020, 11:29:23)
[Clang 6.0 (clang-600.0.57)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
21/01/23 12:53:17 WARN Utils: Your hostname, Snehas-MacBook-Air.local resolves to
a loopback address: 127.0.0.1; using 192.168.2.12 instead (on interface en0)
21/01/23 12:53:17 WARN Utils: Set SPARK_LOCAL_IP if you need to bind to another ad
dress
21/01/23 12:53:19 WARN NativeCodeLoader: Unable to load native-hadoop library for
your platform... using builtin-java classes where applicable
Using Spark's default log4j profile: org/apache/spark/log4j-defaults.properties
Setting default log level to "WARN".
To adjust logging level use sc.setLogLevel(newLevel). For SparkR, use setLogLevel(
newLevel).
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /__ / .__/\_,_/_/ /_/\_\   version 3.0.1
      /_/

Using Python version 3.9.0 (v3.9.0:9cf6752276, Oct  5 2020 11:29:23)
SparkSession available as 'spark'.
>>>
```

First Stop: SparkContext

Main entry to Spark functionality

Created for you in Spark shells as variable sc

In standalone programs, you would make your own

Ways to create RDD

- RDD is used for efficient work by a developer, it is a read-only partitioned collection of records.
  - Using parallelized collection
  - From existing Apache Spark RDD &
  - From external datasets.

Creating RDDs

```
# Turn a local collection into an RDD
sc.parallelize([1, 2, 3])

# Load text file from local FS, HDFS, or S3
sc.textFile("file.txt")
sc.textFile("directory/*.txt")
sc.textFile("hdfs://namenode:9000/path/file")

# Use any existing Hadoop InputFormat
sc.hadoopFile(keyClass, valClass, inputFmt,
conf)
```

Spark with Scala and Python

```
Spark session available as 'spark'.
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /___/ .__/\_,_/_/ /_/\_\   version 3.0.1
      /_/

Using Scala version 2.12.10 (Java HotSpot(TM) 64-Bit Server VM, Java 1.8.0_261)
Type in expressions to have them evaluated.
Type :help for more information.

scala> sc.parallelize(0 to 100).collect()
res0: Array[Int] = Array(0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 1
6, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 3
6, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 5
6, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 7
6, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 9
6, 97, 98, 99, 100)

scala>
```

Spark-Scala

PySpark

```
Using Spark's default log4j profile: org/apache/spark/log4j-defaults.properties
Setting default log level to "WARN".
To adjust logging level use sc.setLogLevel(newLevel). For SparkR, use setLogLeve
l(newLevel).
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /__ / .__/\_,_/_/ /_/\_\   version 3.0.1
      /_/

Using Python version 3.9.0 (v3.9.0:9cf6752276, Oct  5 2020 11:29:23)
SparkSession available as 'spark'.
>>> sc.parallelize(range(0, 100)).collect()
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 2
2, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 4
2, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 6
2, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 8
2, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99]
>>>
```

Spark-Getting Data from HDFS

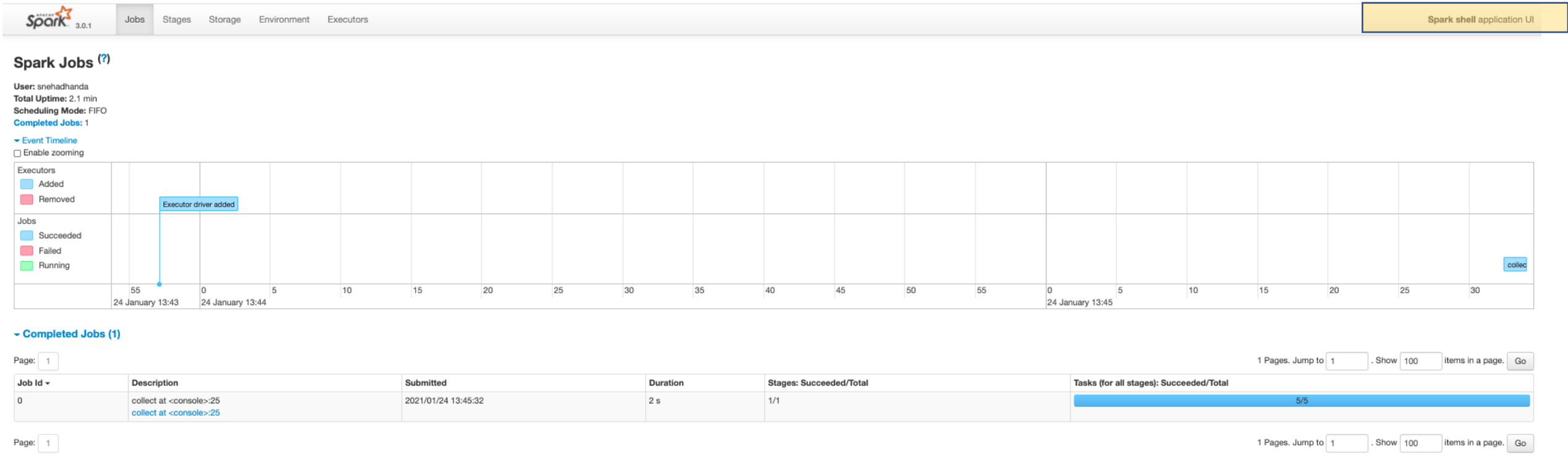
```
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /___/ .__/\_,_/_/ /_/\_\   version 3.0.1
      /_/

Using Scala version 2.12.10 (Java HotSpot(TM) 64-Bit Server VM, Java 1.8.0_261)
Type in expressions to have them evaluated.
Type :help for more information.

scala> val text=sc.textFile("hdfs://localhost:9000/Dataset/wc.txt")
text: org.apache.spark.rdd.RDD[String] = hdfs://localhost:9000/Dataset/wc.txt MapPartitionsRDD[1] at textFile at <console>:24

scala> text.collect;
res0: Array[String] = Array(Deer Bear River, Car Car River, Deer Car Bear)

scala>

scala>
```

Spark-Getting Data from local system

```
scala>

scala> val book = sc.textFile("/Users/snehadhanda/work/Book")
book: org.apache.spark.rdd.RDD[String] = /Users/snehadhanda/work/Book MapPartitionsRDD[10] at
textFile at <console>:24

scala> book.collect
res8: Array[String] = Array(userId,jobId,Clicks, 1,31,3, 1,1029,66, 1,1061,93, 1,1129,0, 1,117
2,77, 1,1263,30, 1,1287,38, 1,1293,44, 1,1339,17, 1,1343,76, 1,1371,12, 1,1405,1, 1,1953,11, 1
,2105,88, 1,2150,20, 1,2193,61, 1,2294,46, 1,2455,18, 1,2968,61, 1,3671,30, 2,10,83, 2,17,19,
2,39,68, 2,47,99, 2,50,40, 2,52,98, 2,62,46, 2,110,13, 2,144,94, 2,150,28, 2,153,34, 2,161,39,
 2,165,85, 2,168,33, 2,185,27, 2,186,56, 2,208,30, 2,222,65, 2,223,73, 2,225,28, 2,235,9, 2,24
8,17, 2,253,64, 2,261,34, 2,265,70, 2,266,54, 2,272,51, 2,273,26, 2,292,26, 2,296,77, 2,300,69
, 2,314,78, 2,317,57, 2,319,36, 2,339,74, 2,349,47, 2,350,36, 2,356,55, 2,357,54, 2,364,67, 2,
367,74, 2,370,8, 2,371,72, 2,372,20, 2,377,75, 2,382,77, 2,405,58, 2,410,56, 2,454,69, 2,457,4
6, 2,468,71, 2,474,...

scala> book.partitions.length
res9: Int = 14

scala>
```

```
snehadhanda@Snehas-MacBook-Air Book % ls
BX-Book-Ratings.csv     Users.csv               jobs.txt
BX-Books.csv            books_test.csv          movies.csv
BX-Books.txt            job_clicks.csv          movies.txt
Books.csv               job_clicks.txt          student.csv
Ratings.csv             jobs.csv
```

Localhost: 4040 – Spark-shell



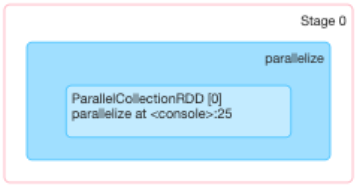
DAG Visualization –Spark-shell

Spark 3.0.1 | Jobs | Stages | Storage | Environment | Executors

Details for Stage 0 (Attempt 0)

Total Time Across All Tasks: 0.2 s
Locality Level Summary: Process local: 5
Associated Job Ids: 0

▾ DAG Visualization



▸ Show Additional Metrics
▸ Event Timeline

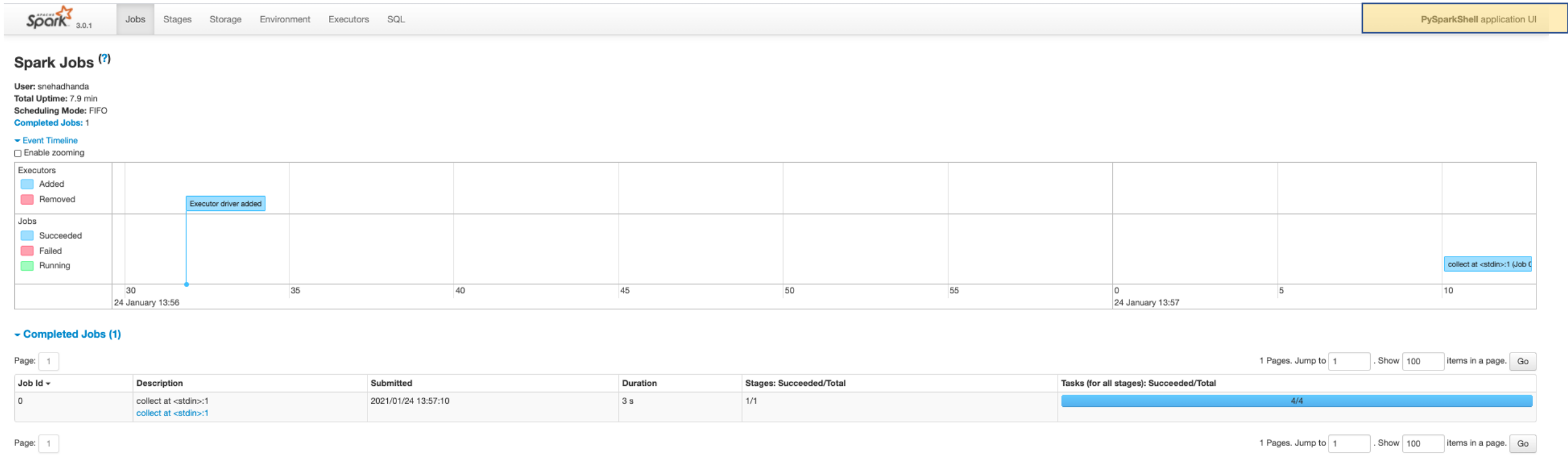
Summary Metrics for 5 Completed Tasks

Metric	Min	25th percentile	Median	75th percentile	Max
Duration	19.0 ms	40.0 ms	41.0 ms	41.0 ms	42.0 ms
GC Time	0.0 ms	23.0 ms	23.0 ms	23.0 ms	23.0 ms

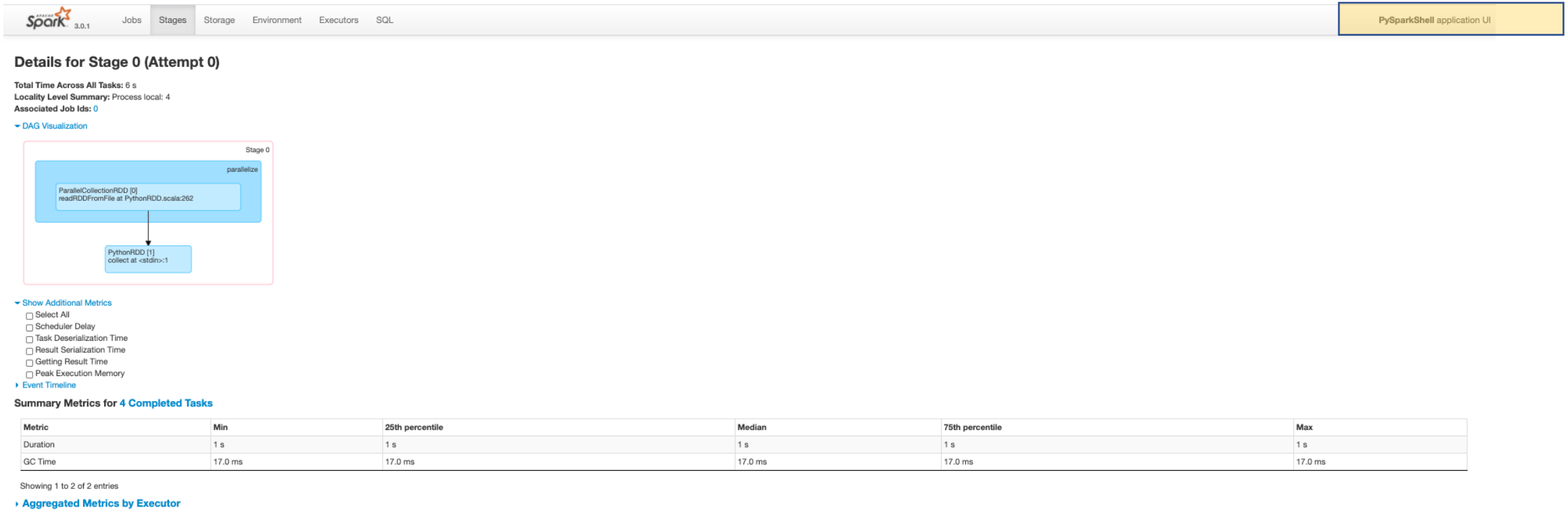
Showing 1 to 2 of 2 entries

▸ **Aggregated Metrics by Executor**

Localhost:4040 - PySparkShell

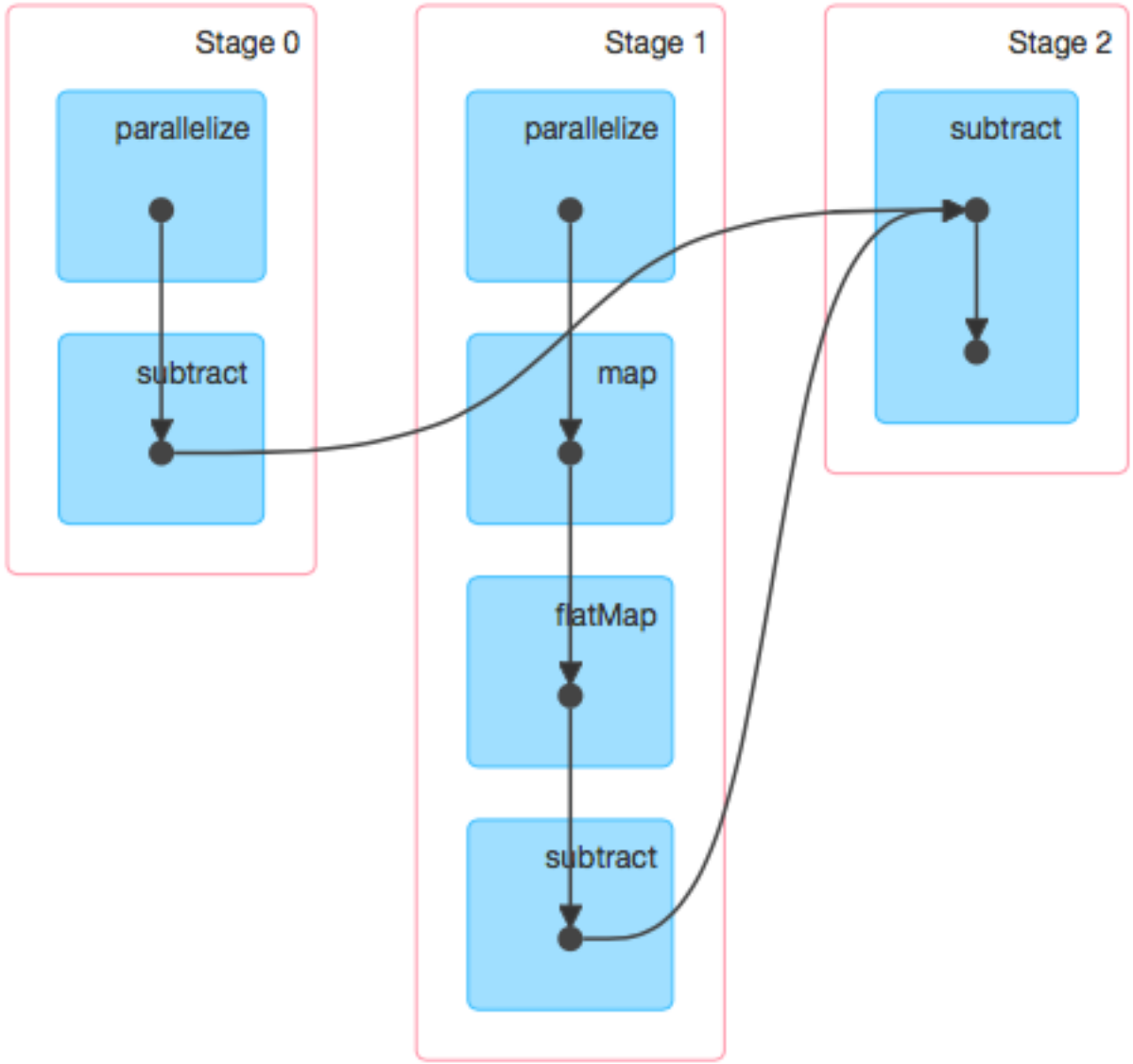


DAG visualization - PySpark



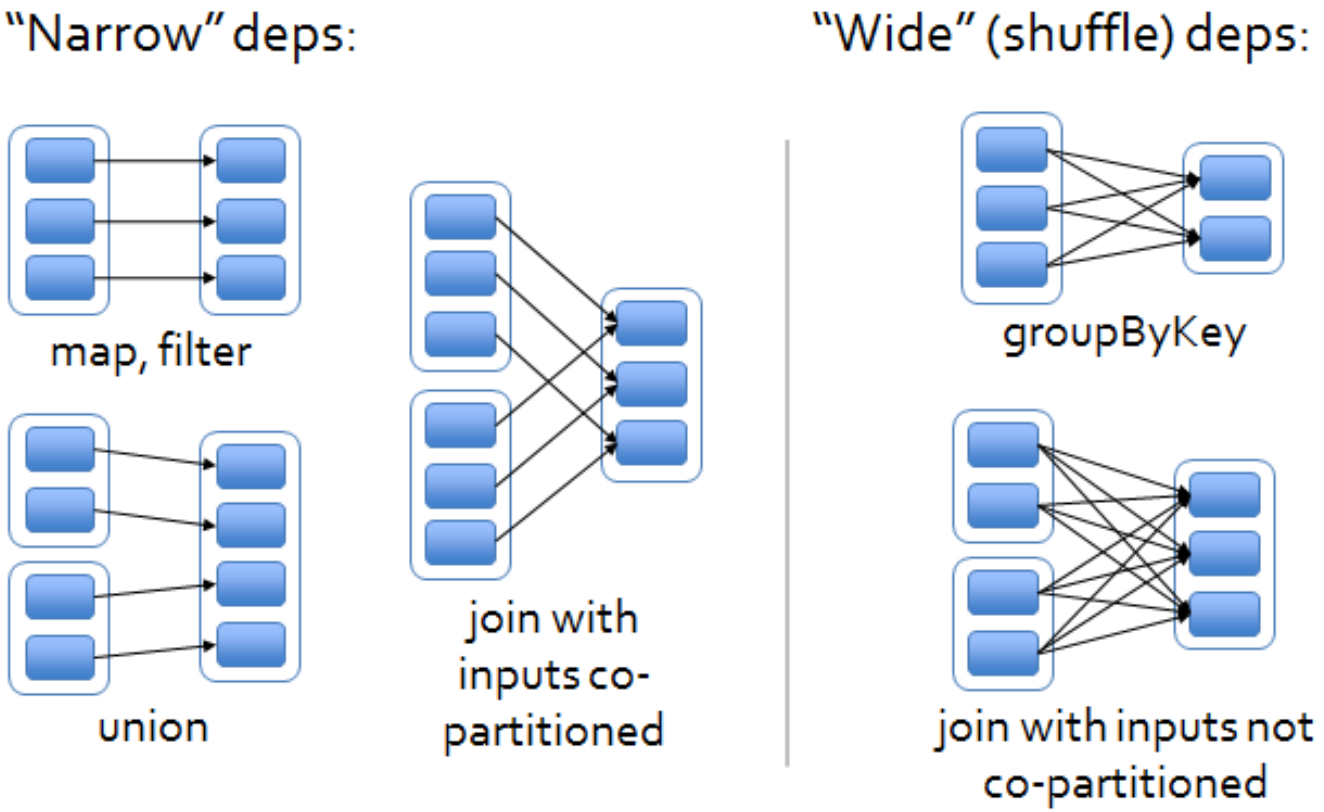
DAG visualization

Multiple
stages DAG



Transformations

- Map Transformation
- Filter Transformation
- flatMap Transformation
- distinct Transformation
- union Transformation
- intersection Transformation
- subtract Transformation



Basic Transformations

```
nums = sc.parallelize([1, 2, 3])

# Pass each element through a function
squares = nums.map(lambda x: x*x)   # => {1,
4, 9}

# Keep elements passing a predicate
even = squares.filter(lambda x: x % 2 == 0) #
=> {4}

# Map each element to zero or more others
nums.flatMap(lambda x: range(0, x))  # => {0,
0, 1, 0, 1, 2}
```

Map Transformation

```
scala> val rdd1=sc.parallelize(List(1,2,3,4))
rdd1: org.apache.spark.rdd.RDD[Int] = ParallelCollectionRDD[5] at parallelize at <console>:24

scala> val maprdd1 = rdd1.map(x=>x+5)
maprdd1: org.apache.spark.rdd.RDD[Int] = MapPartitionsRDD[6] at map at <console>:25

scala> maprdd1.collect
res5: Array[Int] = Array(6, 7, 8, 9)

scala>
```

Filter Transformation

```
scala> val rdd1=sc.parallelize(List(1,2,3,4))
rdd1: org.apache.spark.rdd.RDD[Int] = ParallelCollectionRDD[5] at parallelize at <console>:24

scala> val maprdd1 = rdd1.map(x=>x+5)
maprdd1: org.apache.spark.rdd.RDD[Int] = MapPartitionsRDD[6] at map at <console>:25

scala> maprdd1.collect
res5: Array[Int] = Array(6, 7, 8, 9)

scala> val filterrdd1 = rdd1.filter(x => x!=3)
filterrdd1: org.apache.spark.rdd.RDD[Int] = MapPartitionsRDD[7] at filter at <console>:25

scala> filterrdd1.collect
res6: Array[Int] = Array(1, 2, 4)

scala>
```

flatMap Transformation

```
scala> val rdd2=sc.parallelize(List(1,2))
rdd2: org.apache.spark.rdd.RDD[Int] = ParallelCollectionRDD[8] at parallelize at <console>:24

scala> val maprdd2 = rdd2.map(x=>x.to(3))
maprdd2: org.apache.spark.rdd.RDD[scala.collection.immutable.Range.Inclusive] = MapPartitionsRDD[9
] at map at <console>:25

scala> maprdd2.collect
res7: Array[scala.collection.immutable.Range.Inclusive] = Array(Range 1 to 3, Range 2 to 3)

scala> val flatmaprdd2 = rdd2.flatMap(x=>x.to(3))
flatmaprdd2: org.apache.spark.rdd.RDD[Int] = MapPartitionsRDD[10] at flatMap at <console>:25

scala> flatmaprdd2.collect
res8: Array[Int] = Array(1, 2, 3, 2, 3)

scala>
```

Distinct Transformation

```
scala> val rdd3 = sc.parallelize(List(1,1,3,4,5,3,4,5,2,3,2,3,7,3,2))
rdd3: org.apache.spark.rdd.RDD[Int] = ParallelCollectionRDD[11] at parallelize at <console>:24

scala> val distinctrdd3 = rdd3.distinct
distinctrdd3: org.apache.spark.rdd.RDD[Int] = MapPartitionsRDD[14] at distinct at <console>:25

scala> distinctrdd3.collect
res9: Array[Int] = Array(4, 1, 5, 2, 3, 7)

scala>
```

Union Transformation

```
scala> val rdd4 = sc.parallelize(List(1,2,3,4))
rdd4: org.apache.spark.rdd.RDD[Int] = ParallelCollectionRDD[15] at parallelize at <console>:24

scala> val rdd5 = sc.parallelize(List(4,5))
rdd5: org.apache.spark.rdd.RDD[Int] = ParallelCollectionRDD[16] at parallelize at <console>:24

scala> val unionrdd = rdd4.union(rdd5)
unionrdd: org.apache.spark.rdd.RDD[Int] = UnionRDD[17] at union at <console>:27

scala> unionrdd.collect
res10: Array[Int] = Array(1, 2, 3, 4, 4, 5)

scala>
```

Intersection Transformation

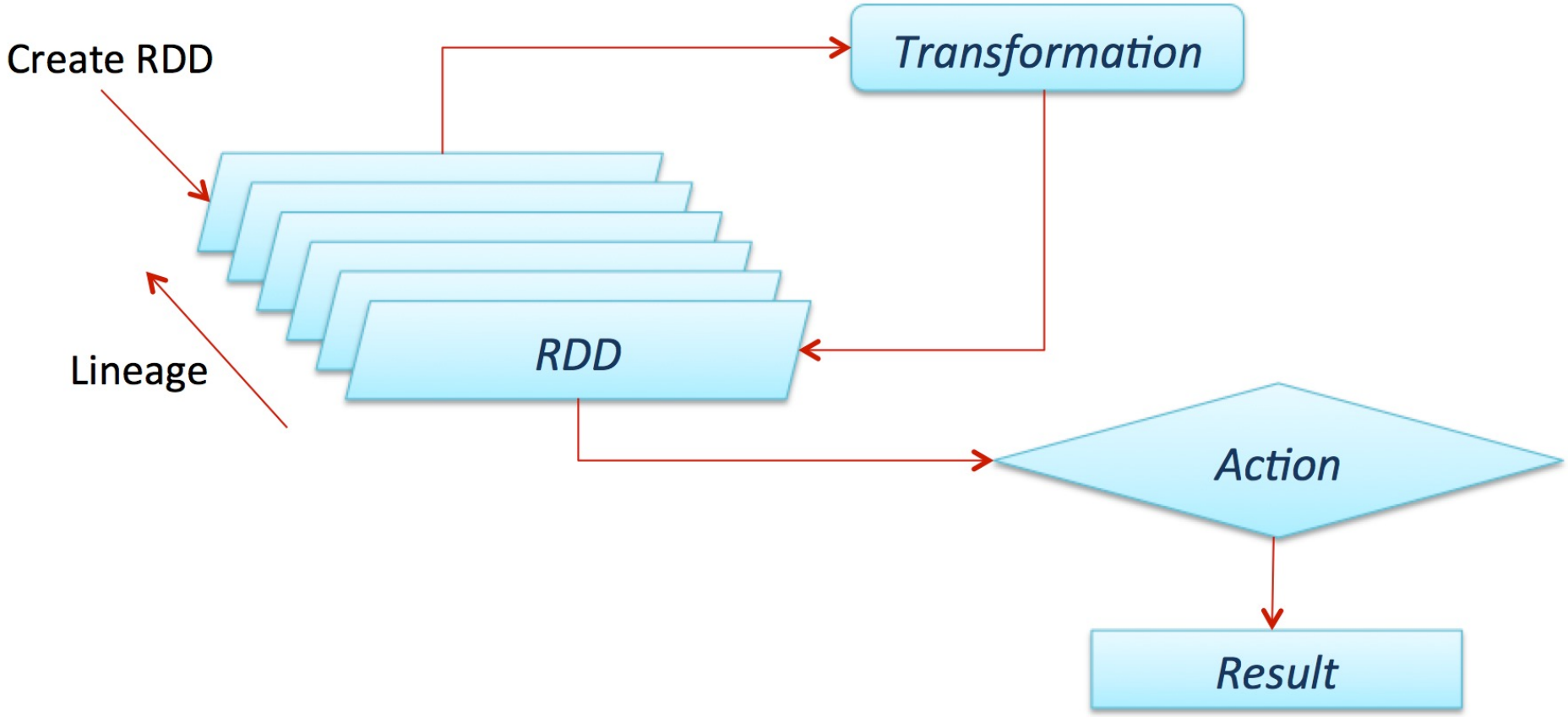
```
scala> val rdd4 = sc.parallelize(List(1,2,3,4))
rdd4: org.apache.spark.rdd.RDD[Int] = ParallelCollectionRDD[15] at parallelize at <console>:24

scala> val rdd5 = sc.parallelize(List(4,5))
rdd5: org.apache.spark.rdd.RDD[Int] = ParallelCollectionRDD[16] at parallelize at <console>:24

scala> val unionrdd = rdd4.union(rdd5)
unionrdd: org.apache.spark.rdd.RDD[Int] = UnionRDD[17] at union at <console>:27

scala> unionrdd.collect
res10: Array[Int] = Array(1, 2, 3, 4, 4, 5)

scala> val intersectionrdd = rdd4.intersection(rdd5)
intersectionrdd: org.apache.spark.rdd.RDD[Int] = MapPartitionsRDD[23] at intersection at <console>
:27

scala> intersectionrdd.collect
res11: Array[Int] = Array(4)

scala>
```

Subtract Transformation

```
scala> val rdd4 = sc.parallelize(List(1,2,3,4))
rdd4: org.apache.spark.rdd.RDD[Int] = ParallelCollectionRDD[15] at parallelize at <console>:24

scala> val rdd5 = sc.parallelize(List(4,5))
rdd5: org.apache.spark.rdd.RDD[Int] = ParallelCollectionRDD[16] at parallelize at <console>:24

scala> val unionrdd = rdd4.union(rdd5)
unionrdd: org.apache.spark.rdd.RDD[Int] = UnionRDD[17] at union at <console>:27

scala> unionrdd.collect
res10: Array[Int] = Array(1, 2, 3, 4, 4, 5)

scala> val intersectionrdd = rdd4.intersection(rdd5)
intersectionrdd: org.apache.spark.rdd.RDD[Int] = MapPartitionsRDD[23] at intersection at <console>
:27

scala> intersectionrdd.collect
res11: Array[Int] = Array(4)

scala> val subtractrdd = rdd4.subtract(rdd5)
subtractrdd: org.apache.spark.rdd.RDD[Int] = MapPartitionsRDD[27] at subtract at <console>:27

scala> subtractrdd.collect
res12: Array[Int] = Array(1, 2, 3)

scala>
```

Actions

- collect
- reduce
- take
- top



Basic Actions

```
nums = sc.parallelize([1, 2, 3])

# Retrieve RDD contents as a local collection
nums.collect() # => [1, 2, 3]

# Return first K elements
nums.take(2)   # => [1, 2]

# Count number of elements
nums.count()   # => 3

# Merge elements with an associative function
nums.reduce(lambda x, y: x + y)  # => 6

# Write elements to a text file
nums.saveAsTextFile("hdfs://file.txt")
```

Reduce Action

```
scala> val rdd6 = sc.parallelize(List(1,2,3,4,5))
rdd6: org.apache.spark.rdd.RDD[Int] = ParallelCollectionRDD[28] at parallelize at <console>:24

scala> rdd6.reduce((x,y) => x+y)
res13: Int = 15

scala>
```

Take Action

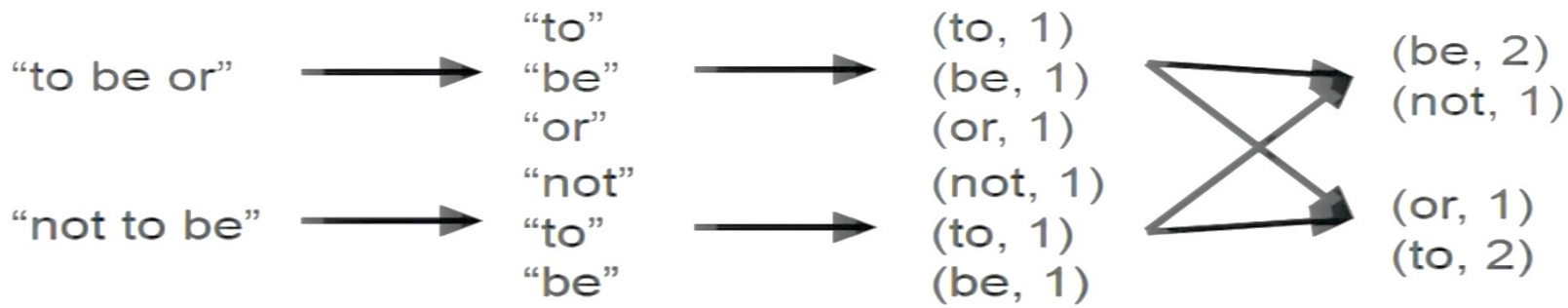
```
scala> val rdd6 = sc.parallelize(List(1,2,3,4,5))
rdd6: org.apache.spark.rdd.RDD[Int] = ParallelCollectionRDD[28] at parallelize at <console>:24

scala> rdd6.reduce((x,y) => x+y)
res13: Int = 15

scala> rdd6.take(2)
res14: Array[Int] = Array(1, 2)

scala>
```

Top Action

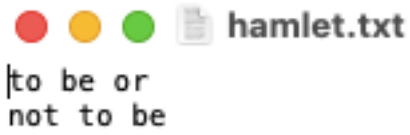
```
scala> val rdd6 = sc.parallelize(List(1,2,3,4,5))
rdd6: org.apache.spark.rdd.RDD[Int] = ParallelCollectionRDD[28] at parallelize at <console>:24

scala> rdd6.reduce((x,y) => x+y)
res13: Int = 15

scala> rdd6.take(2)
res14: Array[Int] = Array(1, 2)

scala> rdd6.top(3)
res15: Array[Int] = Array(5, 4, 3)

scala>
```

Example: Word count

```
lines = sc.textFile(“hamlet.txt”)
counts = lines.flatMap(lambda line: line.split(“ ”)) \
              .map(lambda word: (word, 1)) \
              .reduceByKey(lambda x, y: x + y)
```



MapReduce - Scala




```
scala>

scala> val text=sc.textFile("hdfs://localhost:9000/Demo/hamlet.txt")
text: org.apache.spark.rdd.RDD[String] = hdfs://localhost:9000/Demo/hamlet.txt MapPartitionsRDD[7]
 at textFile at <console>:24

scala> val counts = text.flatMap(line => line.split(" "))
counts: org.apache.spark.rdd.RDD[String] = MapPartitionsRDD[8] at flatMap at <console>:25

scala> counts.collect
res7: Array[String] = Array(to, be, or, not, to, be)

scala> val map = counts.map(word=>(word, 1))
map: org.apache.spark.rdd.RDD[(String, Int)] = MapPartitionsRDD[9] at map at <console>:25

scala> map.collect
res8: Array[(String, Int)] = Array((to,1), (be,1), (or,1), (not,1), (to,1), (be,1))

scala> val reduce = map.reduceByKey(_+_)
reduce: org.apache.spark.rdd.RDD[(String, Int)] = ShuffledRDD[10] at reduceByKey at <console>:25

scala> reduce.collect
res9: Array[(String, Int)] = Array((not,1), (or,1), (be,2), (to,2))

scala>
```

WordCount - Spark

```scala
val textFile = sc.textFile("hdfs://...")
val counts = textFile.flatMap(line => line.split(" "))
                     .map(word => (word, 1))
                     .reduceByKey(_ + _)
counts.saveAsTextFile("hdfs://...")
```

Scala

```python
text_file = sc.textFile("hdfs://...")
counts = text_file.flatMap(lambda line: line.split(" ")) \
    .map(lambda word: (word, 1)) \
    .reduceByKey(lambda a, b: a + b)
counts.saveAsTextFile("hdfs://...")
```

Python

http://spark.apache.org/examples.html

MapReduce in Python

pyspark-map.py

```
1  from pyspark import SparkContext
2
3  sc = SparkContext.getOrCreate()
4
5  text=sc.textFile("hdfs://localhost:9000/Demo/hamlet.txt")
6
7  counts = text.flatMap(lambda line: line.split(" ")) \
8      .map(lambda word: (word, 1)) \
9      .reduceByKey(lambda a, b: a + b)
10
11 for element in counts.collect():
12     print(element)
13
14 counts.saveAsTextFile("/Users/snehadhanda/work/result.txt")
```

Run: pyspark-map

```
Using Spark's default log4j profile: org/apache/spark/log4j-defaults.properties
Setting default log level to "WARN".
To adjust logging level use sc.setLogLevel(newLevel). For SparkR, use setLogLevel(newLevel).
21/01/09 11:49:24 WARN Utils: Service 'SparkUI' could not bind on port 4040. Attempting port 4041.
21/01/09 11:49:24 WARN Utils: Service 'SparkUI' could not bind on port 4041. Attempting port 4042.
('to', 2)
('be', 2)
('or', 1)
('not', 1)

Process finished with exit code 0
```

Working with Key-Value Pairs

- Spark's 'distributed reduce' transformations act on RDDs of key value pairs
- Python:

```
pair = (a, b)
        pair[0] # => a
        pair[1] # => b
```

- Scala:

```
val pair = (a, b)
        pair._1 // => a
        pair._2 // => b
```

- Java:

```
Tuple2 pair = new Tuple2(a, b);
// class scala.Tuple2
        pair._1 // => a
        pair._2 // => b
```

Some Key-Value Operations

```
pets = sc.parallelize([(“cat”, 1), (“dog”, 1),
(“cat”, 2)])
pets.reduceByKey(lambda x, y: x + y)
# => {(cat, 3), (dog, 1)}
pets.groupByKey()
# => {(cat, Seq(1, 2)), (dog, Seq(1)}
pets.sortByKey()
# => {(cat, 1), (cat, 2), (dog, 1)}
```

- reduceByKey also automatically implements combiners on the map side

Other Key-Value Operations

```
val visits = sc.parallelize(List(
  (“index.html”, “1.2.3.4”),
  (“about.html”, “3.4.5.6”),
  (“index.html”, “1.3.3.1”)))
val pageNames = sc.parallelize(List(
  (“index.html”, “Home”), (“about.html”, “About”)))
visits.join(pageNames)
// (“index.html”, (“1.2.3.4”, “Home”))
// (“index.html”, (“1.3.3.1”, “Home”))
// (“about.html”, (“3.4.5.6”, “About”))
visits.cogroup(pageNames)
// (“index.html”, (Seq(“1.2.3.4”, “1.3.3.1”),
Seq(“Home”)))
// (“about.html”, (Seq(“3.4.5.6”), Seq(“About”)))
```

Controlling the level of Parallelism

- All the pair RDD operations take an optional second parameter for number of tasks

```
words.reduceByKey(lambda x, y: x + y, 5)

words.groupByKey(5)

visits.join(pageViews, 5)

Can also set spark.default.parallelism
property
```

Using Local Variables

- External Variables you use in a closure will automatically be shipped to the cluster:

```
query = raw_input("Enter a query:")
pages.filter(lambda x:
x.startswith(query)).count()
```

- Some caveats:
  - Each task gets a new copy (updates aren't sent back)
  - Variable must be serializable (Java/Scala) or Pickle-able (Python)
  - Don't use fields of an outer object (ships all of it!)

Other RDDs Operations

- sample(): deterministically sample a subset
- cartesian(): cross product
- pipe(): pass through external program

- See programming guide for more
- http://spark.apache.org/docs/latest/

Hadoop Compatibility

- Spark can read/write from any storage / format that has plugin for Hadoop!
- Examples: HDFS, Hbase, Cassandra, Avro, SequenceFile
- Reuses Hadoop's InputFormat and Output APIs
- APIs like SparkContext.textFile support filesystems, while SparkContext.hadoopRDD allows passing any Hadoop JobConf to configure an input source

Create a SparkContext

Scala

```scala
import spark.SparkContext
import spark.SparkContext._

val sc = new SparkContext("masterUrl", "name", "sparkHome", Seq("app.jar"))
```

Cluster URL, or local / local[N]

App name

Spark install path on cluster

Java

```java
import spark.api.java.JavaSparkContext;

JavaSparkContext sc = new JavaSparkContext(
    "masterUrl", "name", "sparkHome", new String[] {"app.jar"}));
```

Python

```python
from pyspark import SparkContext

sc = SparkContext("masterUrl", "name", "sparkHome", ["library.py"]))
```

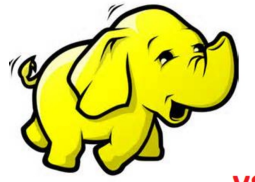
Complete App: Scala

```
import spark.SparkContext
import spark.SparkContext._

object WordCount {
  def main(args: Array[String]) {
    val sc = new SparkContext(“local”, “WordCount”, args(0), Seq(args(1)))
    val lines = sc.textFile(args(2))
    lines.flatMap(_.split(“ ”))
         .map(word => (word, 1))
         .reduceByKey(_ + _)
         .saveAsTextFile(args(3))
  }
}
```

Complete App: Python

```
import sys
from pyspark import SparkContext

if __name__ == "__main__":
    sc = SparkContext( “local”, “WordCount”, sys.argv[0], None)
    lines = sc.textFile(sys.argv[1])

    lines.flatMap(lambda s: s.split(“ ”)) \
         .map(lambda word: (word, 1)) \
         .reduceByKey(lambda x, y: x + y) \
         .saveAsTextFile(sys.argv[2])
```

Hadoop vs Spark

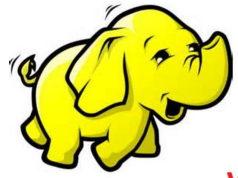


vs.

Spark ?

Parameter	Hadoop	Spark
Data Processing	Batch Processing	Batch/ Real-time/ Iterative/ Interactive/ Graph Processing
Performance	Faster than traditional system	100x times than MapReduce
Compatibility	Compatible	Spark and MapReduce are compatible with each other
Ease of use	Hadoop provides add-ons to support users but doesn't have interactive mode	User-friendly APIs for Scala, Java Python and R etc. Provides interactive mode for developers.
Price	Less costly as MapReduce model provides cheaper strategy	Costlier than Hadoop since it uses in-memory processing
Fault Tolerance	Storing data in HDFS	RDDs for fault tolerance
Latency	High latency computing framework	Low latency computing framework
Scalability	Yahoo as around 40,000 node Hadoop cluster	Spark cluster has 7,000 nodes
Difficulty	Need to hand code every operation	Tons of high-level operators

Hadoop vs Spark

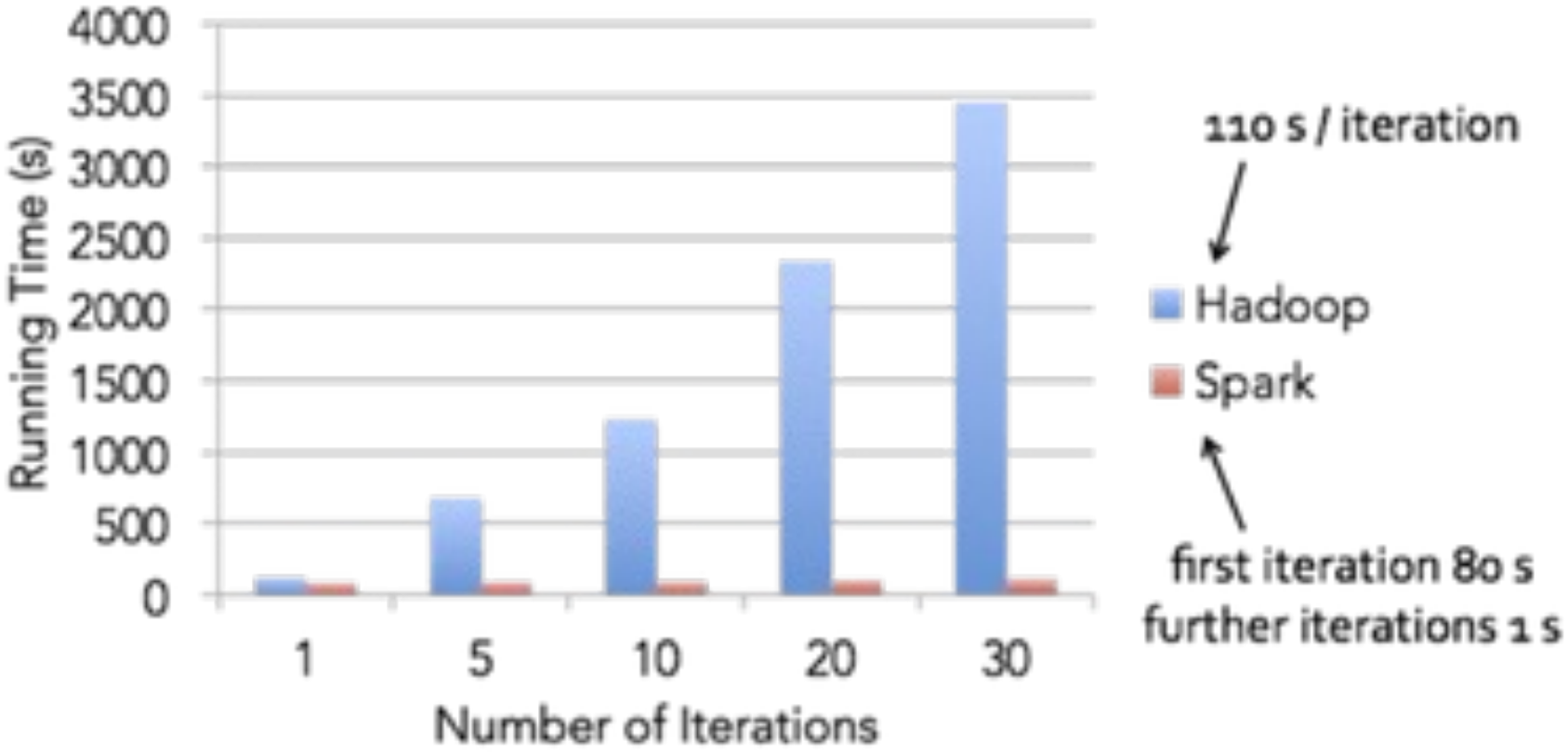


vs.

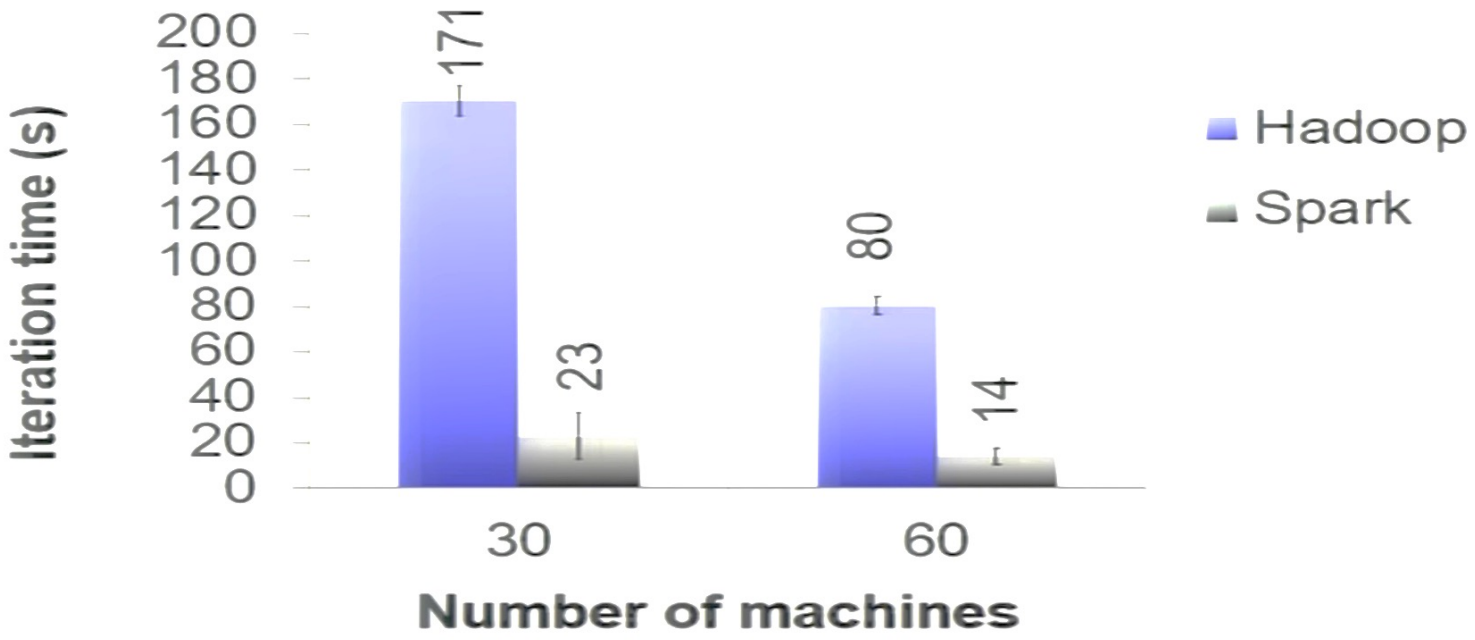
Spark ?

Parameter	Hadoop	Spark
Easy to Manage	Only provides the batch engine	Batch/interactive/streaming in same cluster
Real-time analysis	Perform batch processing	Process real-time data
Interactive mode	No	Yes
Recovery	Naturally resilient to system faults	RDDs allows recovery
Scheduler	Needs an external job scheduler	Own flow scheduler
Programming Language support	Primarily Java others C, C++, Ruby, Groovy, Perl, Python	Scala, Java, Python, R, SQL
SQL support	Hive	Spark SQL
Language Developed	Java	Scala
Machine Learning	Apache Mahout	MLlib
Caching	No	Yes
Hardware Requirements	Commodity hardware	Needs mid to high-level hardware

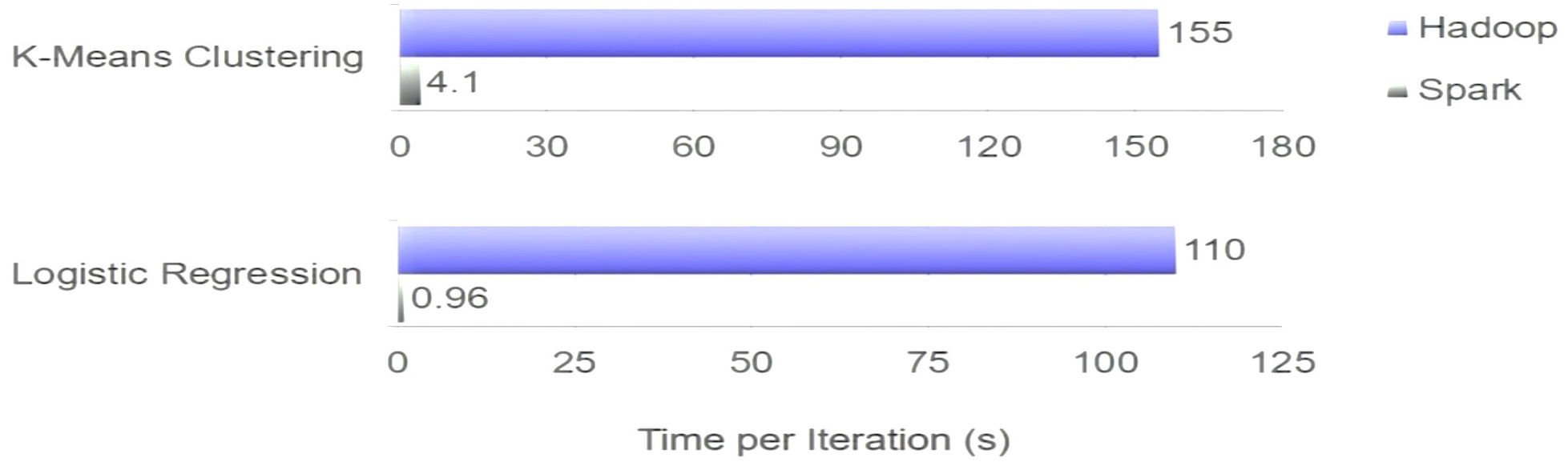
Performance Comparison



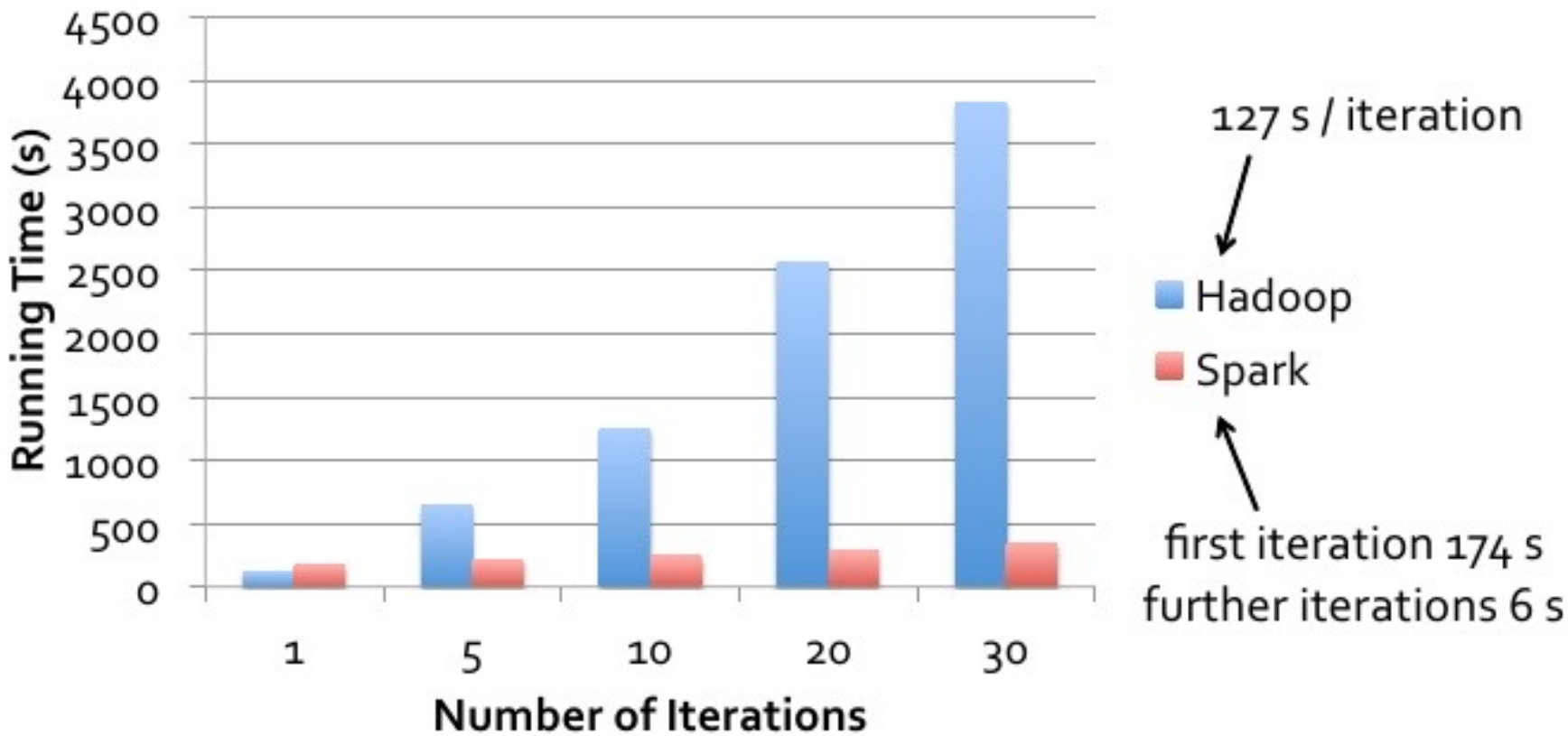
PageRank Performance Comparison



Performance Comparison



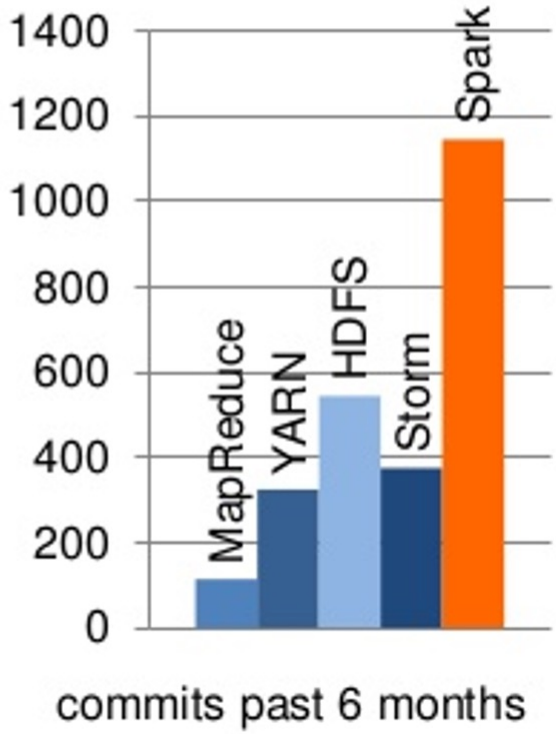
Logistic Regression Performance



Spark Community

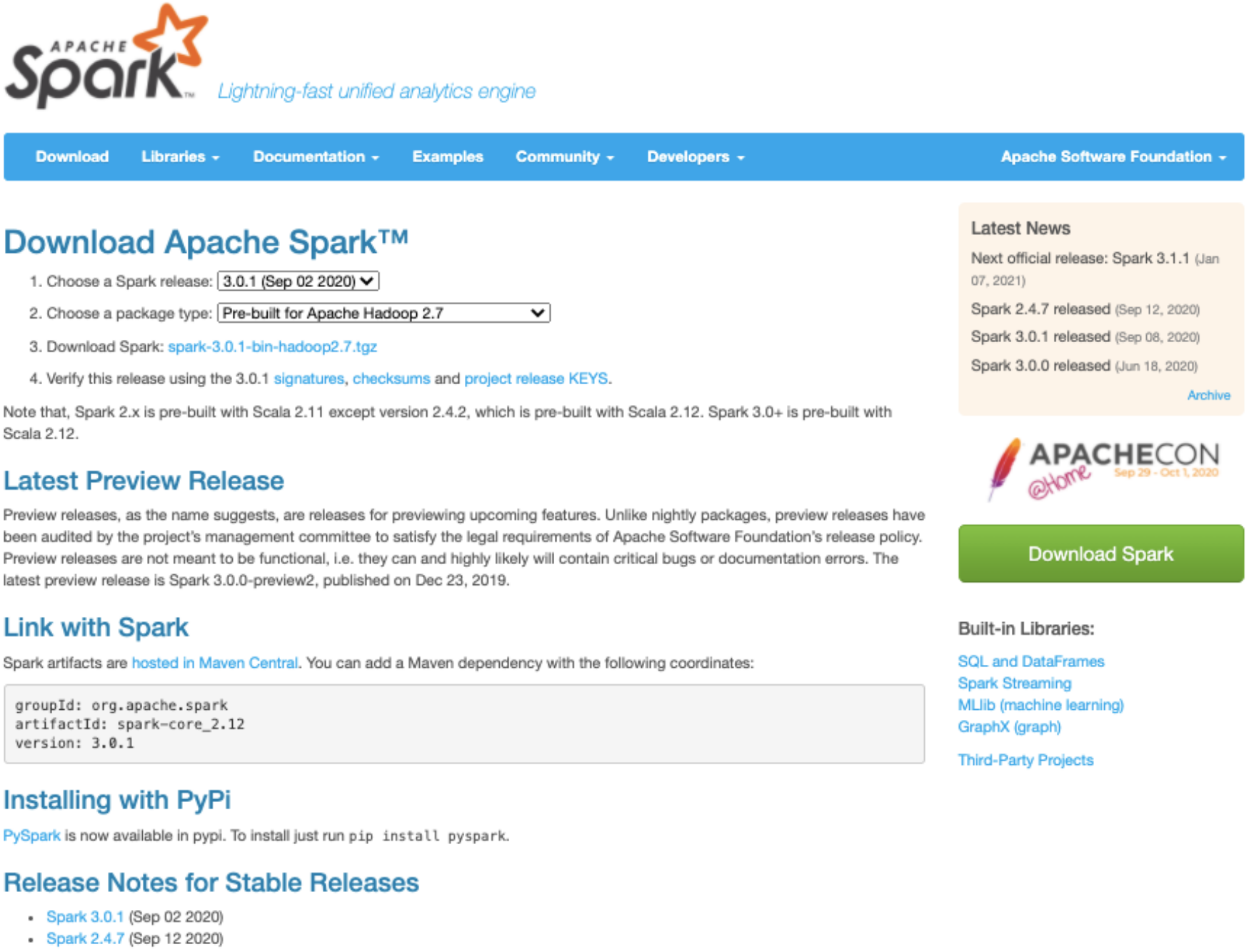
250+ developers, **50+** companies contributing

Most active open source project in big data



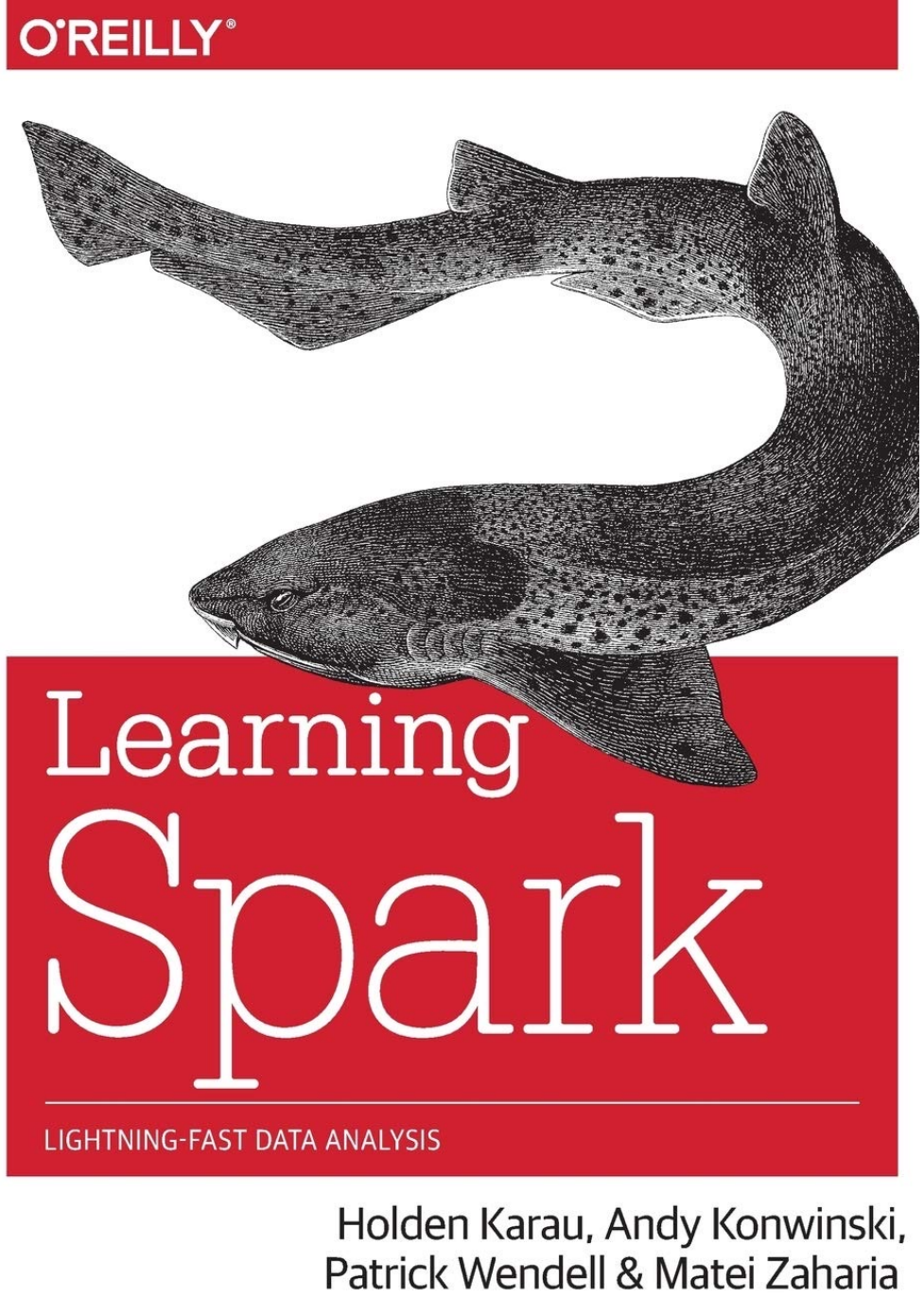
Spark Installation

- Apache Spark



Summary

- Spark offers a rich APIs to make data analytics fast; both fast to write and fast to run
- Achieves 100x speedups in real applications
- Growing community with 50 companies contributing
- Details: http://spark.apache.org/



References

- Pyspark and SQL Basics:
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  - https://datacamp-community-prod.s3.amazonaws.com/65076e3c-9df1-40d5-a0c2-36294d9a3ca9
  - https://spark.apache.org/
- Reference books:
  - Learning Spark: Lightning-Fast Big Data Analysis
  - Spark: The Definitive Guide: Big Data Processing Made Simple